PROCEEDINGS
OF THE . .
INSTITUTION OF
BRITISH FOUNDRYMEN.

1921-1922.

Containing the Report of the Nineteenth Annual Conference, held at Birmingham, June 21, 22 and 23, 1922; and also Papers and Addresses presented at Branch Meetings held during the Session 1921-1922.

Institution of British Foundrymen.
Head Office:
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THE INSTITUTION OF BRITISH FOUNDRYMEN.

OFFICERS 1923—1924

President :

Oliver Stubbs, M.I.Mech.E., Openshaw, Manchester.

Vice-Presidents :

R. O. Patterson, "Thorneyholme," Wylam-on-Tyne.
E. H. Broughall, Edgwick Foundry, Foleshill, Coventry.

Past Presidents :

R. Buchanan, F.R.S.A., 35, Thornhill Road, Handsworth, Birmingham. 1904 and 1905.
H. Pilkington. (Deceased.) 1906-1907.
F. J. Cook, 139, Poplar Avenue, Edgbaston, Birmingham. 1908 and 1909.
P. Longmuir, D.Met., Ravens Cragg, Wortley, Sheffield. 1910 and 1911.
C. Jones. (Deceased.) 1912.
S. A. Gimson, 40, Glebe Street, Leicester. 1913 and 1914.
W. Mayer. (Deceased.) 1915.
J. Ellis, 6, Eckstein Road, Clapham Junction, London, S.W.11. 1916 and 1917.
T. H. Firth, Brightside Foundry and Engineering Co., Ltd., Sheffield. 1918.
John Little, M.I.Mech.E., 20, St. Ann's Square, Manchester. 1919.
Matt. Riddell, Etna Iron Works, Falkirk, N.B. 1920.
Oliver Stubbs, M.I.Mech.E., Openshaw, Manchester. 1921.
H. L. Reason, M.I.Mech.E., M.I.M., 29, Hallewell Road Edgbaston, Birmingham. 1922.

General Council :

†F. Adam, 25, Mitchell Avenue, Jesmond, Newcastle-on-Tyne.
*A. R. Bartlett, 1, Lower Park Road, Belvedere, London, S.E.
†J. Beecroft, 53, Culshaw Street, Fulledge, Burnley.
*J. Cameron, Cameron & Roberton, Kirkintilloch, N.B.
†W. F. Cheesewright, Col., D.S.O., 5, Duke Street, Adelphi, London, W.C.2.
*W. T. Evans, Mount Pleasant, Sunny Hill, Normanton, Derby.
†H. Field, 12, Bayswater Road, Handsworth, Birmingham.
*A. Firth, Prior Bank, Cherry Tree Road, Sheffield.
†W. J. Flavell, Carters Green Passage, West Bromwich.
†J. W. Frier, 5, Northumberland Villas, Wallsend-on-Tyne.
†S. Glover, Rookery Farm, Keresley, near Coventry.
†C. Gresty, North-Eastern Marine Eng. Co., Ltd., Wallsend-on-Tyne.

†E. E. G. Grimwood, 6, Balmoral Terrace, Glebelands Road. Ashton-on-Mersey.
*J. Haigh, 9, Bradford Road, Wakefield.
†M. B. Herbst, Saxby House, Corbridge-on-Tyne.
*E. Carey Hill, Rowland Hill & Sons. Ltd., King Street. Coventry.
†J. Hogg, 365, Manchester Road, Burnley.
†J. R. Hyde, 27, Hastings Road, Millhouses, Sheffield.
†A. L. Key, 271. Reddish Road, S. Reddish, Stockport.
†Wesley Lambert, J. Stone & Co., Ltd., Deptford, S.E.14.
†J. Lucas, "Sherwood," Forest Road, Loughborough.
†W. H. Meadowcroft, 72, Elliott Street, Tyldesley, Manchester.
†W. J. Paulin, 1, Stannington Grove, Heaton, Newcastle-on-Tyne.
*H. Pemberton, 15. Wolfa Street, Derby.
†G. F. Roberts, Rosedale, Earlsdon Avenue, Coventry.
*J. G. Robinson, 17, Gibraltar Road, Halifax.
*J. Shaw, 39, Montgomery Road, Sheffield.
†R. J. Shaw, 41, Dorset Road, South Ealing, W.5.
*H. Sherburn, c/o The Richmond Gas Stove Meter Co., Ltd., Grappenhall Works, Warrington.
†W. H. Sherburn, Rotherwood, Stockton Heath, Warrington.
†J. N. Simm, 61, Marine Drive, Monkseaton.
†W. Slingsby, Highfield Villa, Keighley.
†S. G. Smith, 86, Barton Road, Stretford, Manchester.
†J. A. Spiers, "Belah," Marston Road, Leicester.
†T. Vickers, Central House, 75, New Street, Birmingham.
†A. Wardle, 30, Tettenhall Road, Wolverhampton.
†H. Winterton, 2, Lorne Terrace, Maryhill, Glasgow.
†D. H. Wood, 7, Augusta Road, Moseley, Birmingham.
* Elected at Annual Conference. †Branch Delegates.

BRANCH PRESIDENTS AND SECRETARIES

(Ex-officio on General Council).

BIRMINGHAM.

J. B. Johnson, 27, Ball Fields, Tipton, Staffs.
H. J. Roe, 33, Herbert Road, Bearwood, Birmingham.

COVENTRY.

C. H. Dicken, 2, Ash Street, Daisy Bank, Bilston, Staffs.
J. M. Meston, 37, Melville Road, Coventry.

EAST MIDLANDS.

S. H. Russell, Bath Lane, Leicester.
H. Bunting, 17, Marcus Street, Derby.

LANCASHIRE.

R. A. Miles, 46, Dean Lane, Newton Heath, Manchester.
T. Makemson, 21, Beresford Road, Gorse Hill, Stretford. Manchester.

BURNLEY SECTION OF LANCASHIRE.

W. A. Hartley, Stonebridge Foundry, Ltd., Colne, Lancs.
J. Pell, 100, Rose Grove Lane, Burnley.

LONDON.

V. C. Faulkner, Bessemer House, 5, Duke Street, Adelphi, London, W.C.2.
H. G. Sommerfield, "Hanthorpe," Woodhouse Road, N. Finchley, London, N.12.

NEWCASTLE-ON-TYNE.

J. Smith, Harton Lea, Harton, South Shields.
H. A. J. Rang, 2, St. Nicholas Buildings, Newcastle-on-Tyne.

SCOTTISH.

A. Lawrie, 40, Glebe Street, Kilmarnock, N.B.
W. H. Bound, 69, Minard Road, Shawlands, Glasgow.

SCOTTISH—FALKIRK SECTION.

G. Walker, 21, Napier Place, Bainsford, Falkirk, N.B.
A. Rennie, "Kilnside," Falkirk, N.B.

SHEFFIELD.

J. Shaw, 39, Montgomery Road, Sheffield.
W. A. Macdonald, 62, Bannerdale Road, Sheffield

WEST RIDING OF YORKS.

A. A. Liardet, Thwaites Bros., Ltd., Bradford.
A. Love, 232, Gladstone Street, Bradford.

Hon. Treasurer:

F. W. Finch, 52, Denmark Road, Gloucester.

General Secretary:

William G. Hollinworth, 38, Victoria Street, London, S.W.1.

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Institution of British Foundrymen

ANNUAL CONFERENCE HELD AT BIRMINGHAM.

June 21, 22 and 23, 1922.

Civic Welcome.

The nineteenth annual meeting and conference opened on Wednesday, June 21, at the Chamber of Commerce Building, the hall being filled with members from all over the Kingdom. The retiring president, Mr. Oliver Stubbs, took the chair during the first part of the proceedings, having with him on the platform the Lord Mayor of Birmingham (Alderman David Davis), the Principal of the University of Birmingham (Mr. G. Grant Robertson), the President of the Birmingham Chamber of Commerce (Mr. F. Hickinbotham), the ex-President of the Chamber (Mr. J. C. Field), and the Secretary of the Institution (Mr. W. G. Hollinworth). Among representatives from other countries present were Mr. S. Flagg and Prof. E. Touceda, America; MM. E. Ramas and E. V. Ronceray, France; MM. J. Leonard and J. Varlet, Belgium.

The Lord Mayor offered a hearty welcome to the Institution. Remarking that Birmingham was the birthplace of the Institution in 1904, but that it had not received a visit from the members collectively since 1909, he expressed a hope that the next interval would not be so long. Their object, so far as he gathered from the charter, was extremely simple—to learn from one another.

There was a time when a great deal of suspicion existed on the part of manufacturers with regard to those who desired to see their factories and the processes carried on in them. He thought that period had passed away in favour of a freer exchange of learning.

MR. H. L. REASON
(President of the Institution of British Foundrymen).

Mr. Reason is general manager of the Birmingham Works of the United Brass Founders and Engineers, Limited, Holloway Head. He has twice occupied the chair of the Birmingham Branch of the Institution, and in 1915 he received the Institution's diploma for a contribution on "Non-ferrous Alloys." During the war Mr. Reason was a member of an Air Board Committee set up to deal with the standardisation of aircraft fittings.

PRINCIPAL GRANT ROBERTSON said that in the Birmingham University they were closely associated with some of the objects and purposes of the Institution. They had great departments of applied science, above all in engineering and in metallurgy, and their Professor of Metallurgy (Professor Turner), who had a distinguished name in the science that the Institution represented, was present at the Conference as one of their members. It was their object and duty in the University—through science, through education, through research, through the training of character—to assist as far as they possibly could the

MR. W. G. HOLLINWORTH

(The General Secretary of the Institution of British Foundrymen).

prosperity of the great industries, particularly in the Midlands. There never was a time in British industry when trained brains were of more importance for our industrial future.

Mr. Hickinbotham, in echoing the welcome, acknowledged the assistance which had been given by the Institution of British Foundrymen and the British Cast Iron Research Association towards making the Foundry Exhibition at Bingley Hall a success. It was one of the desires of traders like himself that they should be more associated with the work of education.

The Retiring President thanked the Lord Mayor, the Principal, and the President of the Chamber of Commerce for their welcome, and said he was particularly gratified that they had there an international gathering, and that it had been the privilege of the Institution of British Foundrymen to do something to bring about a better understanding between nations than had been accomplished in political quarters. It had been his pleasure recently, along with their Past-Presidents, Mr. T. H. Firth and Mr. F. J. Cook, to visit the United States. They had an opportunity of meeting their American friends, or, as he should say, their American cousins, and he hoped that as a result of their visit they brought the English-speaking races very much closer together. He trusted all present would do all they possibly could to increase the friendship that had been so happily inaugurated. They had a great pride in their Institution. They were purely a technical body; they were not dealing with labour or commercial matters, but were endeavouring to help each other so that they would be better able to stand in competition and take that place in the world to which they were entitled, and which he still believed they held, as first in the foundry industry. They were downright glad to see their visitors from America, France, and Belgium. (Applause.) He would beg the Lord Mayor before he left to present the Oliver Stubbs gold medal to Mr. F. J. Cook, who had been unanimously indicated as the member of the Institution who in the opinion of the Council had rendered the most meritorious service during the year.

Mr. Cook was greeted with musical honours on ascending the platform to receive the medal. The Lord Mayor made the presentation in a few well-chosen sentences.

Mr. Cook, in reply, said the position was the most embarrassing, but the most pleasing, he had ever occupied. He had always had a deep interest in the Institution and its work, and had been proud to serve it.

The Lord Mayor and those who had accompanied him to welcome the members of the Conference then withdrew.

Greeting to Prince of Wales.

The Retiring President said, knowing they were a loyal body, he had that morning sent the following telegram in their name to the Prince of Wales at York House :—

" The Institution of British Foundrymen in conference at Birmingham extend their best wishes upon your safe return, and trust the objects of your visit have been entirely fulfilled.—Oliver Stubbs, President."

Salutations Between Britain and America.

The Retiring President next read a cablegram which he had sent in the name of the Institution to Mr. Cook, to be read at the American Foundrymen's Congress, as follows :—

" Convey heartiest greetings to President and members with all good wishes for successful convention and inspirations of International Foundrymen's Congress in near future.—Oliver Stubbs, President, Institution of British Foundrymen."

Mr. Cook had brought home from America the following letter in reply, addressed to the Institution of British Foundrymen :—

" Gentlemen,—The cordial greetings and messages of goodwill from the Institution of British Foundrymen were delivered to us by your representative, Mr. F. J. Cook. His paper was a most helpful contribution to our festival session, and caused much favourable comment. We are indebted to Mr. Cook and to your Institution.

" The visits of Messrs. Stubbs, Firth and Cook have done much to make us feel closer to you, and it is our hope that visits between representatives of your Institution and our Association may continue in the future. British and American Foundrymen have much in common, and nothing but good can come from personal contact and exchange of ideas. Your representatives have made us appreciate this, and we hope that they realise our friendly feeling for you, and will carry this thought to your Institution.

"The subject of an International Foundrymen's Congress is being given much thought by us, and we hope the establishment of such a congress is not far off.

"Accept our thanks for your messages, our best wishes for your meeting and exhibition, and the hope that you may succeed in all you undertake. Believe us to be, yours most sincerely,—AMERICAN FOUNDRYMEN'S ASSOCIATION (C. R. MESSINGER, Vice-President)."

A further message from their American friends, dated June 17, was as follows:—

"Accept heartiest congratulations and best wishes for your meeting and first exhibition. Visit of your splendid representatives has done much to stimulate genuine friendship between your Institution and our Association, which we hope will grow stronger in all things. In the future cooperation between us will mean much to both countries.—AMERICAN FOUNDRYMEN'S ASSOCIATION."

Annual Report and Balance Sheet.

The report and balance-sheet, as circulated in printed form, were next submitted, and passed.

The report of the Council and the balance-sheet which are presented herewith were taken as read.

The General Council have pleasure in presenting to the members their report of the progress and work of the Institution during the past session, 1921-22.

Four General Council meetings have been held during the session—at Blackpool, York, Birmingham, and Manchester respectively. Representatives of the Branches from all parts of the country have attended the meetings, and there has been an average attendance of twenty-five.

The respective Branches have the following members attached:—

	Members.	Associate Members.	Associates.	Total.
Birmingham	47 (50)	96 (99)	20 (35)	163 (184)
Coventry	29 (33)	64 (92)	8 (34)	101 (159)
East Midlands	29 (35)	61 (89)	9 (18)	99 (142)
Lancashire	85 (84)	139 (148)	3 (7)	227 (239)
London	74 (75)	64 (54)	7 (6)	145 (135)
Newcastle-on-Tyne	85 (77)	108 (92)	30 (36)	223 (205)
Scottish	69 (68)	162 (160)	50 (73)	281 (301)
Sheffield	85 (82)	96 (104)	15 (13)	196 (199)
West R. of Yorks	27	14	—	41
General	17 (30)	12 (26)	—	29 (56)
Totals	547 (534)	816 (864)	142 (222)	1505 (1620)

The figures in brackets are for the Season 1920-1921.

In addition to the figures shown above, there are seven members, thirteen associate members, and four associates whose election has been confirmed, but whose subscriptions have not yet been paid. Excluding the latter, the total number of members on the roll of the Institution on April 30, 1922, was 1,505, showing a decrease for the session of 75. It is necessary to state, in partial explanation of the decreased membership, that no name is included in the list where subscription is owing for 1920 and onwards. Five deaths have been recorded.

Whilst a number of members have been lost during the past year, principally on account of the severe depression in trade in many parts of the country, and in a few instances through the necessary increase in subscriptions, it is satisfactory to your Council to be able to report that the losses have been diminished to a large extent by the acquisition of new members in nearly every Branch, due mainly to the efforts of Branch officers and the growing desire of others in the trade, who have recognised the advantage of being connected with an institution like our own.

Subscribing Firms.—The members will be pleased to know that up to the present twenty-seven subscribing firms have been elected. The Council feel assured that many more could be induced to become subscribing firms by a little effort on the part of our members. The Newcastle Branch has eleven, Sheffield six, Lancashire five, Coventry four, London one, and the West Riding of Yorks Branch has submitted one for confirmation at the next General Council meeting.

National Ironfounding Employers' Federation.—The offer of the N.I.E.F. of £200 for the awarding of a gold medal, to be known as the "Oliver Stubbs Medal," was gratefully accepted by your Council, and rules and regulations governing the gift have been circulated to the members. The first medal will be awarded at the coming conference.

Royal Charter.—This has been granted by H.M. Privy Council during the year, and a copy of the Charter may be had by members who have subscribed to the special fund for this purpose. The total legal charges have been settled for £500. The total sum obtained by private donations and bank interest up to the time the Charter was granted amounted to £406 14s. 10d., showing the sum of £93 5s. 2d. required to clear off the solicitor's account. The question of raising the balance without touching the funds of the Institution was considered at the General Council meeting held in Manchester in March last, and it was decided to endeavour to raise the requisite amount in donations from members who had not previously contributed. The sum of £58 7s. was promised or handed to the General Secretary in the Council room, or sent since, leaving the difference still to be obtained of £34 18s. 2d.

It is felt by the Council that a number of our members will appreciate the privilege of having had a share in the Royal Charter Fund and their being asked to help to clear off the balance without its being a charge on the Institution funds. This will be specially pleasing to those who initiated the project and liberally subscribed to the same.

British Cast Iron Research Association.—The Council are pleased to report that this Association, which was formulated by our Institution in 1919, has during the past year appointed a member of the Institution, Mr. J. E. Fletcher, M.I.Mech.E., as the Director of Research. Some important foundry problems have been investigated for its members and a series of researches upon fundamental problems have been commenced, which will be of very great benefit to the members of our Institution and the industry generally. Six members of the Institution Council are on the Council of the Association, and the Institution is also officially represented by Mr. H. L. Reason and Mr. E. H. Broughall.

British Engineering Standards Association.—Our representatives are Messrs. R. Buchanan, F. H. Hurren and F. J. Cook. Mr. Buchanan has been appointed chairman of a sub-committee to deal with grey iron castings, and Mr. Cook as chairman of sub-committee to deal with malleable castings for automobiles.

Standardisation of Test Bars.—The sub-committee appointed report progress *re* this. The views of the Branch committees have been received and the information is being tabulated for discussion and further consideration.

The Director of Research has been appointed to represent the British Cast Iron Research Association, and the specification, when submitted to General Council, will embody the views of both Associations.

The British Engineering Standards Association have intimated that our views will be welcomed, and, where possible, will be embodied in future specifications, if they meet with the wishes of the committee dealing with the subject.

Other Committees.—In addition to the committees previously named. others have been formed during the year to deal with new rules to comply with the Royal Charter requirements, and publications.

General Council.—The members who are retiring in accordance with the rules are Messrs. E. H. Broughall, A. Hayes (both desire not to be re-elected) and Mr. John Shaw, who is willing further to serve the interests of the Institution. Five will require to be elected at Birmingham to complete the ten members as per rules.

New Section at Burnley.—This was opened in the autumn of last year, and is making satisfactory progress.

New Branch at Bradford.—This has now been opened under the title of the West Riding of Yorks Branch. and is progressing satisfactorily.

New London Office.—A new central office has been taken at 38, Victoria Street, London, S.W.1, which is quite satisfactory for our requirements.

The General Council have pleasure in recording the visit of your President. Mr. Oliver Stubbs, and Past-President, Mr. T. H. Firth, to the United

States of America. During the visit they were the guests of the American Foundrymen's Association, and were given a very enthusiastic and generous reception. Mr. F. J. Cook, a Past-President, is presenting a Paper to the American Foundrymen's Association at their annual Convention in June, and, as you will see by our Convention programme, we are to have a Paper by Professor E. Touceda, who will present the same on behalf of the American Foundrymen's Association. We are also being favoured with papers by members of the French and Belgian foundrymen's societies. Your Council attach very much importance to the interchange of papers, and hope in the future much more progress will be made in this direction.

The accounts and balance-sheet of the Institution are presented herewith :—

INCOME AND EXPENDITURE ACCOUNT,

From 1st January to 31st December, 1921.

EXPENDITURE.

				£	s.	d.
Postages				70	9	7
Printing and Stationery, including Printing of Proceedings				380	8	10
Council, Finance and Annual Meeting Expenses				45	13	10
BRANCH EXPENSES :—						
Lancashire	£52	3	2			
Birmingham	33	5	4			
Scottish	79	3	11			
Sheffield	43	13	6			
London	43	10	10			
East Midlands	22	11	4			
Newcastle	47	8	2			
Coventry	30	1	4			
				351	17	7
Illuminated Address				6	6	0
Audit Fee				6	6	0
Incidental Expenses				11	3	10
Salaries—Secretarial Staff				300	0	0
Rent of Office				50	0	0
Bank Charges and Interest				1	17	4
Depreciation—Furniture, etc.				8	4	0
Balance of Income over Expenditure				283	17	6
				£1,516	4	6

INCOME.

	£	s.	d.
Subscriptions Received	1,421	4	6
Sale of Proceedings, etc.	5	10	0
Interest on War Loan	22	10	0
Rent Received, Heating and Ventilating Engineers	25	0	0
Income Tax Refunded	42	0	0
	£1,516	4	6

BALANCE SHEET,

31st December, 1921.

LIABILITIES.

		£ s. d.
Subscriptions paid in advance		155 18 6
Sundry Creditors		250 0 0
ROYAL CHARTER FUND—		
Balance per last Account	£251 4 4	
Interest on Deposit to date	5 10 6	
	255 14 10	
Less: Payment to Solicitors	200 0 0	56 14 10
Surplus at 31st December, 1920	255 14 4	
Add: Excess of Income over Expenditure for the year ended 31st December, 1921	283 17 6	539 11 10
		£1,002 5 2

ASSETS.

	£ s. d.	£ s. d.
CASH IN HANDS OF SECRETARIES, VIZ. :—		
Lancashire	6 8 2	
Birmingham	2 12 11	
Scottish	15 4 7	
Sheffield	42 10 3	
London	5 2 1	
East Midlands	9 6 8	
Newcastle	22 4 10	
Coventry	5 18 7	
	£109 8 1	
General Secretary, Petty Cash	3 15 1	113 3 2
London Joint City and Midland, Bank, Ltd.—		
General Account	326 1 11	
Royal Charter Fund Account	56 14 10	382 16 9
Investment Account—		
5 per cent. National War Bonds and 5 per cent. War Loan at cost		432 10 1
Furniture, Fixtures and Fittings—		
Per last Account	81 19 2	
Less: Depreciation 10 per cent.	8 4 0	73 15 2
		£1,002 5 2

We have prepared and audited the above Balance-Sheet with the Books and Vouchers of the Institution, and certify same to be in accordance therewith.

J. & A. W. SULLY & Co.,

Chartered Accountants, AUDITORS.

19/21, Queen Victoria Street, London, E.C.4.

April 24, 1922.

Election of President.

Mr. Stubbs next proposed the election of Mr. H. L. Reason as his successor in the presidency, remarking that with Mr. Reason at the head of affairs they would be in safe hands.

Dr. Longmuir (Sheffield), as a Past-President, seconded the nomination, and in endorsing Mr. Stubbs's encomiums, said they liked to have men of Mr. Reason's type to direct their destinies.

Mr. M. Riddell (Falkirk), as another Past-President, supported the motion, which was unanimously carried. The new President was hailed with great enthusiasm when Mr. Stubbs, having divested himself of the chain of office, mounted a chair to place it on the herculean shoulders of his successor.

Presentation to Mr. Riddell.

Between this ceremony and the President's reply there was interposed the presentation of an illuminated address in album form to Mr. Riddell in recognition of his eminent services in the chair and in other ways. Mr. Stubbs handed over the testimonial.

Mr. Riddell, in response, said some people did not look with favour on the foundrymen; they thought theirs was a rather low status, but he intended to uphold the dignity of the Institution as long as he had breath.

The President, thanking the Conference for the honour conferred upon him in his election to the chair, said he looked upon it as an honour done also to the Birmingham Branch of the Institution, which had rendered yeoman service to their cause. Having regard to the nominations that were coming forward for the future, there was every hope and prospect of the next Conference being held in Newcastle. He paid a tribute to the work of his immediate predecessor, observing that they would all connect with Mr. Stubbs's year of office his propaganda efforts with the National Ironfounders' Federation and the cementing of the friendship between this country and the United States by the visit he paid to their American cousins.

Election of Officers.

Mr. T. Firth (Sheffield), proposing Mr. H. Jewson (East Dereham) as senior Vice-President, said Mr. Jewson had been associated with them for a large number of years, and had been a regular attendant at the Council meetings. He was sure that in him they would find a very capable President when his turn came to occupy the chair.

Mr. M. Riddell (Falkirk) seconded, and said Mr. Jewson was one of the oldest members of the Institution; in fact, he was one of the five original members who were present that day.

Mr. Jewson, having been unanimously elected, returned thanks, and said the Institution had his heartiest sympathy and support. He loved the work of the Institution, and, so far as he was able, he would in every way do all he could during the coming year to support the President. At the same time, he hoped they would understand the difficulty he had to face in the fact that, being situated in the centre of Norfolk, it took him a whole day to get to Birmingham.

Mr. Oliver Stubbs proposed Mr. R. O. Patterson (Wylam-on-Tyne) as junior Vice-President. Mr. Patterson was President of the Newcastle Branch, which was one of the strongest in the Institution, and they were all aware of the good work he had done.

Mr. F. J. Cook (Birmingham) seconded, remarking that those who had had any connection with the Newcastle Branch would know the valuable work Mr. Patterson had done there. He was sure Mr. Patterson would leave nothing undone to make the efforts of the Institution successful.

The proposition being carried, Mr. R. Buchanan (Birmingham) proposed that Mr. F. W. Finch (Gloucester) be re-elected Hon. Treasurer, which Mr. H. Sherburn (Warrington) seconded. This was also carried unanimously; Mr. Finch, in reply, acknowledged the vote by saying it would give him the greatest pleasure to continue in office.

The President next intimated that five members were to be elected on the Council. There were eight nominations, and he would ask Messrs. Firth and Riddell to act as scrutineers. The result of the ballot was subsequently announced as follows:—Messrs. A. R. Bartlett, London; J. Shaw, Sheffield; H. Pemberton, East Midlands; H. Sherburn, Lancashire; E. H. Broughall, Coventry.

THE PRESIDENT moved that Messrs. R. Buchanan, F. J. Cook and W. Mayer (Dumbarton) be re-elected trustees, which was agreed to; and also that Messrs. J. & A. W. Sully & Company be re-appointed auditors, which was carried.

The Presidential Address.

GENTLEMEN,—

It is thirteen years ago since our Convention was held in Birmingham, this being our nineteenth Convention, and on behalf of the East Midlands, Coventry and Birmingham Branches, I extend to you all a very hearty welcome. It is extremely pleasing to the Conference Committee that in their arduous work under the guidance ot the Reception Committee all classes of citizens have participated to make the Conference both enjoyable and interesting.

The progress our Institution has made and continues to make must be very gratifying to every member. Had it not been for the moulders' strike, which was followed by the terrible slump in trade, I think our membership would have been doubled.

Subscribing Firms.

Although it is only just over two years ago since we added subscribing firms to our membership, we have already enrolled 27 firms, and as time goes on and firms recognise and appreciate the valuable work our Institution is doing for the industry, we shall not be counting them in tens, but hundreds.

Royal Charter.

The fact that the King, after making the fullest investigations into the nature of our work, has seen fit to grant the Institution a Royal Charter in recognition of the great work we are doing, should be sufficient recommendation for all time to convince anyone of the importance of our work. In connection with this we should place on record our indebtedness to our Past President, Mr. T. H. Firth, whose efforts to raise the Institution to the level of our other great Institutions have been crowned with success.

Position of the Institution.

It should give the members much pleasure to know that the Institution is now in a stronger position as regards membership and finance than it has ever been in its history. As soon as the funds of the Institution permit we have still a large field for extending the scope of our work, and I would like to make two suggestions, the first of which is that we should present every member upon joining the Institution with a book containing formulæ and useful information on foundry work such as:—Air required in cupola melting. Weight of castings from weight of pattern. Weight of metals. Pouring temperature. Approximate melting points. Annealing temperatures. There is a good deal of tabulated information that when put into book form for easy reference would be of invaluable help to the student of foundry problems. I believe that the effect of such a book on new members who wish to make a study of foundry work and improve their technical knowledge would be far reaching, and the information would form the basis for their future studies.

The second has reference to the publication of Papers. I consider all Papers read before the Institution should be circulated in full, with discussions to every member, instead of the present method of issuing the proceedings once annually with a selection of Papers. A commencement should be made by having two publications, the first mid-way in our Session, say, January, and the other as soon as possible after the sessions are closed. These could be supplemented by monthly bulletins giving a short summary of current developments, similarly to the American Foundrymen's Association.

Diplomas and Medals.

During the past year important developments have taken place in this direction to encourage members to write Papers. In addition to the diplomas which are presented for the best Paper read at each Branch annually, our Past-President, Mr. Mayer, has invested a sum of money, the interest from which will provide a gold and silver medal, to be presented for the best Paper read each year at the Scottish and Newcastle Branches alternately. In order to perpetuate the name of Mr. John Surtees, of Newcastle, who did important pioneer work in connection with loam and dry sand moulding, the medals are to be called the John Surtees Memorial Medals.

Oliver Stubbs Medal.

In addition to these medals the National Ironfounding Employers' Federation have invested a sum of money, the interest of which will provide a gold medal to be competed for by the whole of the members of the Institution, and it has been our privilege and pleasure to see the Lord Mayor present the first medal. This medal has a threefold purpose. It is a token of appreciation from the members of the National Ironfounding Employers' Federation for the great services Mr. Stubbs has rendered, and it is their wish that his name shall for all time be associated with the industry.

It gives those who do important work for the industry through our Institution a token of recognition.

It shows that the employers recognise and appreciate the important work our Institution has done, and is doing, for the ironfounding industry.

British Cast Iron Research Association.

As there appears to be some misunderstanding in connection with the work and functions of the Association and our Institution, I propose to explain that whilst the work of both is to improve foundry productions, there is a distinct line of demarcation. The Institution of British Foundrymen enables all foundry workers, whether they are moulders, foremen, managers or proprietors, to attend meetings at which valuable Papers are read and discussed. The three important features in connection with this are:—The writer of the Paper derives great benefit from his research work. Every member has the privilege of joining in the important discussions which follow the reading of all Papers. By the exchange of views, and members keeping themselves posted up with the most up-to-date methods of production both as regards material and finish, it will readily be seen by this means the Institution does some of its most valuable work.

With a body of men determined and anxious to take advantage of every modern development there are bound to be numerous instances where from lack of funds, apparatus or laboratories it has not been possible to carry important research work forward to a successful conclusion. It is at this point where the employers, assisted by the Government, come in and take an equal share as the British Cast-Iron Research Association, with a view to carrying forward valuable research work that would benefit the industries, and to organise an Information Bureau containing all existing data in connection with foundry work carefully indexed for the use of all its members.

The information that is being continually requested varies from what some would call elementary to the most difficult propositions which require research, but it will be appreciated that from the questions asked the greatest difficulties in the industries can be located and earmarked for research.

Whilst we realise the important research work that can be done to improve the ironfounding industries it is very gratifying to know that whilst the Government were exploring every avenue to effect economy they realised that to withdraw the grants to industrial research would be a step in the wrong direction, and they would be failing in their duty if they did not assist our industries to keep first position among the leading industrial nations of the world.

Research Work.

If an example was needed to point out the necessity of research work a splendid illustration is given by Sir Robert Hadfield, who, in a recent Paper, stated that the world's output of steel was about 1,860 million tons, of which 660 millions were lost by rusting in use. For the year 1920 the loss by rusting during use has been estimated at 29 million tons, the annual cost being probably over 700 million pounds sterling. Members visiting the Exhibition will be interested to see Dr. J. Newton Friend's exhibit showing the effect of rust in its various stages in connection with various metals.

Seeing the developments that have recently taken place in connection with rustless steel it is only reasonable to assume that in the near future developments will also occur with regard to cast iron.

From the foregoing remarks I have endeavoured to make it clear that there is ample room for both the British Cast-Iron Research Association and the Institution of British Foundrymen in the iron-founding industry. It is not generally understood that practically all industries owe their birth and sustenance to the iron and steel foundries.

International Foundry Trades Exhibition.

In the exhibition there are 1,000 tons of the most modern foundry equipment, with between 300 and 400 h.p. to exhibit same under working conditions, together with pig-iron, alloys, sands, refractories, also fine examples of foundry productions. One of the outstanding features of the Exhibition is the air drying oil sand core, which disposes with the necessity of core drying stoves, in fact there is almost everything to assist the foundryman to produce sound castings.

You will be interested in an extract from a letter we have received from Sir Robert Hadfield in connection with the Exhibition:—

"As one of the Honorary Members of the Institution of British Foundrymen, and a member of the British Cast-Iron Research Association, I should like to offer my heartiest good wishes for the success of this important Exhibition. Exhibitions of this nature for several years have been arranged in the United States and have proved of great educational value. I sincerely trust that the same results will follow here.

"The foundryman is often given a secondary position in the technical world. Just why this is I do not know. The greatest possible skill, patience, and high technique are required by those conducting foundry operations, whether master or moulder. Some of the greatest technical achievements to-day depend upon the skill shown in the foundry, whether as regards cast-iron, cast steel or non-ferrous alloy castings.

"I hope a special effort will be made to interest the workmen themselves by those conducting the Exhibition so as to increase the value of the work of the foundryman, which is a fascinating art."

The Exhibition is the result of a great enterprise under most difficult conditions, and it should be placed on record that it is the outcome of propaganda work by the Midland branches of the

Institution of British Foundrymen. I am led to believe the splendid Exhibition in connection with foundry equipment will be such an education that from now onwards there will be a rapid decline in obsolete methods of production.

Before concluding I should like to say how pleased we are that our 1922 Convention should be held when peace is again reigning in our industry. Without being unduly optimistic I share the view of many others that with the lock-out ended it is the earnest desire of both employed and employers to take full advantage of the revival that has begun to show itself in trade, and I hope at the end of my year of office we shall be able to look back upon a year that has been freed from both industrial and political anxieties of the last few years, and the peace and prosperity we are longing for will have reigned in its place.

Dr. Longmuir (Sheffield) proposed that a hearty vote of thanks be given to the President for his splendid address, which he said had supplied them with a good deal to think about, and the motion, after being seconded by **Mr. Jewson**, was carried with acclamation.

Charter Fund.

The Secretary announced in regard to the special fund for meeting the changes in connection with the Royal Charter that the previous night 17 guineas was subscribed by the Council, which left a balance of 7 guineas more to raise in order to clear themselves. To this statement **The President** added that members of the Council were particularly anxious that the whole of the fund should be subscribed voluntarily, and as a result of further subscriptions there and then it was announced the following day that only 7 guineas more were required to close the fund.

THE ANNUAL DINNER.

University Efforts to Aid Industrial Prosperity.

The annual dinner of the Institution was held at the Grand Hotel, on Wednesday evening, the President (Mr. H. L. Reason) being supported by a distinguished company. The function was a complete success. A special item in the musical programme which attracted general attention was the appearance of Madame S. H. Tring, the President's daughter, who sang in charming style. **The President** proposed the loyal toast, and referred appreciatively to the Prince of Wales' visit to India. He also asked Prof. Turner to remedy an omission in the earlier proceedings by proposing a hearty vote of thanks to the retiring President and the officers for their services during the year.

Prof. Turner said the work Mr. Oliver Stubbs had done called for their special recognition. He had, amongst other things, done all that was possible to promote international understanding among foundrymen; the foundrymen of America, France, Belgium, and other parts of the world who were associated with them, not only in competition and friendly rivalry, but also in mutual help. The vote was carried with enthusiasm.

Mr. Oliver Stubbs, who proposed the toast of "The City and Commerce of Birmingham," pleaded for a practical interest in education. If they had paid greater attention to education they would probably be taking a greater part in the world's commerce to-day. In America the main part of the business population would, in the course of no very distant time, be educated at the universities. While Manchester was known for its cotton, Bradford for its wool, and Sheffield for its steel products, Birmingham had a reputation for its brass ware; but Birmingham was also remarkable in that it was the centre of a greater variety of industry than any other town could boast. He urged that the improvement of the canal for traffic would help to reduce freights. and finally mentioned that the dies for the medal presented to Mr. Cook were made in the city.

The Lord Mayor (Ald. David Davis), in reply. remarked that the Foundry Trades Exhibition at Bingley Hall was one of which the city might well be proud; and referring to the University, said it was working in harmony with the commercial and industrial community to raise the standard of education.

Mr. F. Hickinbotham (President of the Chamber of Commerce) also responded, and after expressing the view that trade was gradually improving and giving reasons therefore ventured to say that the cry they had heard about Germany capturing the trade of the world was mere moonshine. From reports which they had read, and which many of them had received from private sources, it would appear that things were not always what they seemed. If they could only keep their heads and avoid any fresh difficulties in the way of strikes or lock-outs, he saw no reason why the improvement which had set in should not continue.

Mr. C. Grant Robertson, Principal of Birmingham University, gave the chief toast of "The Institution of British Foundrymen," and in a humorous opening leading up to a serious essay on industry and education, referred to the important position held by the Institution in the industrial and commercial life of the country. How else the reading of Papers, inexhaustible in their application, how otherwise a rising membership, and how else the tackling so seriously of those problems with which their Institution was concerned. The large attendance that night and the success of the exhibition proved this importance. He sincerely congratulated them on the exhibition, and hoped the consequences to them of its success would be a large number of orders. Proceeding, he pointed to the close relation between the efficiency of higher education and the prosperity of industry, and spoke of what Birmingham University and Manchester University, among the modern seats of learning, were doing to promote industrial and commercial progress. He therefore thought that the Universities were entitled to get full support of their ally in the great struggle to maintain the industrial supremacy of Great Britain. In the United States and in Germany the work that had been done and the money spent on universities, apart from the ethereal, political or civic consequences, had brought in large industrial dividends. They, in England, whatever their shortcomings in the past, were now alive to their needs, and they did want the enlightened leaders of industry to keep in close touch with university life. It was part of the Birmingham University policy to become associated with the best industrial thought and activities in the city and the Midlands, and he gratefully acknowledged the help which he had received from the leaders of industry and those connected with the business of the city during the last two years. One of the functions of the universities was to train and produce the research worker, and in discussing the value of research as a primary essential in progress, he said that he was delighted to see that the Institution was giving cordial support to research in the proper sense of the term in the interests of the great trades and industries they represented.

The President, in response, reviewed the history of foundry work, and said they had now arrived at a stage when they made automatic machines, fitted with magazines, which had to be charged with castings which must be regular in shape and size. The ironfounder had now to produce castings not only perfect in shape, but sound in every detail, and such as to stand severe tests and conform to the most rigid specifications. Indeed, the iron industry to-day had arrived at a stage when it was going to take its proper place in the engineering world. For a long time past engineers had come to them for castings of this nature, and almost expected the machine; they did not want to do any work at all in fitting a casting, and if they had to put a file on a casting they were apt to grumble, so that to-day they had really to produce in the foundry the finished article; and hence with the minimum amount of grinding or shaping, the various parts could be assembled, and there was the complete machine. He thoroughly endorsed what Principal Grant Robertson had said in regard to holding their place in the industrial world. They had now to work more closely in accordance with the scientific control of the foundry by taking full advantage of the research work and facilities offered by universities, chemists and metallurgists. Concluding, the President expressed very great pleasure that their gathering was of such an international character—France, Belgium and America being represented by some of its foremost men—and complimented the Convention Committee on the splendid arrangements which had been made for the Conference meetings.

Mr. C. Retallack proposed the health of "The Guests," and Sir Herbert Austin and Mr. S. G.

Flagg (America) responded. Sir Herbert said that the engineering world had awakened to the fact that "anything would do in the foundry" was no longer possible. Given improved accommodation and equipment, foundries would turn out better work. While the American foundryman could make malleable castings to very fine limits, he supposed they in Great Britain were able to make steel almost as fine. The exhibition at Bingley Hall proved this. At Longbridge they could obtain much better results from steel than from malleable castings, perhaps because they had gone into the matter a little more.

SECOND DAY.

When the Conference was resumed on Thursday morning the attendance was not so large as on the opening day, but there was a big muster of members, who manifested a keen interest in the technical problems introduced for discussion by specialists at home and abroad. Precedence was given, on the initiative of the President, to the Papers by the French and Belgian visitors.

A Newcastle Convention.

During an interval in the second session on Thursday the President mentioned that an exhibition was on view at Birmingham Technical School, which had gone to a lot of trouble to arrange it for their inspection. The next Convention, he announced, would be held in Newcastle owing to circumstances over which they had no control. Dr. Johnson had asked him to make the announcement, and he was doing so at this early stage for two reasons; first, that members of the London Branch would know the exact position, and, secondly, that the gentlemen of the Newcastle Branch would know that from that day they would have to take steps to make the necessary arrangements.

Foreign Visitors Honoured.

The President next proposed that the Convention elect Mons. E. Ramas, Mons. J. Leonard, Mr. S. Flagg, Prof. E. Tonceda, Mons. J. Varlet, and Mr. D. McLain as honorary members. He coupled Mr. McLain's name with the others because that gentleman was to have read a Paper, but it could not be got through in time to include in the programme. His motion was in the nature of a token of friendship and of appreciation of the visit to their Conference of these gentlemen, a visit which, to all intents and purposes, made it an international gathering; and they desired to show in a practical way how much they did appreciate their presence, which had gone a long way to making a success of the Convention. (Applause.) Mr. Flagg and Mons. Ronceray, he added, were already members of the Institution, but would be changed to honorary membership.

Mr. F. J. Cook seconded, and in testifying to the desire of their American friends for closer touch with them, said he was looking forward to a larger international meeting in two or three years' time. The proposition was carried with acclamation.

Mons. Ramas then acknowledged the honour, Mr. Faulkner interpreting the speech by saying: The President of the French Foundry Association thanks you very sincerely, in the name of the French Foundrymen's Technical Association, and also on behalf of Belgium and America, for the great honour you have done to his Institution and to them. He thanks his English comrades for the very kind reception accorded to him and for the enjoyable time they have given him. The sentiments of fraternity which existed between us during the war will, he has not the slightest hesitation in saying, be developed; and as they have already divided the sacrifices of war, they will go forth into the future with exactly the same confidence as has existed in the past.

The various Papers were then read and discussed.

At the close of Thursday's session a resolution was proposed by The President that the heartiest thanks of the Convention be passed to the authors of the Papers for the valuable information placed before them. So far as the character and quality of the Papers and their number were concerned, he said they could safely take credit to themselves for having the best Convention in their history.

Mr. Harley (Coventry) seconded, and the vote was carried with acclamation.

The President obtained the ready consent of the meeting to despatch messages of sympathy with

Mr. Charles Jones, Mr. Mayer and Mr. Gimson, whom he described as three past-presidents of the Institution, on account of their enforced absence through illness.

Subsequently, in closing the technical session, the President expressed the indebtedness of the Institution to The Foundry Trade Journal, which was their official organ, and to its Editor in connection with the editing of the Papers and doing so much to give publicity to their work. He should like to say, on behalf of the members assembled, how very much they appreciated this valuable help, and he therefore proposed that their very best thanks be accorded to The Foundry Trade Journal, and particularly to the Editor, Mr. Faulkner, for the extremely valuable work they did on behalf of the Institution.

Mr. J. Ellis (Past-President) said he had great pleasure in seconding, and in stating that he was cognisant of the very useful work which The Foundry Trade Journal had done for them in the inauguration of the Institute. He doubted very much whether they would be in the proud position they were to-day but for the help and assistance of that paper. In coupling the name of Mr. Faulkner with the vote of thanks, he could assure them that no one worked more energetically for the Institution than Mr. Faulkner, particularly in reference to the London Branch, and especially for that Conference.

The proposition was carried by loud applause.

NEW METHODS OF TESTING CAST IRON.

By E. V. Ronceray, M.I.Mech.E. (Paris).

Presented on behalf of the French Association Technique de Fonderie.

In order to comply with the invitation of the Institution of British Foundrymen to present a Paper at the Birmingham meeting, the French Association Technique de Fonderie has thought it advisable to select a subject of world-wide interest —one referring to the research of two French scientists on new methods of testing cast iron. Both of them are well known in England. One of them, M. Fremont, received the Bessemer Medal at the Paris meeting of the Iron and Steel Institute in September last; the other, M. A. Portevin, is a Carnegie Medallist, and has sent quite a number of papers to the Iron and Steel Institute.

It seems as if a great deal of advancement can be expected in the foundry from the systematic use of such methods. They deserve to be carefully considered and tried.

In early times, the transverse test was used. As far back as 1790 the Ramus testing machine, known as the Monge machine, is described in the "Annales de Chimie."* The great scientist, Monge, described the machine and used it, and he was considered as the inventor. M. Ch. Fremont's research showed that the real inventor was Michel Ramus, manager of the Creusot Foundry. The bars were 80 mm. square and about 50 cm. long. They were supported by one end and loaded at the other end.

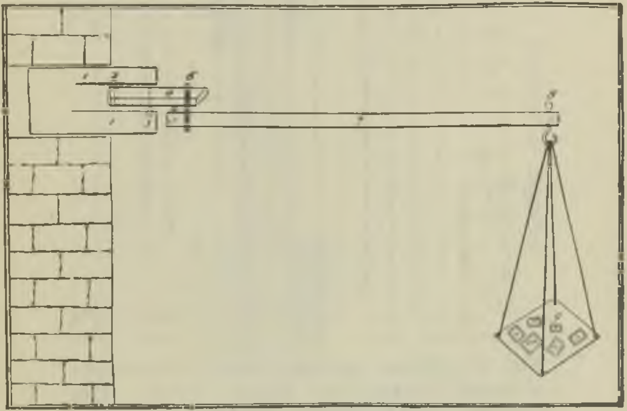

Fig. 1.—Apparatus used for Testing Cast Iron at the Creusot Royal Foundry in 1790.

Fig. 1, taken from M. Fremont's memoir, shows the Ramus machine. This same machine† is described by Monge, who was thought to be its inventor, though Monge mentions the Creusot machine.

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* Ch. Fremont, "Nouvelles Methodes d'essais Mécaniques de la Fonte," p. 11.

† "Description de l'Art de Fabriquer les Canons, Paris an II 1794," p. 18.

It is a very curious fact that though M. Fremont and many others consider at the present time that the transverse test is the ideal one, and that Monge test is still described in most French specifications, it has been practically abandoned and replaced by two stupid tests, the tensile and the impact tests.

Colonel Prache, in his Paper before the French and Belgian Associations Convention at Liège, October, 1921, said :—" What has stopped the improvements being made with semi-steel during the war are the tests imposed by the War Office. Those who have made semi-steel shells know that these tests had a very distant relation to the castings that were to be produced."

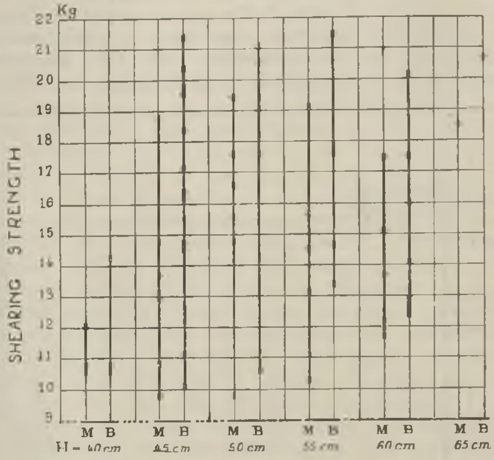

Fig. 2.—Graph showing the relationship between Shock and Shear Tests. The abscissa gives height of drop, and the ordinates the corresponding resistance to shearing. *M*, Shear Test-pieces taken from centre of Shock Test-piece. *B*, Shear Test-piece taken from the edge of the Shock Test-piece.

In America transverse tests have been made in the past on square or rectangular bars of all sizes and lengths. Great efforts have been made recently in that country to come to an agreement for a standard bar, and to impose it on other countries. A round bar 1¼ in. dia. was selected, and it was to be broken on supports 12 in. apart. But the pipe industry of U.S.A. uses a bar 2 in. × 1 in. placed flat on supports 24 in. apart, and the car-wheel men generally use the same, whilst many works retain the old 1-in. square bar broken on supports 12 in. apart. Bars have been used with

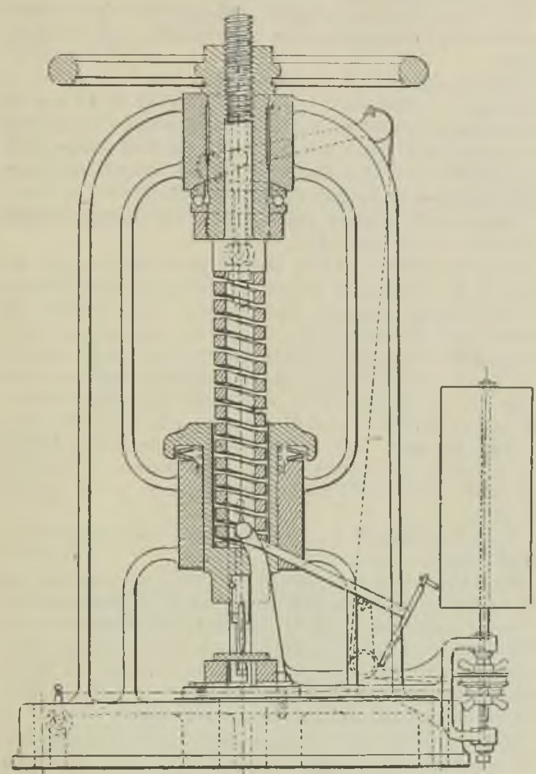

Fig. 3.—Section through Fremont's Transverse Testing Machine for Small Samples.

supports 3 ft. and even 5 ft. apart, while Keep experimented on bars ½ in. dia.

In England the standard test piece is usually a casting 3 ft. 6 in. long × 2 ft. deep × 1 in. wide, broken on supports 3 ft. apart.

In France, as mentioned, Monge tests have been practically superseded by the tensile and impact tests.

The impact test is made on a bar 40 mm. × 40 mm. × 200 mm. long. A weight of 12 kg. is raised and dropped on the bar, which is set on supports 160 mm. apart. The initial height of weight is not the same in all specifications, nor the increase in height after each blow.

The tensile test is made either on testing pieces 16 mm. or 25 mm. dia.

To demonstrate that the impact test is of no value, M. Fremont made transverse experiments with broken impact test-pieces, the results of which are shown in Fig. 2. For each set of bars having broken at a given figure, he made shear-tests on pieces taken on the middle and on the edge of the bars. The dots refer to shear-tests; M is for middle, and B for the edge of the bar. It can be seen that some of the bars which broke at a small height gave excellent tests, while the reverse happened with bars broken at a great height.

This is sufficient to condemn this test apart from other reasons.

Everybody is convinced that the tensile test is of no value for cast iron on account of its sensitiveness to an oblique pull. In fact, M. Portevin has demonstrated by the method of mirrors that it is entirely valueless when it is made under ordinary conditions. The same happens for hardened steel, which possesses similar characteristics.

Tensile tests are accepted but not recommended in America; they are very little used in England and cut out of German specifications. The best French experimenters are of the opinion that it must not be used under ordinary conditions.

Cast-iron structure varies with the rate of cooling, and consequently the thickness of sample and condition of pouring. It seems almost unbelievable that, even in this time of progress and science, the qualities of cast iron have been observed on separately-cast test-bars which are entirely different in structure from castings. It is certainly very difficult to get from the same ladle of molten iron test-bars giving the same results, but what can be expected from a test-piece cast separately, of a thickness entirely different from the casting considered and generally cast at a different time.

Colonel Prache was quite justified in stating that "War Office tests prevented foundrymen from making better shells," and M. Portevin that "On the point of view of the quality of metal for projectiles, it was difficult to make a worse choice of testing methods." It is quite easy to understand that to get the best results on different shell thicknesses different thicknesses of test-bars should be used.

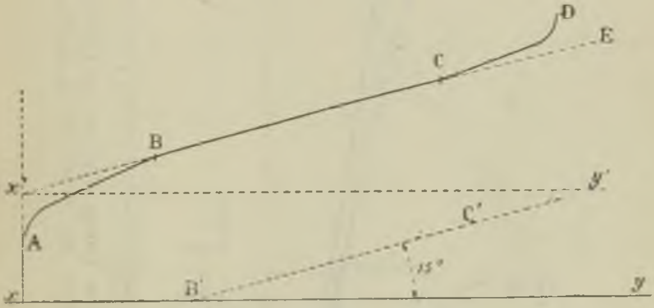

FIG. 4.—DIAGRAM AS PRODUCED AND THEN CORRECTED. ABSCISSÆ GIVES THE LOAD, AND THE ORDINATES THE CORRESPONDING DEFLECTION.

But the best way would certainly be to ascertain the quality of castings on themselves rather than on test-bars more or less different from them, or next to that, on a small sample taken on one out of a lot of castings.

The work of M. Fremont and M. Portevin refers to such methods, which in the author's opinion are the incentive to considerable progress in the foundry. Their methods will enable foundrymen to select the best composition of metals and the best foundry methods; they will enable the designer to alter his drawings according to the

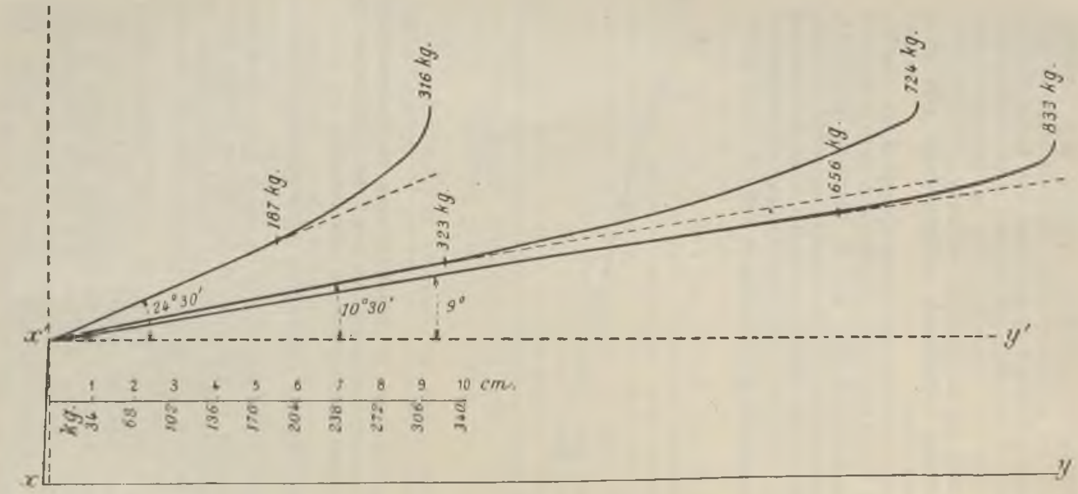

FIG. 5.—TYPICAL DIAGRAM OF TESTS ON THREE SAMPLES OF CAST-IRON OF VERY DIFFERENT QUALITIES. ABSCISSÆ AND ORDINATES AS IN FIG. 4.

results shown by numerous readings taken in different parts of the castings.

The result will probably be to bring further confidence in cast iron, the products being more regular and reliable.

It would be a great advantage if such methods were submitted to a Committee composed of members of the various foundry organisations, in order not only to decide on the tests to be recommended, but also on the size of test-pieces, so that results of all foundries or investigators can be compared.

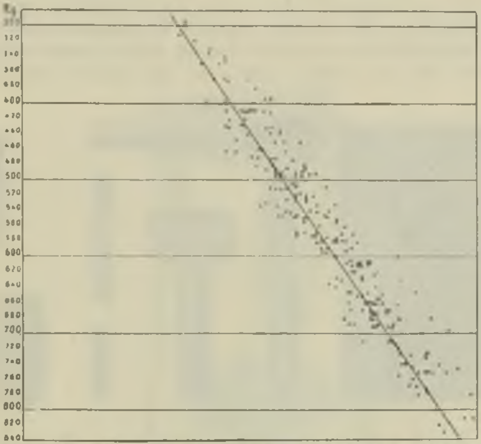

FIG. 6.—GRAPH SHOWING THAT FOR CAST-IRON THE RESISTANCE TO SHEARING IS PROPORTIONATE TO THE DEFLECTION. ABSCISSÆ TRANSVERSE BREAKING LOAD, AND ORDINATES CORRESPONDING SHEAR BREAKING LOADS.

Fremont's Transverse Testing Machine.

To study the quality of a cast iron in the laboratory, M. Fremont recommends the static transverse test. But considering that the test had to be made on a sample taken from the castings, he designed a machine to deal with small samples. He also thought that it was necessary to record the condition of the test. He selected the size of

10 mm. width × 8 mm. thick × 35 mm. long, so that a sample could be cut out of any portion of any casting in order to study all parts of it and arranged the machine with a recording apparatus.

This machine is shown in Fig. 3. To verify the practical value of the machine he made tests on 110 samples, for most of which he knew the practical value.

The size of test-piece selected determined the maximum power of the machine. It is of 1,000 to 1,500 kgs. capacity, but this power must be applied gradually without any shock. The best device was thought to be a screw driven by a hand wheel, with the insertion, between the screw and the punch, of a large spring which transmits gradually, and without shock, the power of the screw.

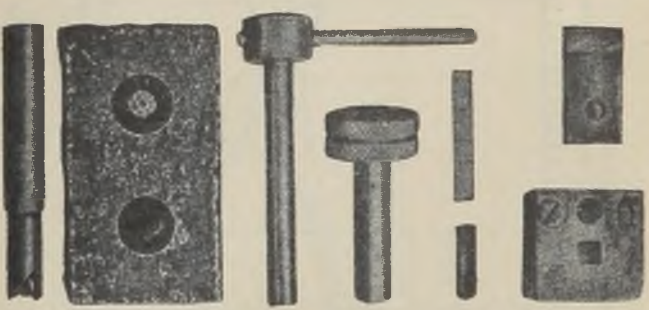

Fig. 7.—From left to right: Trepanning Tool—Sample Trepanning—Square and Round Test-pieces—Chisel and its Adjustable Blade.

The weight of moving equipment is balanced by a spring, resting in a groove of the machine-frame. The spring yields proportionally to the power applied at the ratio of 1 mm. for 43 kgs. The breaking of test-pieces takes place when the screw has made from 3 to 8 revolutions, according to the strength of the sample, which allows of a very simple and easy reading of the applied load. To measure the elastic limit and elastic coefficient, a recording apparatus is provided.

By a convenient arrangement a drum is moved by a metallic wire in connection with the large spring, so that 1 mm. corresponds to 3.4 kg. The deflection of the test-piece being very small, it must be amplified about 200 times.

Fig. 4 shows the diagram produced. The left part shows a curve, which is the result of the contacting a test-piece with the recording finger. The real starting point is x′, x′y′ being considered as the zero line. Where the line ceases to be straight, at C, the elastic limit is attained, and the angle C, x′y′ gives the measure of the elastic coefficient.

The breaking is always sudden, on account of the nature of cast iron. To protect the recording apparatus from accident, two Belleville washers are placed under the tool holder; the stroke of the punch is then limited to 2 mm., and, in addition, a special arrangement is provided for the horizontal levers to avoid trouble when breaking of sample occurs.

FIG. 8.—LEVER-ACTUATED MACHINE FOR SHEAR-TESTING CAST-IRON.

The machine is gauged by measuring the deflec-

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tion of the spring for a given load or by pressing with it on a scale. A similar process is used for the deflection of the test-piece, in using a Palmer caliper for pushing the levers.

Fig. 5 shows three typical diagrams corresponding to different qualities of cast iron arranged to permit comparison between them.

The first gave a breaking load of 316 kg. associated with an angle of 24 deg., 30 secs.; the second, a breaking load of 724 kg. with an angle of 10 deg., 30 secs.; whilst the third was 833 kg. with an angle of 9 deg.

It shows that the deflection has varied in the ratio of one to three. The elastic coefficient can be determined from the deflection record. The numerous experiments made by M. Fremont show that the stronger the iron the smaller is the deflection, while it does not vary much for the steel.

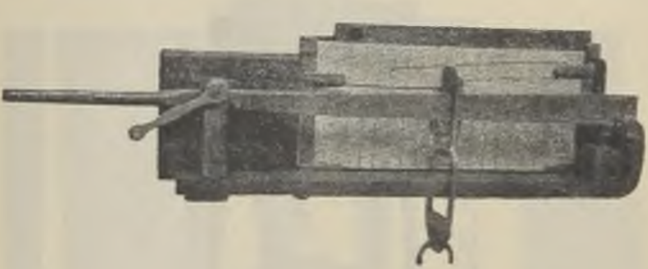

FIG. 9.—ARRANGEMENT OF MECHANISM AND RECORDER OF THE MACHINE SHOWN IN FIG. 8.

M. Fremont recommends this method for the study of the metal and conditions of specifications. For the inspection of castings he recommends the shearing test.

Shearing Tests.

The shear test has been devised in view of daily inspection of castings produced. In a previous work on steel, M. Fremont had been able to demonstrate that the phenomenon of shearing or punching was of the nature of tensile and not of slipping, as was supposed, each fibre of metal acting as a separate testing piece, which elongated under the pressure of the test.* He was able to show that, for steel, there was a direct relation between shearing and tensile strength.

To ascertain what was the case for cast iron he made experiments on the 110 samples he had used for the transverse tests. He found that shearing strength is in proportion to the transverse strength, as is shown in Fig. 6.† Other experiments have shown that tensile strength is equal to shearing strength for cast iron. Consequently, a shearing test is quite satisfactory for inspecting purposes, and, moreover, is not liable to the errors of tensile tests.

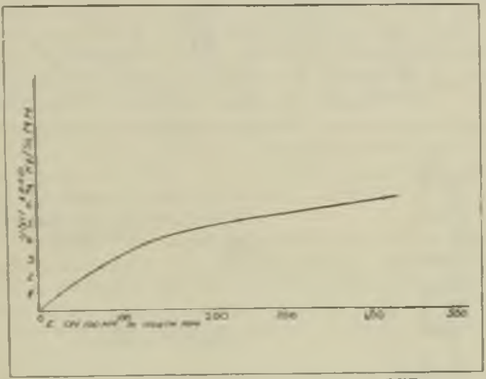

FIG. 10.—TENSILE TEST ON A 155 MM. SEMI-STEEL SHELL AT ITS NOSE.

To judge the casting on itself, M. Fremont put forward the testing of either a square piece, 5 m/m × 5 m/m, cut out of the casting, or a round piece 5.64 m/m dia. drilled out of it, that is in every case 25 sq. mm.

This method was presented by him to the International Congress for Testing Methods, N.Y., 1912, and, criticising it, Dr. Moldenke said:‡ " Shearing pressure is applied to this rod, cutting off little pieces every $\frac{1}{8}$ in. and the average taken.

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* See Memoir on " Le Rivetage Ste. d'Encouragement pour l'Industrie Nationale, 1906."

† This has been confirmed by further experiments of M. Portevin on Semi-Steel. See " Revue de Metallurgie." p. 761, Dec., 1921.

‡ " Principles of Iron Founding," Moldenke, p. 163.

The proposal is exquisite in its novelty and ingenuity."

It is often possible to cut off, on finished pieces, little prisms that can be machined to the size of 5 × 5 mm. But when this is not possible the same results are obtained by drilling with a hollow drill, a hole in some part where there will be later on an assembling hole, or to drill a hole in an unimportant part to be plugged afterwards, or else by sacrificing a casting.

The hollow drill is 10.5 mm. dia. with a hole 5.64 mm. dia., so that the small cylindrical piece remaining has 25 sq. mm. The detaching of test-piece is obtained by using a small special tool (Fig. 7) made up of two eccentric tubes fitted together, the inside of small tube being 5.64 mm. dia., and outside of large one 10.5 mm. dia. When the eccentricities are completing each other they are pushed inside the circular groove formed by the hollow drill, then turning the lever of external tube, while the inside one is held firmly, the piece is broken out.

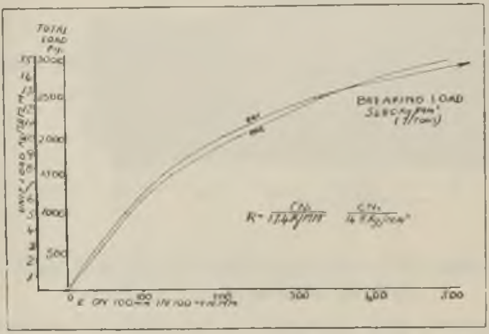

Fig. 11.—Tensile Test on Two Samples taken from 220 mm. Shells swollen after firing.

The test-piece, either square or round, is then sheared, a figure being obtained by measuring the required load every $\frac{1}{8}$ in. to ascertain the strength of cast iron at different thicknesses. A test-piece 20 mm. long ($\frac{7}{8}$ in.), weighing 4 gr., is sufficient to take four readings; that is, 1 gramme per reading instead of several pounds. The shearing is effected through parallel and not oblique blades. There is one square and one round hole in the blades.

The machine for utilising the method is shown in Fig. 8. It will be slightly altered for rendering its use easier in practice. It is simply composed of a lever having a fixed point, with an arrangement to press on the blade by a weight moved alongside the lever. The weight is moved by a handle, pulling on the weight-roller, through a string (Fig. 9), but a hand-wheel and screw arrangement will be provided in future machines. Power is increased in relation to leverage; when the power corresponds to strength of sample, breaking occurs.

During the testing, a pencil is moving along a sheet of paper, giving a diagram similar to the one shown in Fig. 9. A table prepared according to the constants of the machine gives the strength of sample tested.

Of course, this shear test can be made on tensile testing-machines of corresponding power fitted with a shearing device, but it is thought that the little special machine described will be preferred by foundrymen on account of its simplicity and low cost.

It may be interesting to mention some results obtained by M. Fremont on an automobile engine on which he made numerous tests:—

	Tons per sq. in.
Inside of cylinder (tensile strength by shearing)	12·7—17·8
Outside of Water Jacket	12·0—14·6
Piston..	10·6—13·0
Piston Rings	17·8—25·1

Of course an outside test piece would not have shown different strength for the same casting.

M. Portevin's Test.

During the war M. Portevin had the opportunity to test numerous defective semi-steel shells. His opinion on the value of War Office testing methods has been given above as the conclusion of his work. However, he tried to find better and quicker methods to ascertain the value of cast iron. Though his observations were entirely on semi-steel, they can be of service to the foundry, for many of the defective shells he examined were no better than ordinary castings of low phosphorus contents. His methods would have to be investigated in relation to high phosphorus castings before drawing definite conclusions from them.

Portevin, having noticed that ball-tests gave an indication on the value of shells, started experiments to find the relation between ball impression and carefully made tensile and compression tests. These last tests were considered as important, not only because cast iron is often used on compression, but because one of the most important points for shells was that they had to resist an enormous compressive force when the gun was fired. Most of the defective shells tested swelled on the firing test, which was systematically made on a few shells being taken at random from each lot.

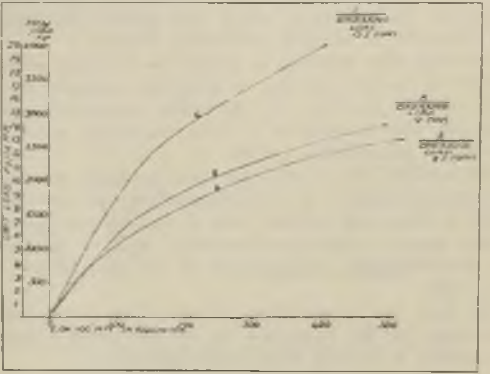

FIG. 12.—TENSILE TEST ON THREE SAMPLES OF SEMI-STEEL SHELLS. *A*, CONTRACTED; *B*, SWELLED; AND *C*, BROKE DOWN ON FIRING.

Knowing the importance of oblique pulls on tensile test results, Portevin took special precaution to avoid all chances of error by using the very long and tedious, but only reliable, method of mirrors.

Elastic Limit.

He found that it was very difficult to determine a value for the elastic limit of cast iron. The curves obtained by observing the deformations in relation to load, Figs. 10, 11 and 12, do not show any straight portion. The properties of metal can thus only be defined by the entire curve. Figs. 13, 14 and 15 give the curves for other samples. The nine samples employed vary between 4 and 17.1 tons per sq. in. tensile strength, and Tables I. and II. outline respectively their chemical and physical characteristics, it being understood that the "limit of proportionality" used by Portevin instead of elastic limit is only given where a straight part can be more or less seen at the beginning of the curves.

Attention is called to the fact that where it has been thought possible to indicate a "limit of proportionality" it is generally less than one-third of breaking strength.

TABLE I.—*Chemical Composition of Samples Used.*

Fig. No.	Chemical analysis.					
	T.C. Ct.	Gr. C. Cg.	Si.	Mn.	P.	S.
	%	%	%	%	%	%
10	3.82	3.25	1.50	0.75	0.13	0.14
12 (curve A) . .	3.65	2.95	1.46	0.77	0.11	0.15
11 (curve B) . .	3.67	2.98	1.48	0.64	0.10	0.16
12 (curve CN2)	3.48	2.86	1.47	0.64	0.06	0.12
13	3.71	3.30	1.30	0.78	0.16	0.19
12 (curve CN1)	3.50	2.87	1.44	0.70	0.06	0.12
14	3.23	2.70	1.13	0.62	0.09	0.19
11 (curve C) . .	2.97	2.35	1.27	0.65	0.07	0.22
15	3.44	2.73	1.24	0.76	0.16	0.14

Modulus of Elasticity.

These curves enable one to determine Young's modulus from the indication on the axle of loads of the straight part of surve when such exists, or the tangent to the origin of the curve in other cases. It can immediately be seen that, contrary to what happens with steels, the modulus varies considerably. It passes from 2,500 to 7,300 tons per sq. in., and it varies, roughly, proportionally to the tensile breaking-load Rt, as can be seen by Fig. 16.

It can be expressed by the empirical formula

$$Mt = 385\ Rt + 1150.$$

The strongest irons have the highest modulus of elasticity. They are less deformable, and consequently more influenced by oblique pulls. That is one more reason in favour of prohibiting ordinary tensile tests for cast-irons.

Sounding Tests.

The sounding of projectiles during the war was tried by a special committee as a means of investigation. It was found that—(a) For steel shells it can give a useful indication by observing the length of tone to disclose cracks. (b) For semi-steel shells the height of tone gives an indication of the value of metal. For a same size of projectile, the lower was the tone the worse was the metal. Consequently the sound was retained so as to give an idea of the value of the metal of semi-steel shells, and not of steel shells.

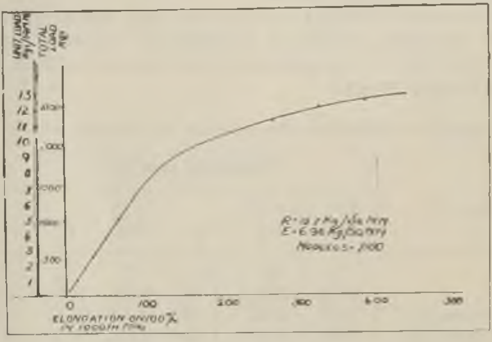

FIG. 13.—TENSILE TEST OF 155 MM. SEMI-STEEL SHELL WHICH SWELLED ON FIRING.

The above conclusions about modulus of elasticity explain why. It is known that the height of sound given by a solid depends on the speed of propagation of sound in it, and that this speed increases as the square root of the modulus of elasticity.

For ordinary carbon steels, the modulus is about the same, and thermal treatments do not change it more than 10 per cent., whilst for semi-steels it varies from 1 to 3. The differences in semi-steel are 100 per cent. each way from the average, and it is very easy to find, by the sound only, what are the best shells of a lot. This remark may be of considerable practical interest.

Compression Tests.

As far as possible, cast-iron is used in compression in daily practice. The powder explosion compresses the back of shells, so that the swelling at this time may be very serious; in fact it is the only important deformation to consider for estimating the value of projectile during firing. This, it appears important to determine the properties of metal under compression. The compression test only requires simple and short testing pieces, so that this is still a further reason for scrapping the tensile and, in preference, using the compression test.

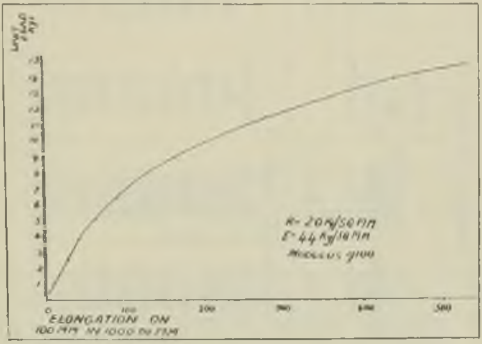

Fig. 14.—Tensile Test on 293 mm. Semi-Steel Shell.

M. Portevin made experiments on cylinders 16 mm. dia., by 16 mm. high with a recording apparatus. The breaking load and elastic limit were observed. Shortening and swelling were measured afterwards, but on account of the shortness of samples it was not thought advisable to ascertain the modulus of elasticity from the compression. It is one of the advantages of the transverse test, as it gives an evaluation of the coefficient of elasticity.

TABLE II.—*Comparative Mechanical Tests on Samples shown in Figs.* 10-18.

	Tensile Test (1)			Compression Test (2)					Transverse Test (4)	
Fig. No.	Breaking load.	Limit of proportionality.	Modulus of elasticity.	Breaking load.	Apparent elastic limit.	Reduction of length at breaking.	Diametrical swelling.	Ball Test	Breaking load.	Deflection
	Rt.	Ept.	Mt.	Rc.	Eac.	a.	g.	(3)	Rf.	f.
	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.	Tons per sq. in.	Per cent.			Lbs.	mm.
10	4.4	—	1,841	23.2	13.9	9.0	0.17	105	1,485	—
11 (curve A)	8.5	(1.9)	4,191	39.4	17.1	15.9	0.27	131	1,485	0.28
11 (curve B)	9.3	—	4,000	40.7	19.0	17.5	0.27	143	1,595	0.35
12 (curveCN2)	9.4	—	3,873	41.6	20.3	18.7	0.34	149	1,628	0.32
13	9.9	4.4	4,508	(38.8)	(20.6)	(24.4)	(0.44)	143	—	—
12 (curveCN1)	11.0	—	5,016	42.3	23.4	17.2	0.30	149	1,650	0.38
14	12.7	2.	5,715	49.3	24.7	23.4	0.41	163	—	—
11 (curve C)	13.5	(5.8)	5,905	63.5	31.7	28.1	0.50	187	2,035	0.30
15	16.9	3.0	7,302	63.8	31.7	23.8	0.35	207	—	—

(1) On screwed test pieces 16 mm. dia by 150 to 200 mm. working length.
(2) On cylinders 16 mm. long by 16 mm. dia.
(3) Ball 10 mm. dia ; load 3,000 kg. ; time 15 secs.
(4) On samples 10 by 10 by 65 mm. ; distance between supports 30 mm. ; radius of supports and punch 2 mm

In the cast-irons examined (see Table II.) the tensile breaking load, Rt, is about 1-4 to 1-5 of compression breaking load, Rc.

The approximate empirical formulæ of comparative results could be written—

$$Rc = 2.5\ Rt + 18.$$

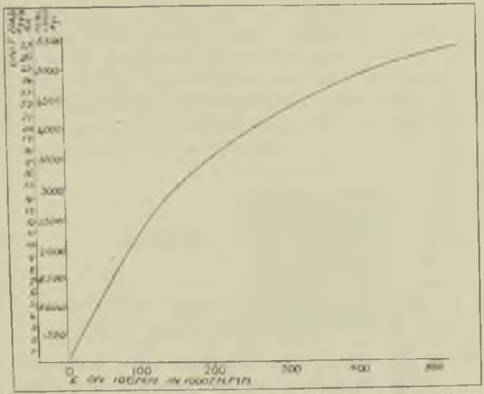

Fig. 15.—Tensile Test on a Sample of Semi-Steel Shells.

From a much larger number of readings (about 100) it was shown that the apparent ratio of elastic limit to compression can be expressed by following empirical formula for samples 16 mm. high—

$$Eac = 0.2\ Rc - 20.$$

Elastic Limit and Modulus of Elasticity for Tensile and Compression.—It would be absurd to compare tensile and compression elastic limits of Table II., the experimental conditions not being sufficiently accurate, and also because the definition is too conventional. The size of tensile and compression testing pieces being very different, M. Portevin thought it advisable to make new tests, so as to be able to get accurate data for shell firing.

Similar sized test pieces were selected (Fig. 17) and similar accurate testing methods used. It was necessary to use short pieces on account of the tendency of compressed samples to bend; the length is twice the diameter for tensile, as well as for compression samples. The mirror method was used, the distance between the supports being 50 to 55 mm. The samples were taken as round bars, 60 mm. dia., cast from the same ladle, three of each. The amplification of longitudinal deformation was 700, while the accuracy of machining was

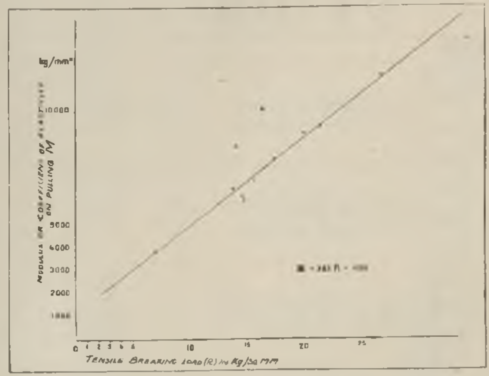

Fig. 16.—Showing the Relation between the Modulus of Elasticity and the Tensile Strength.

within 1-100 of a mm.; the variations in length observed on two opposite generatrix noted every 500 kgs., and the test-speed about 1,200 kgs. (2,640 lbs.) per minute. At the beginning the observation of deformations under small loads enabled to interpose lead cushions to reduce oblique pulls to minimum. The accuracy of readings was 1-50,000 of lengths measured.

The material used was of average quality (about Rt = 25 kg.mm.², or 15 tons per sq. in.).

The results of experiments are shown in Table III. and Figs. 18 and 19.

It can be deduced that the limit of proportionality to tensile, Ept = 3.5 kg.mm.², or 2.2 tons per sq. in.; the limit of proportionality to compression Epc = 12 kg.mm.², or 7.6 tons per sq. in.

From Table III. the following remarks can be made:—

(a) The tensile and compression breaking loads are, roughly, to the ratio given by empirical formula—

$$Rc = 2.5\ Rt + 18.$$

(b) Previous formula would give for the values of Rt and Rc found an apparent elastic limit Eac = 50 kg.mm.^{2} (31 tons per sq. in.), whilst the experiments only give 32 kg.mm.^{2} (20.2 tons per sq. in.). The reason is that test-pieces were five times longer, and also that the accuracy was greater. It can be seen by the shape of the curves that this may make a great difference.

(c) The rule, often used, that the compression elastic-limit is three times greater than tensile is entirely wrong; the ratio can vary between 1 and 4 according to the conventional definition adopted and the accuracy of readings on account of the fact that test pieces for tensile and compression are vastly different in length, consequently no comparison is of any value.

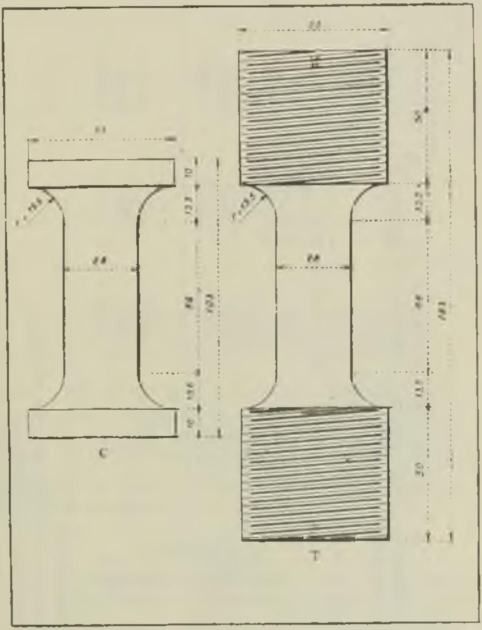

Fig. 17.—The Cylindrical Part Must be Exactly Parallel.

TABLE III.—*Tensile and Compression Tests on Semi-Steel 25 Kg. mm.² Tensile Breaking Load.*

Nature of test.	Marks of test pieces.	Limit of proportionality. (1)	Apparent elastic limit. (2)	Breaking load.	Deformations.			Modulus of elasticity.
					In length.		In section at the breaking load. (5)	
					At the limit of proportionality. (3)	At the breaking load. (4)		
		Tons per sq. in.	Tons per sq. in.	Tons per sq. in. Per cent.	Per cent.	Per cent.		Tons per sq. in.
Tensile	T.B.1. ..	2.0	13.6	13.6	0.0256	0.384	0.16	8,064
	T.B.2. ..	2.5	16.8	16.8	0.0332	0.597	0.16	7,778
	T.B.3. ..	2.3	16.2	16.2	0.0289	0.540	0.16	8,032
Compression ..	C.B.1. ..	8.25	20.3	57.2	0.115	16.0	34	7,175
	C.B.2. ..	7.2	20.6	56.7	0.105	16.2	31	7,483
	C.B.3.	6.7	19.5	57.6	0.086	16.4	37	7,810

(1) Results (calculated).
(2) Measured on the diagrams by the machine.
(3) ,, with mirror apparatus.
(4) ,, on 56 mm. of length by determining results with mirror apparatus and direct measurement on samples.
(5) ,, on the breaking section for tensile pieces and on the middle of the length for compression pieces.

(d) As for steel, the modulus of elasticity to tensile and compression are practically equal, the average value being 12 by 10^3 kg.mm.^{2} (7.6 by 10^3 tons per sq. in.).

There is a large difference between the values found for the limit of proportionality Epc = 12 kg.mm.^{2} and the apparent limit of elasticity Eac = 32 kg.mm.^{2}, which, on account of the condition of the test, can be said to be the lower and upper limits of the real elastic limit. So that it can be said that for a cast-iron (semi-steel) breaking at 25 kg.mm.^{2} at the tensile test, the limit of deformation to compression is between 10 and 30 kg.mm.^{2} In fact, under a load of 20 kg.mm.^{2} there is a slight permanent contraction of 0.013 per cent. (the total contraction under the load being then 0.16 per cent.), but to show it the readings must be made with an approximation of 1-50,000 of the length.

FIG. 18.—TENSILE TESTS ON SEMI-STEEL.

Ball Test.

I. *Comparison with Tensile Test.*—The ball test has not yet been used for the qualification of cast irons. Moreover, the roughness of the tensile test as usually practised renders a comparison valueless.* However, the accurate tests made by M. Portevin are of considerable interest in order to

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* See Portevin, "Revue de Métallurgie," Dec. 1921, p. 775 F. Wust and K. Kettenbach. F. Wust and R. Meissner Tests.

find out whether the ball test gives reliable data on the tensile, etc., strength of cast iron.

From Table II. data has been obtained which shows a remarkable agreement between tensile strength and ball number. The empirical formula giving the relation is —

$$R\ T = 0.2 \text{ area} - 13.$$

II. *Comparison with Compression Test.*—Here there is a much larger number of readings to work upon, and they show that there is a fair agreement between ball number, compression breaking load and compression elastic limit, determined, as previously mentioned, on cylinders of 16 mm. dia. by 16 mm. length, which can be expressed by empirical formulæ—

$$Rc = 0.5 \text{ area} - 5.$$
$$Ec = 0.4 \text{ area} - 25.$$

Fig. 20 shows graphically the relation between the four values of ball area Rt. Rc. and Ec.

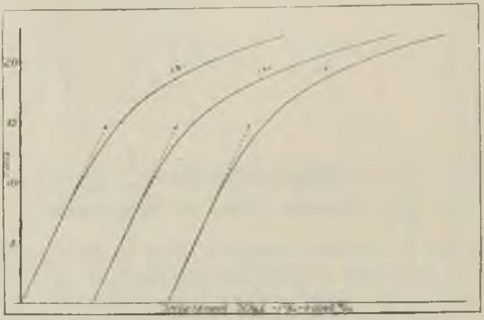

FIG. 19.—COMPRESSION TESTS ON SEMI-STEEL.

It must be remembered that these ball tests have been made on machined shells, and it may be that some care must be taken to avoid mistakes when the print is made on the skin.

However, this, so simple a test, is most interesting if it is proved that it applies, as it is probable, to common cast iron. Its advantages are that it is very simple, quick, cheap, indestructible, individual, and indelible.

Conclusion.—In conclusion the writer, on behalf of the French Association Technique de Fonderie, calls the attention of parent societies to the importance of the methods here set out for the future advancement of the foundry trade. Up to now the methods used were costly and uncertain. It can be said that, providing an agreement is made between the interested societies to standardise the test-pieces and condition of tests, a considerable amount of data can be obtained in a comparatively short time, if all foundrymen are willing to use such reliable, cheap, and simple methods.

It cannot be questioned that at present, in order to determine international specifications for castings, it is too early, but the A.T.F. strongly recommends that a committee is immediately formed between the interested societies to decide if the sizes of testing pieces proposed by MM. Fremont and Portevin cannot be adopted by all foundrymen with a view to render comparable tests made in

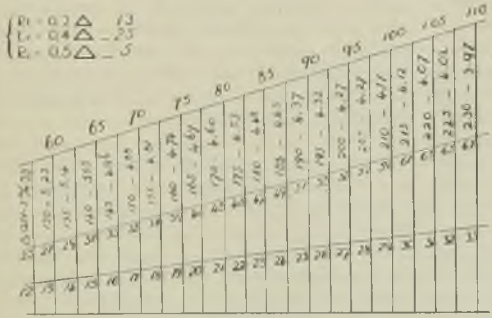

FIG. 20. — SHOWING THE RELATIONSHIP BETWEEN THE BRINELL NUMBER, THE TENSILE STRENGTH (TOP LINE), THE COMPRESSION ELASTIC LIMIT (MIDDLE LINE), AND COMPRESSION BREAKING LOAD (BOTTOM LINE), ALL IN KILOS PER SQ. MM.

different countries, and, when decided, to investigate the value of the sounding test, and to carry out experiments and collect data from members, with a view to reporting results at a Joint Foundrymen's Meeting.

Discussion.

Tensile Tests Criticised.

Prof. Turner, who was called upon to open the discussion, said they had brought before them in the paper a system of testing which was novel, and which might be revolutionising in its effects. One realised at once that it was a great advantage to be able to take a piece of the actual casting and test that instead of depending on outside testing, which might or might not correspond with the character of the main casting. They had had methods of testing the hardness of the interior of a casting by drilling holes under suitable conditions, but though those drillings might be analysed they did not give an opportunity of testing the physical character of the metal. In this method of testing, a cylinder was drilled and pieces could be cut off and examined, by compression or shearing test. He gathered that the author did not approve of tensile tests for cast iron, and he (Prof. Turner) knew some of the objections raised to it, but he must say his own experience had been that, provided one could get a straight pull, which was the essential point for cast iron, the tensile tests were of very great value. They must remember, however, that they used cast iron for purposes which were quite different in many cases from the purposes for which they used steel. If they required the properties of steel obviously they should use steel; if they required other properties then the cheaper material, cast iron, could be used with advantage. They had been too much in the habit of testing cast iron by methods which were applicable to steel. It might be advisable, as suggested in this paper, to consider together (he thought the idea of a joint committee was an admirable one) what were the best tests on such occasions. He was interested in the sounding tests described by M. Ronceray, because those methods had been used for steel. They gave a ready method with rods of similar characteristics of discerning the amount of carbon: the higher the percentage of carbon the higher would be the note when the rod was struck. But the greatest fundamental fact in the test was that the casting should be of a suitable shape, because there were so many castings that were not suitable for the sounding test. In many other cases, however, by hitting the casting with a hammer and listening to the note it gave one could get a considerable amount of information as to the elastic properties of the material. The paper would, at all events, cause them to think seriously, and would, he believed, be of considerable benefit to the industry.

Impact Test Recommended.

Mr. Shaw, in thanking M. Ronceray for his paper, said that all were pleased to learn how foundry matters are conducted in France. M. Ronceray had been a member for the last 13 years, yet this year he gave his first contribution to the Proceedings. It was to be hoped that now the ice was broken that either he or his compatriots would often favour them. The author had taken for his subject one that was full of interest at the present time, when the question of tests were before the Institution. He (the speaker) agreed with M. Fremont that the transverse test was the best one for grey cast-iron. He also agreed that the tensile was not a true index of the quality of the metal. This might be in part due to the difficulty in obtaining true alignment in the machine, but more from the fact that the tensile test was a measure of the structure of the iron rather than its quality. Mr. Field had unwittingly made a statement that tended to bear that out, when he stated he could obtain a 15 per cent. semi-steel that would give 17 tons tensile, but could not guarantee the transverse. This was also borne out in M. Fremont's paper, given before the International Congress in 1912. With regard to the impact test with the French machine, after two years' daily use he found it gave the best indications of the quality of the iron.

There was no doubt Mr. Fremont's idea was the correct one; no test would enable one to say a casting was a strong one, better than tests taken from the actual casting. Whether the small bars used (roughly 5-16th in. × $\frac{3}{8}$ × $1\frac{3}{8}$ in.) were large enough to give a true indication of the transverse strength, and more particularly the deflection, was open to serious doubt. It must also be remembered that in drilling with the hollow drill, the resultant test piece would be closer in grain at the beginning and ending of the operation, as they consisted of the outer skin of the casting. The centre of the bar would be of a more open structure. As the top V-piece of the machine would exert pressure at this point, the resultant test would be lower.

With regard to the shearing test, he understood that a constant was found from a comparison of the results of the 110 transverse tests with the resistance to shearing of these same bars. This might hold good for the metal under consideration. If they took it that resistance to machining bore some relation to shearing, they all knew how much harder to machine some test bars were than others giving the same transverse test. The very fact that these methods which had been advocated since 1909, and seemed so ideal, had made so little progress, even in France, pointed to a weakness somewhere.

Commercial Aspect of Testing.

Mr. J. R. Hyde welcomed the paper as pointing out the position that tests of cast iron occupied to-day. The Institution of British Foundrymen were taking steps to put their house in order. Although M. Ronceray might understand something of the complex nature of cast iron, and the variation in mass, and the influence mass had on strength, they had to give a test to the engineer that he could reasonably understand, and he (Mr. Hyde) would submit that the tensile test was one of the things they must carefully study. If the defect was in the testing machine, then let them put it to the engineer that he must give them a testing machine which would correct the defect, so that their material should not suffer. Having got that they were provided with an interesting test which would help them to study the true nature of cast iron. With regard to the other tests mentioned by M. Ronceray, they were distinctly interesting, and members must hope that in the near future some research would be undertaken to compare the various tests and draw some conclusion.

Composition Difficulties.

Mr. Young remarked that M. Ronceray had said something that nobody in this country seemed to have the pluck to say. He said:—"It seems almost unbelievable that, even in this time of progress and science, the qualities of cast iron have been observed on separately-cast test-bars which are entirely different in structure from castings." Not only did they not admit that in this country, but they had apprentices in the Institution of British Foundrymen who were taught that test-bars should be cast separately from castings. That meant to say that they wanted to imitate the arbitration bars. Yet here was M. Ronceray saying it was almost unbelievable people could make tests like that. He (Mr. Young) had made a great many of these arbitration tests, and he had no account of any bar cast separately from the casting having the same composition as the casting itself. Therefore they were up against this, not only that the testing was different but that the composition itself was different. In his own recent experience they had been cutting bars out of the castings.

The Author's Reply.

M. Ronceray, replying, said the elongation in cast iron was exceedingly small, and the slightest defect in a test made a vast difference in the result. That was a difficulty with regard to the tensile test. One might have a very good casting yet the tensile test might seem to prove it was no good, The sounding test was very sensitive. Of course, the results of a test depended not only on the analysis and the quality of the iron, but on the way it poured in the casting, on the way it was cooled in the casting, and on the way it was handled afterwards. Sometimes it could be left in the sand, sometimes it was got out quickly. He had often, by way of experiment, cast two testing pieces in the same box from the same runner and got very different results. It was surprising what differences of strength there were in metal bars of the same composition. The speed of cooling was of the first importance, and also the method of taking out the gases. He thought the greatest improvements to be expected in the foundry would come not from small differences of composition, but from the treatment of the metal in the cupola, and afterwards until the casting was delivered.

SAFETY WORK IN FOUNDRIES.

By R. W. Patmore (London), of the Industrial Welfare Society.

The Need for Safety.

According to the " Labour Gazette " and other sources of information it is shown that during the last twelve months an average of three men have been killed each month, and 5 per cent. of the workers engaged in foundry work are injured annually in the foundries of Great Britain. While the percentage of accidents in this particular branch of industry may not be so high as in some other branches (and it must be remembered that the figures and percentage quoted only refer to molten metal and does not include conversion of metal), they are high enough to warrant serious consideration, and the author hopes the subject of his paper will lead not only to a mere discussion by the Foundrymen's Institution, but an actual campaign which will not cease until it has made the foundry the safest occupation in any industry.

Never was there a time in our industrial history when it was so necessary to eliminate accidents; from now on this country will have to face a severe competition to secure the markets of the world, and every unit in this country will have to utilise all its resources, all its strength, to secure and maintain its position in the industrial world. Not by force of arms will any nation gain supremacy, but by using to the full all the man-productive power (both brain and brawn) of its citizens; Great Britain cannot afford to be unnecessarily handicapped in this race, because of accidents or lack of industrial co-operation.

Employers' Responsibility.

For many years employers have been talking about accident prevention, and in 1912 the Institution set up a committee to formulate certain rules in order to avoid accidents. No doubt many employers have made up their mind as to what shall constitute safety precautions, and some have not, but we must all at least think about it. There is a tendency, due perhaps to some psychological action of the mind, among some engaged in the metal industry, to think, because of the nature of the work, that it is impossible to eliminate accidents. While it is not yet possible to operate a foundry on a 100 per cent. record without accidents for an indefinite period, it should be the aim and object of every managing director of a company operating a foundry to attain this happy condition.

One of the human instincts (inherent in every person) is to avoid pain and suffering. The spring of human sympathy is just as deep and pure among employers as it is among the employees, therefore surely every member of the Institution of British Foundrymen is seeking the best methods, and the best way, to place his plant among the 100 per cent. record of no accidents.

Analysis of Foundry Work.

At this juncture it should be understood that the author is not a moulder by trade, or connected with the foundry by profession; his only direct contact with a foundry was when he was apprenticed to the engineering branch of the metal industry. He then spent six months of that apprenticeship in the foundry, which was connected with the works. However, in his experience as a production engineer he has had to lay out operation sheets—therefore, in order that the subject can be understood better it is proposed to outline the ordinary operations which take place in a foundry, from the time the pattern is received until the casting leaves the foundry, after which the nature of accidents that sometimes occur in connection with each operation will be dealt with, and suggestions put forward as to how they may be avoided.

Operations in the Foundry.

In the ordinary way these may be set out as follows :—(1) Laying surface board and pattern; (2) placing drag; (3) riddling sand for facing and set nails; (4) shovelling in heavy sand, ramming, venting drag and striking off; (5) clamping and rolling over; (6) making joint or joints, and riddling sand for facing; (7) placing cope or top; (8) setting gaggers; (9) riddling sand and tucking bars; (10) lifting off and finishing cope or top; (11) drawing pattern from drag, finishing and setting cores; (12) closing mould; (13) clamping mould; (14) building runner; (15) pouring metal; (16) taking out casting; (17) cleaning casting; (18) dispatching casting.

Causes of Accident (Major and Minor).

Placing drag.—The fingers may be trapped or foot squeezed because the men are watching to place the drag square with pattern.

Riddling sand for facing and set nails.—When riddling sand the moulder is apt to rub his hand over the sand; very often slugs are hidden in the sand which cut the flesh.

Shovelling in heavy sand, ramming, venting drag, and striking off.—Great care must be taken to have a proper vent. A poor vent not only creates bubbles and blow-holes, but may be the cause of an explosion.

Clamping and rolling over.—When this operation is being carried out by use of the crane, men should stand clear, even though the box may be properly swung, as the handles, owing to crystallisation, may snap. If roller chains are used hands must be kept clear of the chain.

Placing cope or top.—Fingers get trapped owing to watching the guiding marks.

Riddling sand and tucking bars.—Same accidents as operation No. 3.

Lifting off and finishing cope.—Same as No. 5.

Drawing pattern from drag, finishing and setting cores.—It is a common practice among moulders to use an old file and drive the tang end into the pattern; if a file is not handy a spike is used. Using a file is very dangerous, and the cause of many injuries to the eye; the file is apt to pull out, or in driving it into the pattern pieces of file fly. Wood screws with proper handles should be supplied to each moulder, and it insisted that they be used.

Clamping mould.—In clamping mould it is necessary to see that bolts or clamps are used instead of cotter pins, to examine the bolts, and to see that the threads are not stripped.

Building Runner.—A bad runner will not only making a bad casting, but if too wet it will blow.

Pouring metal.—This operation is the cause of the greatest number of major accidents, therefore too much caution and care cannot be exercised. Burns from molten metal can be reduced by the use of leggings with flaps to cover the eyelets of the shoes, also by wearing asbestos boots. Goggles should be worn when pouring. It is very important that the furnacemen be equipped with protective clothing.

When hand shanks are used the executive in charge of the foundry should make it his special duty to see that the gangways are clear, and pathways as level as possible.

Care must be taken to prevent foot plates, when used as pathways, from raising up; if they do men are liable to catch their toe and trip. They should be sprinkled with dry gravel when pouring takes place.

All cranes should be fitted with gongs so that when molten metal is being carried over the heads of the moulders they will be warned.

All chains should be tested every twelve months, and the maximum load stamped in plain figures.

Taking out casting.—Same as No. 5.

Cleaning casting.—The foundry cleaning room is one of the most difficult departments in the elimination of minor accidents. Eye trouble and deep scratches are the most common. It is not within the province of this Paper to deal with dust. It is very important that methods should be applied in every fettling shop to eliminate dust, because of the injurious effect upon the respiratory organs of those employed as fettlers. Poor health is so often the cause of discontent and inefficiency.

The difficulty of getting workmen to wear goggles is largely overcome when they are made to suit the sight of the operator. A man cannot be expected to wear goggles which, after wearing for about ten or fifteen minutes, make the eyes ache, any more than one would wear glasses to read with that made the eyes ache. Manufacturers of goggles, especially in the United States, are paying particular attention to this problem, and when speaking to representatives, before making purchases they have been willing for me to call men in and try out several lenses before the sale took effect.

It is also recommended that a man be allowed to retain in his possession while employed with the company the pair of goggles that suit him best.

The steaming of the lenses is also another problem which is receiving careful attention. The author understands this is being overcome, and a metal pencil is now on the market.

Danger of Emery Wheels.

Every possibility of danger cannot be eliminated from grinding wheels when revolving at a high speed. The wheel may be chosen with great care, and be sound in every respect, yet there are many things that can happen to cause a wheel to break—a sudden jam will sometimes cause a wheel to burst. To minimise the results of a bursting wheel is to have the safeguards properly attached to the machine.

Machine Operation.

There is no doubt in the author's mind that the use of machines in foundry moulding is as permanent and evolutionary as the machine is in other spheres of industrial activity, and as far as he can discern the moulding machine cannot be classed as hazardous, but care will have to be taken by the operatives in seeing that the box is firmly and properly secured, so that the jarring of machine will not loosen the bolts. Lock or spring washers being used besides the nut are to be recommended.

Safety and Accident Prevention.

The managing director who would render conscientious safety service must first of all make his plant as reasonably safeguarded and ventilated as his resources permit. He must also get the best illumination possible. It has been the author's privilege to visit some foundries since his return to this country, and he is sure from what he has seen that foundrymen are alive to these factors, but no doubt there are many foundries existing in Great Britain to-day where it is possible to make changes that will not only be beneficial from the viewpoint of a safety engineer, but from the production engineer as well. However, it may not be possible for the company to change the present conditions prevailing, but it is possible for every managing director to enthuse into his organisation the spirit of safety.

Safety and Personnel.

Successful safety work is not based upon pretence, and it is of vital importance that every effort, and opportunity, be taken of proving to the employees that the company is sincere; just posting a few bulletins on safety does not bring results. Experience in this work convinces those who have been actively engaged in accident prevention that success does attend if eternal vigilance is kept, as well as a determination to concentrate every energy, every resource necessary to minimise the number of accidents, or reduce them to the vanishing point.

It is very essential that the managing director sets himself the task to ensure that the policy of operating a safe foundry permeates right through his organisation. He must, as it were, test every link of the chain, see that it is sound and imbued with the same spirit and enthusiasm, in order that it be effectual. He must give the lead, especially to the foremen.

Foreman the Keystone of the Shop.

In any industrial establishment the foreman is the keystone of the structure, and too much care cannot be taken in the right selection of foremen. The author's experience has taught him that the men in the department gauge the management by the actions of the foreman. Many boards of directors, managing directors, and general managers have received a shock when they realise that the policy, which had been the intention of the company, had failed to materialise, owing to the wrong interpretation being transmitted to the employees by the foreman. How could it be otherwise, unless the foreman has had the policy of the company explained to him instead of having to guess at it, or perhaps only learns it after he has been on the carpet? If the company has any labour policy, incorporating welfare and safety, the foreman should know of the policy, so that he can transmit it intelligently to those under his control.

The Foreman of To-morrow.

Industry is passing through many changes; one of the most important is the status of the foreman.

The foreman of the future will be the production manager of his department. He will be expected to secure the best results from the labour, machinery and material placed in his keeping: he will have to be a leader of men, display tact, diplomacy and patience. Many of our present-day mechanics, who may be thoroughly capable of doing good work, are slow in adapting themselves to the new conditions and new surroundings. It will be the duty of the foreman to secure for each man a square deal, and instruct the new employee in the little peculiarities of the shop, for it must be noted, and records of accidents prove, that a large percenatge of accidents occur among new employees. If the foreman inspires confidence he will be successful.

Another duty for which the foreman will have to be made responsible is the proper training of the boys. How many employers take the trouble to see whether the boys, or apprentices, to the trade, are taught to avoid doing things in the wrong way? Is it not the common expression to say, "He will get his usual number of bumps. I got mine, and he will learn better some day," but that some day may be too late. The foreman should see that each boy learns of the dangers of the work on which he is engaged, especially the occupational dangers which are inherent and peculiar to the trade. The author is of the opinion that it will be beneficial to the employers if instructors were employed to teach the boys in the foundry, instead of leaving the boy to pick up the trade under the present-day system. Every boy should know what he is doing and why he is doing it.

Co-operation of the Worker.

Having secured the co-operation of the managing director and the foreman towards the elimination of accidents, the problem is how to get the workman to co-operate. This is no easy task, and cannot be accomplished overnight, but by persistent education and patience.

Safety and Education.

Besides the usual method of having a safety committee it would be beneficial to explain to the workers that an accident has a threefold effect:—(1) Suffering to the injured person, causing distress of mind, not only to the person injured, but to those of his immediate relatives; (2) loss of time and wages to the injured person; (3) loss of production to the employer—(*a*) inability of the injured person to perform his usual duties, (*b*) breaking in a new employee.

Suffering and Discomfort.

The economic wastes resulting from carelessness is appalling, but those who stop for a moment to consider the sorrow and desolation which is brought into the home of the injured person by the lapse of thoughtfulness feel that they are spurred on to redouble their efforts in the work of accident prevention.

Loss of Time.

Methods should be devised to bring home to the injured person what accidents cost in the loss of wages. It may be imagined that this will be resented, and appear to be adding insult to injury, but when you tell a workman in a tactful, diplomatic way, perhaps by letter, that he has lost so much wages because of a momentary lapse of thoughtfulness, he begins to think twice before taking risks and hazardous chances.

Loss of Production.

When an accident happens the human instinct is naturally aroused. Not only is the injured person unable to perform his duties, but his nearest workmates are interested to ascertain the extent of the injury, and also to render assistance. If the injury is severe, and will prevent the injured person from following his usual occupation for a period, he will have to be replaced, or the organisation rearranged to fill the gap.

Accident Costs are Production Costs.

Assuming that this is correct, the cost of each accident, with its subsequent loss of output, should be charged up to the department. Surely there is no more logical and better way of bringing safety to the attention of the superintendent or foreman than by adding to their operating costs the cost of all accidents that happen in their department.

If you reduce accidents you inevitably reduce replacement of men, and any industrial engineer knows that the replacement of absent men and temporary disorganisation means decreased production.

Every industrial problem, and especially the accident problem, when boiled down to the last analysis is the man problem. No matter how we analyse the accident or invent safety devices, have general campaigns on "Safety First," we are forced to come back to the individual—the human factor. We must win him, body and soul, to the cause and enrol him under the banner of safety scouts; therefore the author is a firm believer in securing the co-operation of each individual worker, and for this purpose he submits a pledge to which the worker should be asked to subscribe his bond when employed.

The Individual Pledge.

Believing that a careful man is the best safety device, a workman on joining a firm should be asked to pledge himself to (1) keep himself fit, good health being the essential requisite for all things; (2) report to the ambulance room for treatment upon the receipt of the smallest wound or scratch, the neglect of which may result in blood-poisoning and death; (3) use all safety appliances, clothing and guards which have been provided for him and his fellow-workmen, and to see that they are taken care of, kept and used in their proper places; (4) not to wear loose clothing around moving machinery; (5) not to use unsafe tools, but to report such to his foreman; (6) to wear goggles when pouring, grinding and chipping, or performing any operation where material may fly and cause injury to the eye; (7) to keep the floor space in the immediate vicinity of his work clear of objects over which he or others may fall; (8) to be careful in handling and piling material so that no serious injury may result to passers-by; (9) to be just as careful of a fellow-workman's life as he is of his own, remembering that he, too, may have dependents; (10) to report to the foreman at once all unsafe conditions and practices which may come to his knowledge.

Education and Safety.

In addition to the individual pledge, great success has resulted through the cinema. The author recalls one film which his friend Mr. Tenner, one of the safety engineers of the U.S. Steel Corporation, used to exhibit, called " Steel Town." While the condition and types of employees are different in America from those of Great Britain, it is a psychological fact that the brain records a more lasting impression on any subject or object when transmitted through the medium of the eye than that of the ear, so it is to be hoped that a time will come when those responsible for manufacturing films, and those conducting cinema theatres, will co-operate with those responsible for industry to exhibit a film having for its purpose the necessity of using caution and thought in daily occupation.

The day must come—and sooner the better—when educationists will see the necessity of including in the curricula of the schools some simple lectures on accident prevention, in order to train the boys and girls in the elementary principles of safety, so that when they go out into the world they will be better equipped mentally to avoid the common dangers connected with their vocation.

First Aid.

A Paper on safety would not be complete unless reference was made to the rendering of First Aid to the injured. When an accident happens every facility should be at hand to relieve as quickly as possible the pain and distress of mind. It would be of great advantage if every worker would voluntarily take a course of instruction in First Aid to the injured, so that they would be prepared to render efficient help in time of need.

While it may not be within the province of this Paper to outline what should constitute a well-equipped first-aid station, the author takes the liberty of calling attention to the Home Office regulation, dated 1917, No. 1,067, " First Aid and Ambulance Station in Foundries " :—

" In every foundry to which this Order applies, and in which the total number of persons employed is 25 or more, the occupier shall provide, in readily accessible positions, ' First Aid ' boxes or cupboards in the proportion of at least one to every 150 persons.

" The number of ' First Aid ' boxes or cupboards required under this provision shall be calculated on the largest number of persons employed at any one time, and any odd number of persons less than 150 shall be reckoned as 150.

" Provided (1) that an ambulance room maintained in conformity with paragraphs 6, 7, and 8 of this Order may be counted as one of the ' First Aid ' boxes or cupboards required by this Order; (2) that the requirement of ' First Aid ' boxes or cupboards shall not apply to a blast furnace if an ambulance room is provided and maintained as aforesaid.

" Each ' First Aid ' box or cupboard shall contain at least :—(1) A copy of the ' First Aid ' leaflet issued by the Factory Department of the Home Office; (2) three dozen small size sterilised dressings for injured fingers; (3) one dozen medium size sterilised dressings for injured hands or feet; (4) one dozen large size sterilised dressings for other injured parts; (5) one bottle of eye drops; and (6) sterilised cotton wool.

" Each ' First Aid ' cupboard shall be distinctively marked, and if newly provided after the date of this Order shall be marked plainly with a white cross on a red ground.

" Nothing except appliances or requisites for ' First Aid ' shall be kept in a ' First Aid ' box or cupboard.

" Each ' First Aid ' cupboard shall be kept stocked and in good order, and shall be placed under the charge of a responsible person who shall always be readily available during working hours.

" A notice or notices shall be affixed in every workroom, stating the name of the person in charge of the ' First Aid ' box or cupboard provided in respect of that room.

Ambulance Room.

" In every factory to which this Order applies and in which the total number of persons employed is 500 or more the occupier shall provide and maintain in good order an ambulance room.

"The ambulance room shall be a separate room used only for the purpose of treatment and rest. It shall have a floor space of not less than 100 sq. ft. and smooth, hard and impervious walls and floor, and shall be provided with ample means of natural and artificial lighting. It shall contain at least :—(1) A glazed sink with hot and cold water always available; (2) a table with a smooth top; (3) means for sterilising instruments; (4) a supply of suitable dressings, bandages, and splints; (5) a couch; (6) a stretcher.

"Where persons of both sexes are employed arrangements shall be made at the ambulance room for their separate treatment.

"The ambulance room shall be placed under the charge of a qualified nurse, or other person, trained in 'First Aid,' who shall always be readily available during working hours, and shall keep a record of all cases of accident and sickness treated at the room.

Ambulance Carriage.

"At every foundry to which this Order applies, and in which the total number of persons employed is 500 or more, the occupier shall, for the purpose of the removal of serious cases of accident or sickness, provide on the premises and maintain in good condition a suitably constructed ambulance carriage, unless he has made arrangements for obtaining such a carriage when required from a hospital or other place in telephonic communication with the factory."

It is recommended that every member of the Institute will look upon these regulations as the minimum and not the maximum requirements.

Having outlined some of the causes of accidents in a foundry, and in a brief way suggested methods as to how they may be avoided, the author hopes that as the result of this session the number of accidents in this industrial occupation will not only be reduced, but eliminated altogether. It has been said that "nothing is impossible, but it takes little longer time to do it."

This no doubt applies to the problem of accident prevention. Let each and every one engaged in industry make as his slogan, "*No accidents to-day.*"

Discussion.

Mr. A. R. Bartlett (London) pointed out that a man who was temporarily disabled through an accident was frequently a direct loss to his employer in regard to production, because there was not only delay, but in finding a man to take his place they might not secure one so efficient or so well acquainted with the conditions of that particular job. He favoured a machine riddle for sand, and wherever possible using mechanical means and having them properly safeguarded. He suggested that employers should try to interest the men in safety measures, and it must necessarily start with the management. At the same time it was very difficult to get the men to wear goggles. Lighting and ventilating were great points in safety, but the first essential was caution.

THE MANUFACTURE OF LIGHT STEEL CASTINGS.

By H. Bradley (Sheffield).

In this Paper, which has reference to the practice of light steel castings, any reference to academic or laboratory practice has been purposely omitted. It is dealt with from the author's practical experience of a general jobbing steel foundry, making all classes of steel castings from a few ounces up to 14 tons in the rough, and with metal of carbon content varying from 0.08 to 1 per cent. and over, and additionally in chrome and manganese steels.

The Plan of the Foundry.

To run a foundry successfully, the largest output with the minimum amount of handling must be attained. To carry out this successfully, the shop should be planned for the pattern to enter at one end (where there should be shelves or pockets to receive it) and the core boxes with card attached, with works order number, description and quantity off. The card is ruled at back, so that each day's cast may be entered thereon. When the pattern and core boxes are given to the moulder the card should have the man's check number marked on, together with the date.

When possible there should be a separate bay for dry-sand moulds. The work for dry sand should be commenced at the end of the shop, then carried down to the drying ovens, then to the closing and casting floor, where the moulds should be arranged in straight lines, and all runner bushes should be as near one height as possible, so as to avoid hoisting or lowering the ladle. The steel plant should then be fixed as near as convenient, utilising the floor nearest to it for the green-sand moulds, as these are generally of the lightest section of castings, and, therefore, require the steel when in its most fluid state, to avoid short- or faint-run castings.

When the steel is a little on the stiff side it can be used for the thicker section castings. The boxes, after casting, should then pass on a little further to be knocked out and examined, and a note taken of the good and defective castings and recorded on the back of the above-mentioned card. When the job is completed the card should then be handed in to the foundry office, the castings going forward to the cleaning or dressing shop, which should be at right angles to the moulding shop, with tram lines running from one to the other.

The fettling or dressing shop should be equipped with shot-blast plant, oxy-acetylene burning plant, and both circular and band saws, according to size and class of work and output. The castings should then go to the machine shop and despatch shed.

The Making of Castings.

The first thing to consider is the pattern making, which depends, firstly, on the quantities of castings required from each. A good wood pattern will withstand the making of 500 castings from it, either by hand or machine. If repetition work is carried out, then either brass or white-metal patterns are necessary, which should be on the machine for small castings. The author prefers the hydraulic machine for boxes up to 24 in. round or square, and for deep-lift patterns the roll-over machine. For anything over 24 in. the jarring machine can be used to better advantage.

The difference in making a pattern for machine moulding and hand moulding is that it is always necessary to fix core-prints to the pattern for the former under any parts that are undercut, as the sand is jarring downwards, therefore, it naturally falls away from the underside of any projecting part.

Tackle.—The boxes should be strong, light, and made of steel. They should all be interchangeable according to the various sizes either for hand or machine. The double lug box is best, giving a truer alignment. The double lug can be either a slot and hole or two holes.

For patterns with small quantities off and intricate joint, a plaster oddside should be made, as they are easy, cheap, and durable.

For large orders or repetition work, machines are a necessity. They do good in two ways, i.e., by reducing costs, and increasing output on the jobs they are working. They also speed the work up generally in the shop. Two boys working a machine with boxes 10 in. by 10 in. by 4½ in. have produced 180 complete moulds in the day with from two to four cores in each. Two youths, 17 to 18 years of age, have produced 62 moulds, 18½ in. by 16 in. by 5 in. deep, painted and blacked. The quantities vary according to size of boxes and design of castings. To get the full advantage from the larger machine it is essential there should be an electric crane specially for its use.

For large quantities of light castings the Tropenas vessel or electric furnace is to be recommended.

To ensure sound steel castings it is essential to have in the first place a good steel, that is, steel containing the correct composition for the work required, and properlv "killed," in order to ensure it lying quietly in the mould. It is also as essential that the sand be suitable; if being used green, it should have just the correct moisture, and just sufficient bond to work it. Sand, in the first place, should always be dried before milling in order to get the required moisture by adding water, and the necessary binding material. The author prefers to use the natural sands whenever possible. The sands generally used in England for steel castings are Belgian loam, used either by itself or with a small amount of silver sand, Cornish loam with silver sand, and Yorkshire sand with silver sand. Of the three mentioned, the author prefers Yorkshire, as it is easy to work, is tough, but not too close, gives a good skin on either dry- or green-moulded castings, and does not cake in the mill as much as the first two. For cores, the author's practice is to mix eight parts of silica to one of Yorkshire and up to 4 to 1 for moulds, varying, of course, according to weight and design.

Running and Feeding.

Where possible the best system is bottom runners, and in one of the thinner sections of the casting. Careful judgment is required for feeding heads to have the required size and in the right place in order to get a solid casting and avoid wasting steel.

Very soon after casting all runners and feeding heads should be released so as to enable the contraction to take place and avoid having a pull in the casting.

When the pattern is made, it should in the first place be taken into consideration as to whether the casting is to be made green or dry, and the decision generally arrived at is based on how much machining is to be done on the casting, and whether the difference in the two methods of moulding is worth the risk of making an unsound casting by making it in green sand. A further consideration depends upon design of the casting. In such cases it is essential to make it green to allow for the contraction strains taking place and preventing the casting pulling into pieces. In some cases the weight and design must be taken into consideration in deciding these points. If there is no danger of the casting pulling with a dry-sand mould owing to design, it is always much safer to produce a sound casting from dry-sand work than from green-sand work, owing to the properties of the steel used for casting. Of course, there are many different designs of castings to be contended with, and the greatest trouble given to a steel foundry manager is often caused by the designer not having had any steel foundry practice. To produce good, sound steel castings it should always be the aim to have the thicknesses of the metal as much alike as possible. Wherever thick or bulky pieces of steel are joined together with lighter sections, means have always to be found (if the design cannot be altered) to overcome the difficulties encountered. This can be achieved either by using chills or causing the thick portion to freeze approximately at the same time as the thinner sections. In some cases, however, a reinforcement is used, but this is not always a wise policy, owing to the possibility of a mishap, after the casting is put to work, disclosing the reinforcement in any fracture. Naturally, the blame would straightaway be put down to this method. This can be further illustrated by a large mill pinion casting of, say, 2 ft. 6 in. tooth face by 3 ft. diameter in the tooth portion, reduced down to, say, 18 in. or so on the neck portion. The best method of producing this class of casting is to have it cored out. At times, however, it is found that engineers object to this method of coring out. They state they must have a solid casting. In order to meet their views, as far as possible (which steel founders, of course, have to do), it is endeavoured to produce a solid casting. This, however, is an impossibility without some method of reinforcement, as it is impossible to feed the body portion of the casting of the dimensions mentioned, through the size of the neck and the wobbler. Therefore, the method of reinforcement has to be used. This is accomplished by putting in what is called locally a "dummy," sufficiently large to prevent the pipe forming through the top neck and wobbler, which would take place unless something of this description was carried out.

Again, in the case of hydraulic cylinders, in most steel foundries there does not seem to be any set way in which to cast them. This is done either mouth downwards or upwards, but in any case there should be taken into consideration the location of the large bulk of the steel, and the best means of feeding it. As will be realised, it is necessary to feed all steel castings from the head. In iron foundries, a wrought-iron or mild steel feeding rod is used, and small shanks of metal are poured in time after time until it is set. This method cannot be adopted in a steel foundry, as it would pull out the steel instead of causing it to become more solid, as in the case of iron castings.

Another useful illustration is that of locomotive castings. The various parts of these are rather troublesome to make, owing to the varying thicknesses of the strengthening brackets, and it is necessary to give much consideration before starting work, otherwise much trouble is certain to result. These castings are very often made as light as possible, and thick and thin sections are more usually encountered in this class of casting than in most other classes of work.

Core Making.

The core shop should be self-contained, with special drying ovens, as these play an important part in the making of good castings. The stoves should have facilities for eliminating the moisture, as most cores are made either with oil-sands of Bindsandrite, which under the slow baking throws off much steam or moisture. The sand for cores should be very carefully regulated for different classes of work; should be very refractory, with just sufficient bond to stand up to the steel, as there are so many castings which if the core does not collapse very quickly would be wasters, especially in manganese castings such as tramway points and crossings, owing to the contraction. A machine for making standard cores is a great help, as ordinary standard round cores can be stocked and kept in dry places. Obviously it produces a better core, as wooden boxes get out of shape.

Fettling.

Cleaning plays a very important part in the costs, and is always a greater speculation than any other process, owing to so many contributory causes. It may be the sand, or the "compo," but generally, in the author's opinion, it is owing to casting the steel at wrong temperatures. It will be realised that with a ladle of steel, varying from, say, 36 cwt. to 56 cwt., it is almost impossible to have sufficient moulds on the floor at one time to take it at its varying temperatures to suit all castings. But many of the troubles in this department can certainly be overcome with a good shot-blast plant, pneumatic hammers, and swing grinders. There are three methods of removing the feeding heads—burning, sawing, and cutting by the lathe, and obviously the choice will be determined by the design of the casting.

Annealing.

It is obvious that the question of annealing depends largely upon the size of the foundry, and output. The best method, in the outhor's opinion, is the gas-fired stove, but for general jobbing work where all classes have to be dealt with, the movable top is as cheap as any for fairly large quantities. For quick and urgent work—say where it is required to cast one day and deliver the next—a small handy furnace of about 8 ft. by 5 ft. with a door at the front of the furnace can be built, and operated with lever and balance weight.

In conclusion, there are many other points appertaining to the manufacture of steel castings, but those enumerated should be sufficient to provoke an interesting and profitable discussion.

Discussion.

Mr. Bradley emphasised, in introducing his Paper, that he was speaking from a jobbing steelfounder's standpoint, dealing with the sand problem and pouring temperature, and with obtaining a good, sound composition. He contrasted the different requirements for repetition as distinct from jobbing work, pointing out that in the latter case it was more difficult to make good steel castings, and remarking that it was essential they should have machines for doing certain classes of repetition work.

Research on Sand Necessary.

Mr. F. Melmoth (Braintree) observed that an enormous amount of metallurgical investigation had been expended on steel production, and they had to admit that their knowledge of steel was infinitely greater than their knowledge of sand. It was a simple matter to turn out steel perfectly suitable for light castings, but it was more difficult to turn out suitable light steel castings. After the steel left the furnace it was subject to various influences of either incorrect methods of casting, speeds of casting, or incorrect sand. As to the card system, he thought it was in operation in every modern foundry, but the point he had noticed was that it appeared to be very often overdone, and in some cases the card system cost nearly as much as the casting. The runner bushes should be about the same height, so that the ladles would not have to be raised or lowered. Light steel castings as a production article were usually made in the mass production shop. With regard to the point of putting green sand castings nearer the source of the steel because they were lighter sections, in America the conviction was that light castings required drying more than the heavier type; that was, within reasonable limits. He had carried out a great deal of work on light castings, and he was rather coming round to that way of thinking. Mr. Bradley had mentioned electric welding, and there was no doubt, electric welding was considerably cheaper than acetylene welding. Had the author found out any appreciable difference in fluidity in the manufacture of steel castings by the pneumatic processes as compared with the electric furnace? He appreciated the remarks on design, and said that they would secure cheaper and better castings if the designer would consult the foundryman before he made his design.

Temperature Queries.

Mr. Darley asked what was the correct casting temperature, seeing that the speaker alluded to the difference it made in the casting. He found that he could not definitely ascertain what the correct temperature was. The reason why steel was more difficult to handle than cast-iron was because of contraction. Mr. Bradley did not give any idea of what temperature he annealed the castings, and he would like to know whether he annealed all small steel castings, because with different carbons they required different temperatures for annealing.

Mr. Wilkinson said the whole question was an extensive one, and one hardly knew where to begin to discuss it. As to the pouring temperature, there was only one, and that was the highest to which they could get the metal. He said this without any reservation whatever from long experience, and obtained castings entirely free from cracks. Cracks occurred during the setting or freezing of the metal, he said in describing an experiment in which the metal was poured at different temperatures and the mould was altered so that the casting contracted in the sand. He advised that moulds should be constructed so that contraction could properly take place. Anyone having trouble with light steel castings, he recommended that they should cast them with a small gate and make the mould so as to allow for contraction; good results would follow. In his opinion there would be no light steel castings in green sand moulds in future years. But he should not care to trust three to four tons of steel in green sand moulds. It was cheaper to make a dry sand mould than a green one, and there was the advantage of the element of safety in the dry sand mould which was entirely absent in the green sand. If it came to a question of which was the best green sand, it was possible to make sand mixtures with almost any ordinary ironfounders' sand that would give moderately successful surfaces on green sand castings. Where most foundrymen went wrong on green sand was in making it too damp. The difficulty was to work the sand well on the dry side, yet sufficiently strong to resist the metal, but it was possible to get sand with a fair amount of bond and yet dry enough to perform its function properly.

Temperature Variations from Bottom Pouring Ladles.

Mr. Faulkner, after thanking the lecturer, remarked that in discussing the question of light steel castings they were up against a difficult proposition. With the exception of a few leading firms, they were much behind their Continental competitors. And some of the less-known metallurgical countries knew more about light steel castings than they did; indeed, he believed, the best steel castings were made in Italy, with Switzerland a good second.

With reference to the casting temperature it should be pointed out that the first drop of metal out of a bottom-pouring ladle having been in direct contact with the bottom of the ladle would be cold. The metal following would be hotter, being drawn from the body of the ladle until such time as the "time factor" began seriously to operate. The fluidity of electric steel had been adversely criticised, due, no doubt, to the fact that operators, used to handling tool steel, had been called upon to make steel for castings, and contrived to give to this metal the same "deadness" as that necessary for tool steel. This, the speaker affirmed, is not necessary, for, according to Dr. Desch, exceptional deadness eliminates all exothermic reactions such as one associates with steel made by the older processes.

Dry or Green Sand Moulds?

Mr. Harley (Coventry) remarked that he had been concerned with light steel castings in enormous quantities for the past twelve or fourteen years, ranging from 1 oz. to 3 cwt. One speaker had said no green sand steel moulds would be made, and he was not sure whether to support that or not. He had made hundreds of thousands of light steel castings, including lorry wheels, and they had cast these lorry wheels in green sand entirely and with satisfactory results; in fact, they had never had a steel lorry wheel returned. That would prove that there was not much wrong with the method of manufacture. In theory casting in green sand was the best. In his opinion a great deal of the trouble in making steel castings arose from casting them in dry sand moulds. In weights such as he had given there was, perhaps, no choice in the matter, and up to those weights he certainly should not advocate dry sand. They had sufficient to contend with in the "pulling" of mild steel, which had abnormal contraction compared with cast steel; but they intensified their difficulties by utilising hard, resistant dry-sand moulds. They must so design their patterns, and must help that by having a soft, unresisting sand mould, to allow the natural contraction to take place. If contraction took place to the full extent, then they would not have the annoying trouble of cracking. When they started on road wheels they went into this matter and they allowed too little, because the final wheels contracted more and became too small. Contraction was caused in another way; it was very essential in making any castings that the metal should not be too high in phosphorus, 0.07 per cent. being the maximum. He favoured 0.05 per cent. for both sulphur and phosphorus. Respecting pouring temperatures, it was no use attempting simply to reach a little above the melting point. The metal must be taken above the melting point by 300 deg. C., and even with that margin no time must be wasted in getting the boxes cast.

Facing Sand.

As to sand, he at one time thought he should have to send to Sheffield for special mixtures, which were, of course, fairly expensive. But he soon dropped them, because he found that within the limits of weight he had mentioned they could make perfectly good sand mixtures with ordinary red moulding sand, and mixing it up to a varying extent with ordinary floor sand and silica sand. But the basis of all sand mixtures was red sand, which he obtained from anywhere round Birmingham or Tipton. He would like to emphasise one point, that they must not try to get on facing sand the maximum refractoriness. Everybody seemed to insist in steel castings that the maximum of refractoriness was an essential condition upon being able to make a good casting surface. But his experience was that the mixture should be so regulated that it just nearly reached the point of fusion, in contact with the molten metal. If that was done, they would find the sand caked, and that the cake came off very easily and left a beautiful surface on the casting. He must state also that he did not give way to the Italians' steel castings, or those of any other Continental countries in the finish of such castings by their English converter process. He found that for every day-to-day work the converter process gave the most reliable results.

The Author's Reply.

Mr. Bradley, whom the President said would deal with the questions raised in writing, briefly and hurriedly replied on account of the lateness of the hour. Certainly they required the card system as a guide and a record. Generally speaking. in the repetition shop they would expect to use green sand. They all preferred electric welding where possible; it was much quicker and cheaper than the other processes. A question was asked as to oxy-acetylene being much better because it took longer to generate the heat so as not to interfere with the yield-point. But it was not the yield-point, but the cooling process which caused the hardness. Regarding fluidity in Tropenas, he considered better fluidity was obtained from them than from electric furnaces, but they could secure good fluidity from the latter, and they could shank every ounce of metal. As to annealing, they annealed all castings unless they were in a real hurry. Generally, they annealed according to the carbon; the lower the carbon the higher the temperature required. As regards casting temperature, he did not believe there was any instrument made which would record the different proper temperatures, taken from furnace to mould; he should say somewhere between the region of 1,560 to 1,660 deg. C. In reference to sand, they would find at the exhibition a green sand casting 2 to 2½ in. thick which was equal in skin to a good many cast-iron castings. He disagreed that it was cheaper to make a dry-sand than a green-sand mould. A good deal depended on the class of casting and one's experience of sands. They must get the sand to withstand the metal. He must say that he had tried all up to 4 in., but had never found anything to stand up like the Yorkshire sand. Belgian was all right, but when they reached 1 in. and over there was nothing like Yorkshire sand, from which they obtained a much better skin. Also a good deal depended on the way a man rammed the mould; this was where the skilled moulder came in. It was much more difficult to make a good green sand mould and get a good casting than a dry sand mould on that account. Referring to Mr. Harley's comment about wheels, they had made them with green sand and dry, and also with the outside chill for the outside rim, and had found the best results from green sand.

SEMI-STEEL.

By J. Cameron (Kirkintilloch).

In making reference to " Semi-Steel " it has to be admitted that the name is misleading and that it is desirable that proper specifications should be prepared for the various classes of this material. The name is popularly applied to the metal resulting from the use of mild steel added to the pig-irons and scrap melted in the cupola or furnace. The writer wishes to make it clear from the first that the semi-steel described in this Paper is produced in the cupola, using coke as fuel and the usual air-blast. His experience is confined to this practice, and the results obtained and conclusions put forward are the results of over twelve months' continual experience on a fairly large scale, and since then in greater variety of subject but on a smaller scale. The percentage of steel used varied from 15 to 40 per cent., the lower figure for light and the higher proportions for heavier ings.

Semi-steel does not displace either steel or malleable cast iron. The steel scrap in its passage down the cupola by absorbing carbon gradually loses its identity as steel and becomes iron. The metal resulting is simply a high-grade cast iron with fewer impurities and better physical structure.

Test-bars when pulled show no elongation, and there is practically no ductility.

It is the practice of some firms to melt steel scrap in the ladle and call the product semi-steel, but this method is seldom of any practical use. In the first place, the proportion of steel taken up by the molten iron is very small, not much over 5 per cent. in favourable conditions; the steel does not have the chance of being properly mixed and has a tendency to show in patches of uneven grain and hardness.

Fig. 1.—The Micro-structure of Properly Made Semi-Steel Magnified 100 Dias., but reduced more than 50 Per Cent. on Reproduction.

Semi-steel is now being largely worked and its use steadily making headway, and the time has come now for the British Cast Iron Research Association, in co-operation with the Institute of British Foundrymen, to formulate a more correct and scientific name for the material and, if possible, prepare specifications and standard tests.

Ironfounders to-day are being called upon to produce castings of better quality which will machine satisfactorily, to meet the developments of higher speeds and greater efficiency in the engineering industries. They are asked to reduce weights; the standard of tests is being raised in many quarters, and all round more is being demanded. To maintain the use of cast iron for engine cylinders, turbines, compressors and innumerable classes of engineering and electric castings, the claims of semi-steel are well deserving of the most serious consideration.

Properties.

Semi-steel is stronger than usual grey cast iron as regards transverse, tensile, compression and impact tests. It is superior in regard to elasticity toughness, resistance to shock and wear. Properly made, it is close grained, homogeneous, free from hard spots, blowholes or defects. The graphitic carbon is finely broken up, the phosphide eutectic small, well distributed and frequently in well defined mesh formation. Semi-steel is much superior to grey iron for machining. It takes a finer polish, while two very striking characteristics are its faculty for taking a clean-cut screw thread and a clean punch impression.

Owing to its good physical structure resulting from the close grain, the formation of the graphite, combined with its high tensile strength, semi-steel has proved satisfactory for such castings as cylinders, pistons, gear wheels and castings called upon to withstand wear and friction. Mr. McLain claims that it is a self-lubricating metal, and from general experience at home and abroad it has been found an excellent metal for the castings mentioned and for many other purposes.

From experience it has been found that when semi-steel has been supplied for various castings, the buyer soon finds out its qualities, and in some cases asks for this material in all his castings.

Munitions.

The writer's introduction to semi-steel was in connection with munitions. Early in 1917 he subscribed to McLain's system, and towards the end of that year, when approached by the Ministry, was able to undertake the manufacture of aerial bombs in this material. One cupola had been lined to 40 in. dia. on lines laid down by McLain and samples submitted. These proved satisfactory, and

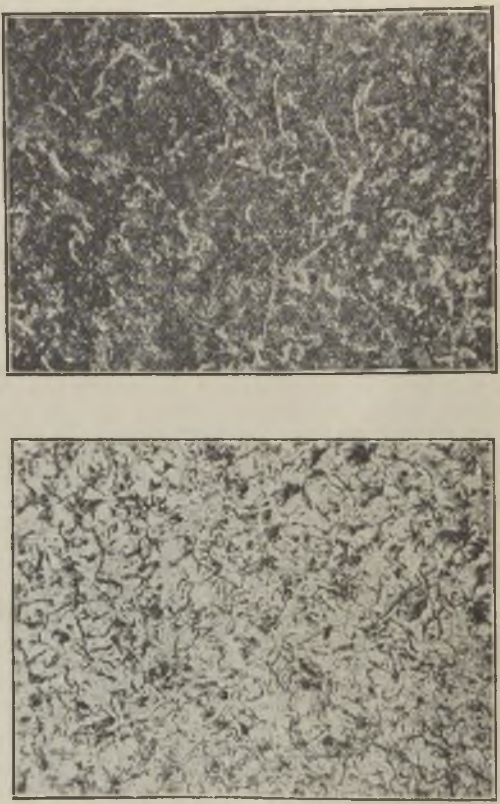

Fig. 2.—Micro-structures of Semi-Steel. The upper is Etched and Magnified at 250 Dias. and the lower Unetched and Magnified 110 Dias.

in a short time his firm was turning out semi-steel on a large scale. On one particular type of bomb 1,400 castings were produced daily. Our own

Government were comparatively late in using semi-steel, although it had been proved satisfactory by our Allies, the French and by the enemy. In America towards the close of the war a huge programme for the manufacture of semi-steel shells and bombs had been arranged. The specification for these called for a tensile strength of 32,000 lbs. on a bar cast 1¼ in. dia. machined to 1.128 in., and also for an impact test as follows:—

"The test specimen, 1½ in. square and not exceeding 1.52 in. on any side, shall be cast with a length of 8 in. and a riser of 4 in. After removal of the riser, the bar will be placed on two knife-edge supports 6 in. apart, which in turn are supported by an anvil weighing at least 1,750 lbs. A weight of 25 lbs. will be caused to fall exactly on the middle of the test-bar. The test will begin with the weight at a height of 12 in., and the test will be repeated with the height of the weight increased by ½-in. intervals until the bar breaks. The height of fall for causing rupture will not be less than 18 in., this height being measured from the upper surface of the bar to the lowest part of the testing weight."

Special air tests with soap solution for gas-shells and hydraulic tests of 4,500 lbs. per sq. in. for 6-in. calibre and under were also applied.

The results of actual use and experimental trials proved the usefulness and efficiency of semi-steel in shells and bombs, particularly as regards fragmentation. In view of the enormous demand for steel towards the close of the war, there is no doubt that semi-steel would have displaced steel in many instances.

Tests.

On over 400 test bars submitted to Ministry officials and tested by them the average result on a bar cast ⅝ in., dia. × 5 in. long was over 18 tons per sq. in. The average result on a bar turned from 12 in × 1 in. × 1 in. section gave 15 tons. It was anticipated that a fair number of bars submitted would fail to reach the minimum of 14 tons specified, but the results proved much more satisfactory than were hoped for.

The first bar to fail was No. 140, followed by a second failure in the same week. On investigation it transpired that the foreman had changed the usual moulder, who understood the correct gating, and when the bars were again made by him no other failure was recorded until after the armistice. The highest result yielded 21.9 tons, but this was beaten by Messrs. A. Ure & Company, of Glasgow, who attained 22.9 tons from a bar cast with 50 per cent. hematite pig.

Messrs. Diamond Foundry Company, Luton using semi-steel on aerial bombs, had a wonderful run of 17 consecutive tensile tests, yielding an average of over 21.1 tons, maximum 22.8; minimum 18 tons.

Special Report, Technical College, Glasgow.

In April, 1918, three bombs and three test-bars, 15 in. × 1 in. × 1 in., were sent to the Technical College, Glasgow, for full report and criticism. Those marked A and D were from usual mixture, while B, C, F and G contained 50 per cent. hematite pig. The report is as follows:

THE ROYAL TECHNICAL COLLEGE, GLASGOW.
July 23, 1918.

MESSRS. CAMERON & ROBERTON, LIMITED,
KIRKINTILLOCH.

SPECIAL REPORT ON SEMI-STEEL AERIAL BOMBS.

DEAR SIRS,—

The following are the results of examination of three samples of aerial bombs and three samples of semi-steel test-bars received from you, marked as under:—

AERIAL BOMBS.

Ref. No.	358	349	357
Mark	A	B	C
Total carbon... ...	3.251	3.270	3.279
Graphitic carbon ...	2.766	2.820	2.822
Combined carbon ...	0.485	0.450	0.457
Silicon	1.820	2.230	2.380
Sulphur	0.062	0.040	0.040
Phosphorus	0.730	0.390	0.500
Manganese	0.820	0.800	0.920

The general analyses suggest that the metal should be of medium hardness with high tensile strength, although the combined carbon might perhaps with advantage have been slightly higher.

The castings were very minutely examined for soundness and found to be good, solid metal throughout and singularly free from blow-holes or flaws.

Microscopical examination showed that in all cases the material was good, close-grained metal with small graphite regularly distributed.

In the case of B some segregation of the phosphide eutectic is shown, due probably to some accidental cause, such as high casting temperature, with quicker cooling, as, strangely enough, this sample is much lower in phosphorus content than the others. In A and C the phosphide eutectic is well distributed in a mesh work formation.

The matrix in all cases is pearlite of small striated variety with some ferrite, indicative of considerable strength with good flexibility.

Machining tests were carried out, and in all cases no difficulty was experienced in machining at a speed of 120 ft. per minute, a speed rather higher than is commonly given for soft cast iron. Practically no difference could be detected in the machining qualities of A, B or C.

This material is some of the best that the writer has ever seen, and the small tensile bar cast on C gave a result of 20.7 tons per sq. in.

Transverse Test Bars.

15 in. × 1 in. × 1 in.

Analyses.

Ref. No.	354	355	356
Mark	D	F	G
Total carbon	3.409	3.426	3.279
Graphitic carbon	2,899	2.848	2.690
Combined carbon	0.510	0.578	0.589
Silicon	2.450	2.120	2.380
Sulphur	0.052	0.038	0.058
Phosphorus	0.600	0.550	0.570
Manganese	0.810	0.520	0.680

The analytical results are such as to suggest that the material would show maximum strength for tensile and transverse combined, and at the same time show good flexibility. This view is confirmed by Professor Longbottom's results, which show an average tensile strength of 15 tons per sq. in. and an average transverse of 26½ cwt. with a deflection of 0.12 in. under 2,500 lbs. (on 1 in. × 1 in. bar at 12 in. centres).

Microscopically, all bars show a structure indicative of strength and reliability. The graphite is in very small and uniformly distributed particles, with phosphide eutectic in an even mesh work formation.

The matrix in all cases is practically wholly pearlitic.

The bars were in every case perfectly sound and free from gas or blow-holes, and broke with a very fine close-grained structure.

Yours truly,
(Signed) A. Campion,
Professor of Metallurgy.

Pig-Irons.

In 1918 ironfounders had to accept such brands of pig-iron as were available. At this time most brands were erratic in analyses, particularly as regards silicon. The Scotch irons were found very suitable. Containing as they do total carbon about 3.60 per cent., medium phosphorus and manganese fairly high, they confirmed the popular dependence on their capacity for carrying scrap and blended well with mild steel scrap. The No. 1 quality was generally used, as machinability was most desirable. When a choice was available, preference was given to highest manganese. Some of the brands showed excellent fluidity, and when other brands were used the tensile strength invariably went up. Hematite iron used with steel scrap give very good results, and some remarkable tests have been attained by using 50 per cent. hematite. The steel scrap may be regulated to counteract the high total-carbon in hematite, which is frequently a source of trouble in grey-iron castings. Hematite was not available in 1918, or it would have been more largely used. With a view of obtaining better tests, trials were frequently made of high-class irons, including cold-blast, special brands, and special cylinder pigs. The results, so far as tests were concerned, were invariably disappointing, as no increase resulted, but occasionally very fine metal was obtained.

One of the strongest arguments in favour of semi-steel is that a founder can use the common irons in everyday use, and by judicious mixing with steel scrap can obtain results only otherwise possible by the use of cold-blast or expensive special irons.

Scrap.

Mild-steel boiler-plate or sections used for stamping of thickness varying from ⅜ in. upwards in fairly large pieces may be used. There are brands of mild high tensile steel and high manganese steel from which many varieties of stampings are made that give excellent results. Steel punchings 8 in. dia. of 1 in. thickness have been successfully tried.

Borings, turnings and small punchings under 1 in. dia. should be avoided, as they lead to troubles occasioned by oxidation, and frequently very small pieces drop into bottom of bed before being thoroughly melted—a frequent cause of hard spots.

Analysis.

The average analysis of aerial bombs referred to reads as follows:—

Si 2.13, S 0.065, P 0.60, CC 0.520, Gr C 2.55, Mn 0.624.

This is not claimed to be an ideal analysis, but proved to be satisfactory for the castings in question. It could be improved by lowering the silicon and increasing combined carbon and manganese. The above analysis yielded excellent tensile tests and was found to be easily machined. It may be stated that it was not possible to procure the pig-irons available in normal times and the best had to be made of the brands obtainable.

It will be noticed that total carbon is low, sulphur and phosphorus within safe limits. There is no doubt that greater strength would have been obtained by a closer approximation to Mr. F. J. Cook's silicon-carbon formula enunciated in his valuable Paper on Diesel engine castings or to the Continental empirical formula (total carbon plus silicon=4.50), but it must be borne in mind that semi-steel freezes more quickly than grey-iron, and the problem was to cast very large quantities, the thickness being under ⅜ in.

In semi-steel some interesting results in regard to silicon were noted. The analysis of the test bar illustrated in Fig. 3 was Si 2.35 per cent., CC 0.802 per cent. This bar was attached to the bomb and moulded in green sand. A gate about

1¼ in. dia. was taken away by an official of the Ministry, analysed and tested. Although the silicon was in this case over 3 per cent., the bar actually yielded a tensile strength over 18 tons. Silicon over 2 per cent. was frequently used in much heavier castings with good results. While a wide range of silicon was found harmless, semi-steel seems sensitive to phosphorus and sulphur. Cleveland iron is largely used by Scotch founders for their light work, and was tried for semi-steel. The resulting castings contained over 1 per cent., and were invariably brittle and lower in tensile strength.

Fig. 3.—Semi-Steel Magnified 100 Dias. but Reduced on Reproduction. It contains 1.03 Per Cent. P.

The sulphur in analysis given is low, and was assumed as indicating good melting and good coke.

Recently in endeavouring to get harder semi-steel, harder irons and scrap were used. The coke obtained was during the miners' strike, and the hardness was obtained, but the metal was so sluggish that a Keep's test-bar, ½ in. sq., would not run, and a 1 in. sq. bar was not machineable. The analysis of two days' results was:—

Si, 1.938 and 1.074; S, 0.150 and 0.143; P, 0.740 and 0.320; CC, 1.060 and 1.390; GrC, 1.82 and 2.04; and Mn, 0.260 and 0.340.

Two test-bars, 15 in. × 1 in. × 1 in. at 12 in. centres, resulted in transverse strength of 36.8 and 40 cwt.

Mr. Field, in his Paper "What is Semi-Steel?"* gave his sulphur content with 10 per cent. steel as 0.110 per cent., with 20 per cent. steel 0.125 per cent. The firm with which he is connected were turning out successfully the same bombs. With this percentage of sulphur it would have been impossible for the writer's firm even to pour the castings. Another "Perplexing Foundry Problem."

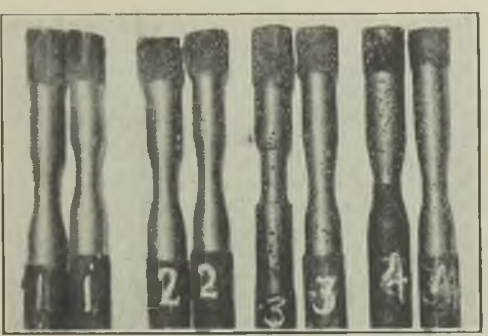

Fig. 4.—Showing the Result of Retarding the Pouring of Semi-Steel.

Mr. W. J. Evans, in a Paper† given to the East Midland Branch gave the following analysis:—

Si, 2.35; S, 0.051; P, 0.63; CC, 0.64; GrC, 2.66; and Mn, 0.76.

He stated that his semi-steel was used for intricate thin castings involving machining with expensive milling cutters. He remarks, "This is

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* Appeared in "The Foundry Trade Journal," March 3, 1921.

† Appeared in "The Foundry Trade Journal," April 13, 1922.

practically identical with the Scotch analysis. The tensile strength of this material is almost always over 16 tons per sq. in."

Semi-steel does not owe its qualities to chemical analysis so much as to its physical structure, and in its structure—almost identical with cold-blast iron—is revealed the secret of its strength and properties.

It is essential to ensure continuity of good results to make frequent microscopic examinations, or consult competent metallurgists. Analysis is excellent in itself, but must be considered in conjunction with the physical structure and cupola practice.

Difficulties.

Semi-steel cannot be properly made under the too common " rule of thumb " methods. Considerably more care and organisation is necessary, and constant supervision essential. The cupola practice and fuel must be good, and everything entering the cupola must be accurately proportioned and weighed, especially *air*.

Correct gating is very essential. The gates and runners must be larger than for iron. Special skill and care and repeated trial should be given to the gating of every semi-steel job, particularly when required in large quantities and when several castings are in a flask.

It must be melted hot and poured quickly. Fig. 4 shows the result of retarding the pouring.

One disadvantage in regard to semi-steel is that while it is comparatively easy to maintain good results when worked daily on a large scale, the writer has to admit, after considerable experience, that to ensure the best results it has to be handled on a fairly large scale. When only one or two charges are required, they can certainly be produced and ordinary iron reverted to, but the results are never so good, so far as tests are concerned, as when melted on the larger scale.

Semi-steel is more sensitive to damp sand than grey iron. Sand should be as dry as possible, and the " swab " used with discretion. A development on the lines of very dry sand, sufficiently open, hard-rammed, is probably an improvement in the near future.

Cupola Practice.

This is a subject on which foundrymen hold varied opinions. Good results are sometimes obtained by unorthodox methods, and it is impossible to lay down hard and fast rules. Whether the bed be high or low, whether one row of tuyeres or more should be used, depends on individual experience, on the nature of the blast, and the chemical and physical properties of the metal and fuel used. Each cupola should be made a special study in itself and persevered with until it gives regularly from day to day its proper quantity of good hot metal and is clean at end of its day's work.

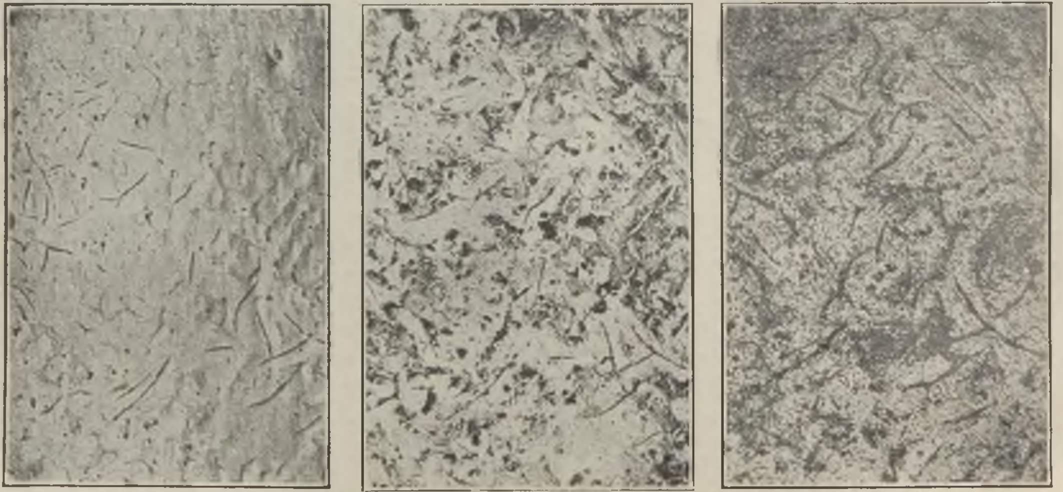
The writer in reference to cupola work can only speak from his own experience.

For semi-steel, a cupola about 36 in. to 42 in. inside lining is preferred. In this size control is easier and the air can be forced to the centre with comparatively little pressure. One row of tuyeres was used, placed as low as the fettling door permitted. To ensure soft blast, the tuyere area was increased to a 1 to 4 ratio, the tuyeres forming practically a continuous belt. All metal and fuel charges were weighed, and at first air regulated by counting the revolutions of a positive blower, latterly by a blast volume-meter. The charges were small—10 cwt. of metal; each charge drawn by itself into bogie ladle and taken away for immediate pouring. These small charges, evenly distributed, seem to facilitate the free working of a cupola and maintain the melting zone at its proper level. Care should be taken with semi-steel to ensure *clean* metal scrap and fuel.

In more than one instance, when the bombs were cast from metal melted with high-blast and small tuyere area, the resulting castings were hard and difficult to machine. On altering the tuyere area as indicated this defect was at once put right.

Melting of Steel.

From observation it was noticed repeatedly that when one or two charges of semi-steel were in the cupola the charge of ordinary grey-iron immediately in front when tapped gave indications of the presence of steel. From this it was con-



As Cast, Unetched.

Same spot. Heated to 760 deg. C. for 2 hours and slowly cooled in muffle.

Same spot. Heated for a further 4 hours at 760 deg. C. and slowly cooled in muffle.

FIG. 5.—MICRO-PHOTOGRAPHS OF TEST-BARS SHOWING THE EFFECT OF HEAT TREATMENT. MAGNIFIED 100 DIAS., BUT REDUCED ON REPRODUCTION.

cluded that the steel scrap, although invariably placed on top of charge, was melting before the pig-iron. Confirmation of this was obtained on Armistice Day when the cupola containing semi-steel charges was drawn just before blast was put on. Pieces of the steel scrap in the first charge had melted round the edges while the pig and iron scrap showed no signs of fusion.

Recently experiments have been carried out with a view of ascertaining the amount of carbon absorbed by mild steel when it melts. Bars of mild steel were placed in contact with incandescent coke under air-blast until fusion took place. Drillings were taken as near fusion point as possible, and at even distances of about 1 in. The results gave surprisingly low figures, the highest percentage being 0.648 of carbon, the average percentage of four bars being 0.530 carbon. The experiment was then repeated in a miniature cupola, filled with coke. Mild steel bars were inserted at 6 in. intervals, and each in turn brought down to the "melting zone."

The first results from trials in a 7-in. dia. cupola on 15 bars gave an average carbon content of 0.386 per cent. carbon. When repeated in 12-in. dia. cupola the average was reduced on six bars to 0.25 per cent. carbon. In the larger cupolette sufficient temperature was attained to procure masses of molten metal in the bed, and on analysis the total carbon absorbed in this case was 1.97 per cent.

An interesting feature was that in every case the melting took place on top of the bars. There were no facilities available for recording temperatures of cupolas, but the steel bars melted easily. The results were unexpected in the low amount of carbon absorbed at the melting stage, much larger figures being anticipated.

In actual practice there is doubtless further absorption of carbon until, in the writer's opinion, about 2 per cent. is attained. This figure varies with height of bed and cupola practice generally.

Heat Treatment.

From trials it has been ascertained that when semi-steel is annealed at a temperature from 760 deg. to 800 deg. C. it loses considerable strength, in tensile strength the reduction varying from 25 to 33⅓ per cent., but the resulting metal was found to be very soft with a certain amount of malleability and ductility. Fig. 5 shows microphotographs of a test bar as cast, heated to 760 deg. C. for two hours, then slowly cooled, reheated for a further four hours at 760 deg. C., and slowly cooled in muffle. Mr. McLain, in one of his pamphlets, shows a bar cast from white iron and steel scrap, which, after a prolonged heating, could be twisted.

With semi-steel of the average analysis given the best results seem to be obtained by one annealing and slow cooling. Strength is reduced, and deflection slightly increased. To obtain more marked results low silicon and phosphorus with the carbon mostly in the combined state would be necessary.

In the Paper presented by Messrs. Campion and Donaldson some interesting and remarkable results have been attained by heat treatment of semi-steel at low temperatures, the loss of strength at temperatures up to 700 deg. C. being considerably smaller than shown by ordinary cast iron.

Literature.

In this country Mr. J. E. Hurst and Mr. M. Riddell were two of the early investigators. In Mr. Hurst's Paper, read at the 1915 Conference, he had not much to say in favour of semi-steel, except to admit its greater strength, but as he admittedly used steel borings, in the light of later experience he could only expect hard spots and other troubles. Mr. Riddell went fully into the theory of the melting of steel scrap, the necessity for thorough mixing and enunciated the principal rules to be observed. He has gone further into the matter since then in a number of Papers to Branch meetings and elsewhere on this subject, and in connection with it, on cupola practice and fluidity.

Mr. Field's Paper, already referred to, contains some valuable information on the subject of semi-steel slags, and on the heat treatment and annealing effects and results.

The veteran Dr. Stead, in his presidential address to the Iron and Steel Institute in 1920, made reference to two great advances in foundry practice during the last twenty-five years; first, the researches of Prof. Thomas Turner on the influence of silicon; and to the production of castings by melting mixtures of steel scrap and blast-furnace metal in the cupola, for they were much superior in toughness and strength to those made from furnace metal alone.

In the States Mr. McLain has given many instructive lectures, and published pamphlets showing types of castings made from this material, with analyses and microphotographs. The late W. J. Keep repeatedly advised the use of steel scrap, and many interesting Papers have been published by Messrs. J. A. Dyer, W. J. Mulcahy, H. E. Diller, and many others. The American Radiator Co. did splendid service, and the record of their practice is well described in "The Foundry," December, 1918.

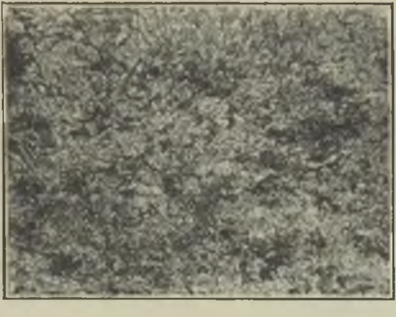


FIG. 6.—TYPICAL STRUCTURE OF STRONG SEMI-STEEL AFTER ETCHING. MAGNIFIED 100 DIAS., BUT REDUCED MORE THAN 50 PER CENT. ON REPRODUCTION.

M. E. Ronceray's able Paper, "How Semi-steel Shells are being Made in France,"* is worthy of special attention. It describes how "fonte acierée" was carefully considered, then adopted on a large scale in France for shells and other munitions. The tests and analyses are given, the

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* "The Foundry," March, 1918.

composition of the final product, with the effects of the various elements, particularly silicon, sulphur and phosphorus and full details of cupola practice.

In connection with French methods, the pre-war experiments on semi-steel shells by Col. Prache and the Paper read by Lieut. Laurent* at the Milwaukee Convention of 1918 should be specially mentioned.

The fine record of achievement and results in munitions made during the war will undoubtedly lead to further developments in semi-steel both in respect to increased demand and in increased knowledge as to how ironfounders may get even better results than have hitherto been recorded. Cost is an important factor, but this is one of the main points in its favour.

When the conservatism of the average British founder will yield to acquiring the necessary scientific details, and become willing to undertake the care and supervision which this material calls for, the writer feels sure that semi-steel will not be confined to a comparatively small number of makers, but will become much more widely used and appreciated.

Addendum.

Mr. J. E. Fletcher, M.I.M.E., has been good enough, in an unofficial capacity, to submit some notes on semi-steel practice based largely on his own experience and on Continental experience. These may be summarised as follows:—

(*A*) *Suggested Analysis to Ensure Best Physical Properties in Cylinder, Hydraulic Valves and Fairly Heavy Munition Castings.*

	Per cent.
Total carbon	2.8 to 3.2
Silicon	1.0 to 1.5
Manganese	0.6 to 0.9
Phosphorus	under 0.30
Ratio $\left.\dfrac{\text{Graphitic carbon}}{\text{Combined carbon}}\right\}$	=3.0 to 3.2

(*B*) *Relationship of Total Carbon to Silicon.*

For castings 2 in. thick and above, the total carbon per cent., plus Si per cent., should be 4.2;

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* "The Foundry," November, 1918.

between 1 in. and 1¾ in. thick, it should be 4.3; between ½ in. and ¾ in. thick it should be 4.5; and between ¼ in. and ½ in. thick the figure 5.0 is given.

(*C*) *Cupola Practice.*

1. Hot and rapid melting is necessary so that the steel does not carburise too rapidly in its descent through the cupola.
2. The charges of steel scrap, pig-iron and coke should be light, the metal charge having a maximum depth of 4 in. to 5 in. when the coke used is in ratio of 1 to 10 of metal melted.
3. The coke used should be of the best, low in ash, high in carbon and of strong, physical character and reasonably porous.
4. The amount of air used should not exceed 30,000 cubic feet or, say, 2,300 lbs. weight per ton of metal melted.
5. The blast pressure should not exceed 8 oz. for 24 in. to 36 in. cupolas, 9 oz. for 36 in. to 48 in. and 10 oz. for 48 in. to 60 in.
6. The following figures, being the total tuyere area per cent. of the cupola area inside lining are suggested; for a cupola of 20 in. dia. the tuyere area should be 30 per cent.; for 40 in. dia. 25 per cent.; for 50 in. dia. 22 per cent.; for 60 in. dia. 20 per cent.
7. The depth of well or hearth of cupola below the tuyeres should not be too great, 15 in. to 18 in. being good practice.
8. The steel scrap should not be too thick or too thin (¼ in. minimum and ⅝ in. maximum is a good rule). Very short pieces are unsuitable, as these tend, as in the case of turnings, punchings and the like, to segregate and promote irregular fusion and carburisation.
9. The amount of air supplied per sq. in. of tuyere area per min. should not exceed 12 cub. ft., and the tuyeres should be well flared out at the inside of the cupola to at least twice the inlet area at wind belt. Flat rectangular shaped openings are better than circular ones.
10. From the above it is evident that high velocity of blast accompanied by high blast-pressures is prejudicial to good results. In actual practice, if each tuyere has an area (at inlet from wind belt) of 1/30th of the cupola area at the tuyere

level, satisfactory results are obtained. A single row of tuyeres gives good uniform melting and generally better working than two or more rows of smaller tuyeres.

11. Such design as indicated in the foregoing fixes the velocity of the blast at about 28 ft. per sec. when traversing the tuyere inlet. (This in the case of 48 in. cupola.) For small cupolas this velocity may be reduced to, say, 22 ft., and for larger (60 in. and upwards) increased to 34 ft. per sec., being influenced by the amount of blast penetration necessary.

12. The height from tuyere level to bottom of charging door, governing the depth of stock column, is of importance, and for semi-steel practice may be given as 20 to 24 times the square root of the cupola diameter at tuyeres—

$$H = 20 \text{ to } 24 \sqrt{d} \text{ in ins.}$$

Thus a 36 in. cupola would have a height from tuyeres to charging door of—

$$20 \text{ to } 24 \text{ times } \sqrt{36} = 120 \text{ in. to } 144 \text{ in.}$$

The higher figure is preferable as assisting rapid melting and economical working.

Mixtures.

The practice of making a semi-steel pig from a 40 per cent. (or 30 per cent.) steel mixture, and of using this in conjunction with pig-iron and scrap with or without a further 10 per cent. or 15 per cent. steel scrap yields good results, the metal being more homogeneous. It is bad practice to mix high phosphorus pig-iron with steel scrap owing to the different fusion points of low and high phosphorus metals.

Low total-carbon content in the pig-irons used is essential, otherwise the semi-steel will be too high in the total carbon, and weak in consequence.

The oxidation losses are greater when using high carbon pig-irons, and tend to the production of porous, oxide-charged metal.

Too much emphasis cannot be placed on the necessity for high-temperature melting and casting. Obviously the higher fusion temperature of 3.0 per cent. carbon iron calls for considerable superheat if fluidity is to be obtained.

Moreover, the quicker the melting the less will be the degree of carburisation in the steel portion of the melted charge, and the lower the final carbon content of the metal produced.

Hematite pig-irons admittedly give the best results in semi-steel mixtures. If the total carbon content is 4.3 per cent. minus, say, 0.29 per cent. for each per cent. of silicon content, a limit is reached. If the total carbon exceeds this the pig-iron is of the high-carbon type and indicates high temperature blast conditions. Below this the graphitic condition is less coarse, and the pig-iron physically stronger. Thus the upper limit of total carbon for a hematite containing 3 per cent. silicon is 3.43 per cent. If higher than this the graphitic structure of the pig-iron will be normally coarse, and Mr. Fletcher believes this coarseness persists in the semi-steel made therefrom, the worse as the silicon content is higher in the semi-steel.

The high total-carbon evil is more pronounced with phosphoric irons. Mr. Fletcher has shown elsewhere that each per cent. of phosphorus displaces about 0.39 per cent. of carbon. Hence the basis limit in a pig containing 3 per cent. silicon,
C. Si P.
1½ per cent. phosphorus is $4.3-(3\times.29)-(1.5\times.39)$ or 2.9 per cent. total carbon. In some hot blast furnaces such a pig may reach 3.5 per cent. total carbon, and it is exceedingly difficult to keep the carbon low in such irons except in small furnaces using low temperature blast. Hence the common fact that high-silicon, high-phosphorus irons absorb carbon rapidly in the blast furnace hearth and in cupola much more rapidly than do hematite irons. Mr. Fletcher has always agreed with the author in his view that phosphorus in semi-steels should be kept low—for the reason given. It is not improbable that the higher limit for carbon in hematites, by reason of the absence of phosphorus, helps the fluidity by raising the proportion of the 4.3 per cent. carbon eutectic in the metal when hot melting is practised.

Discussion.

Introducing his Paper, Mr. Cameron said the results were far better than expected with regard to the test bars. That there were only two failures was very surprising, and the material turned out day after day gave satisfaction to the people who were using it. He must say that they had the unique experience in this work of having the hearty co-operation of every man, woman, and youth in the place. He also acknowledged the great help he had received from Mr. McLain, Prof. Campion, ex-President Riddell, Mr. Fletcher for his valuable addition, and Mr. Shaw for his practical aid when Assistant Director at the Ministry of Munitions.

Mr. S. Flagg (United States) opened the discussion by asking whether in conjunction with the cupola the lecturer used a mixer or receiver.

Tensile Test for Cast Iron Unsuitable.

Mons. E. Ronceray (Paris) referred to certain tests mentioned in the Paper for which he appeared to be in some way responsible, but several tests had been taken, and those tests had been found entirely wrong; some of the worst tests gave good tensile results and some of the best tests gave the reverse. The tensile test was not fit for cast iron, but he fancied that the tests made in France were more reliable. He thought what Mr. Keep had done was wonderful. Mr. Keep, he believed, had, in America, made several thousand tests of high silicon iron, and while on this point he might say that his own experience was that an amount of silicon between 2 and 3 per cent. did not appreciably change the strength of the metal. He had used 3.25 to 3.50 per cent. and had not found any trouble. It was an interesting problem to find out whether more silicon than that would do any harm. He did not think it advisable always to use it, but in the case of large and small castings it would be useful to know the differences that resulted, and that they could safely put more silicon into the latter.

Size of Test-Bar Important.

Mr. J. Shaw said he was indebted to Mr. Cameron for putting before us the methods employed by his firm in attaining the reputation they have in making various castings in semi-steel. There are three points on which he would like to have further information. One of the chief claims for semi-steel is the small size and fine distribution of the graphitic carbon, this property making the metal so useful to resist pressure. In view of this fact, one would not expect a drop of about 3 tons when the tensile bar was increased from $\frac{5}{8}$ to 1 sq. in., turned down to 0.564 in. In this respect it would seem to be little better than ordinary iron. He noted, however, the American Radiator Company put forward tests up to 21 tons on a bar cast $1\frac{1}{4}$ in. dia., turned down to 1.128 in. dia. The mixture was made up of, roughly, $\frac{1}{3}$ steel, $\frac{1}{3}$ pig, $\frac{1}{3}$ remelt, and the analysis was TC, 3.02; GC, 2.36; CC, 0.66; Si, 1.28; S, 0.123; P, 0.104; and Mn, 0.6 per cent. It must be remembered that most of the tests mentioned by Mr. Cameron were made on the $\frac{5}{8}$-in. bar.

Low Sulphur Queried.

The second point noted was the very low S obtained by Mr. Cameron. To keep the S down to even 0.058, his maximum figure, denotes practice not usually attained. When it is remembered that the gain of S in good cupola practice is about 0.035 per cent., add to this the effect of extra fuel often used and the greediness of steel in a red-hot pasty condition to absorb S, it is remarkable. From some hundreds of tests taken by one prominent firm, the average S was 0.112 per cent. This is round about the figure mentioned in the Paper as being obtained by other workers.

A Carbon Absorption Query.

Mr. Cameron, on page 93, gives details of several experiments that tend to show how little C is absorbed during the melting stage. On the other hand, it is difficult to understand when it can be picked up afterwards, when we remember cupolas, with tuyeres as low as possible, running all day and hardly ever botted up, the metal running into a large receiving ladle. There can be practically no contact with the bed in this case once the metal is melted. Yet the lowest recorded in that works was 2.81 per cent. The only record of a low TC that he knew of was one mentioned in the January issue of The Foundry, where a firm using 50 per cent. steel, with the remaining half made up of an 8 per cent. ferro-silicon with 2 per cent. C. This metal was stated to get down to about 1.8 per cent. carbon in the middle of the blow, with 3 per cent. at the start.

High Phosphorus Considerations.

Mr. H. Field (Birmingham) described the Paper as excellent. There was a tremendous future for this high tensile metal—so-called semi-steel. Alluding to Mr. Fletcher's comments, he believed that gentleman recommended them to make a high-steel mixture of 50 per cent. steel, perhaps, and to use it in further work for the purpose of making a low-steel mixture. That would seem to suggest that the whole of the beneficial properties of this material was retained on constant melting. He would like Mr. Cameron to confirm or otherwise as to whether, when a semi-steel mixture was constantly remelted, it retained the properties which it had originally. He quite agreed with the lecturer as to the necessity for a high-melting temperature, and the very great possibility of getting chilled metal if they were not extremely careful in this respect. This metal was much more prone to chill than ordinary cast iron of apparently similar analysis. But on one point he was not in agreement with Mr. Cameron, and he said this for the encouragement of any member who was thinking of launching out in the use of this mixture. Excellent results could be obtained with a high-phosphorus metal; he had worked considerably with mixtures of this kind, and there was in his experience very little difference except in one particular between the high and the low phosphorus metals. That one difference was in regard to the transverse test. But if one wanted a high-tensile strength with 1.5 per cent. phosphorus in a $\frac{3}{4}$-in. bar it was an easy matter to get 18 to 19 tons tensile. On transverse tests certainly high-phosphorus metal did not give such good results. However, if one required a close grain, which was one of the principal purposes of making this mixture, high-phosphorus metal gave it equally as well as low.

Properties of Remelted Semi-Steel.

Professor Turner (Birmingham) said they all felt how important the subject was. He was interested in the comments of Mons. Ronceray in reference to the proportion of silicon which was recorded by the experiments in 1885. It was definitely stated in that Paper that the conclusions related only to material of a certain composition and cast a certain size, and that fact was sometimes omitted. He was very pleased to hear the references to Mr. Keep and his work. It was his pleasure to have had him as a personal friend for a number of years, and his work in relation to silicon in cast iron was of the very highest value. The question had been raised as to the name which they should give to this material. He did not know a better name than that originally given to it by Sterling 80 years ago when he introduced this metal; he called it toughened cast iron. He made it by mixing wrought iron with cast iron, and then combining it with a certain amount of pig-iron. As to the question raised how far the properties of the metal would be retained on repeated melting, he did not think they would be retained. He suggested an explanation years ago in a discussion on the mixing of two different kinds of iron. They found with varying silicon properties which did not correspond with the chemical analysis. He suggested that the beneficial effect in the one case was due to the precipitation of the carbon in matter and form; he used then the language of the time. He should say now that it was due to the precipitation of the carbon—graphitic carbon—in the solid material. It produced a fine state of division, and did not have that brittleness and weakness which they associated with larger flakes. The question of the proportion of silicon was not so important as that of the amount and character of the carbon. Silicon, sulphur, and phosphorus, and so forth, produced a certain balance, and it was the net result with which they were concerned. They wanted first of all the maximum amount of combined carbon the material would contain or sustain without having free cementite. So far as carbon was concerned, they wanted as much as it would stand, and the amount it would stand depended on the quantity of silicon and other elements. The next thing required was that the carbon should be of the right total quantity; it must not be too high, and it must be in the finest possible state of division which they could obtain. If they could get those things together then they obtained the best quality of iron. He thought the Paper was a valuable contribution which they should read with pleasure, not only immediately after the conference, but for years to come.

Type of Pig-Iron Important.

Mr. J. E. Fletcher (Dudley), speaking of the total carbon in the use of various kinds of pig-iron in mixture, said he thought they had some very valuable suggestions in the Paper. Those who had made semi-steel were constantly finding that the type of iron being used was of the highest importance. Mr. Cameron, in mentioning the suitability of high-carbon irons, said they might with advantage use those high in manganese, and referred to hematite irons and steel scrap generally as giving good results. Their American friends were using that type of high-carbon irons and were reaping the advantage. The remarks of the lecturer about the efficiency of the Scotch type of irons corresponded with his own experience, which was that they gave remarkably good results. His own experience in trying to mix steel scrap with cold blast iron with a low carbon content was that the results were very disappointing. He thought the whole thing seemed to point to the fact that the iron is carburised more efficiently when they had iron of a fairly high carbon of the hematite type.

Mr. F. J. Cook (Birmingham) said he would like to draw attention to one paragraph of general interest in regard to obtaining better tests by using high-class irons, including cold blast, special brands and special cylinder pigs. He had been using semi-steel and high-class cylinder irons for the last 15 years, and he could confirm what the lecturer had to say in respect of the bad effects on the tensile strength of the metal. But in dealing with Diesel engine work and liners for high superheated steam he had found a distinct advantage in the wearing properties of the metal which seemed to counterbalance the loss in strength.

Application of Semi-Steel.

Mr. Young (Newcastle) said that Mr. Cameron's paper was one that they had all been waiting for over a long period, and it could scarcely have been placed before them more lucidly. However, he considered care needed to be taken as to how they applied this so-called semi-steel. He did not think it was universally applicable to any and every casting, and as Mr. Shaw had hinted, the thickness of a casting was of very great importance as well as silicon. Going into the exhibition recently he was tackled internationally upon this semi-steel question, but he must confess that he only used it when he wanted it, and one did not want it always. The author had referred to the effect of sulphur, giving two analyses, and stated that good metal could not be made with the amount of sulphur shown. If they looked back through the Paper they would find another analysis contained a low sulphur and high manganese, but here when condemning sulphur there was no manganese. He thought the fault in this iron was with the manganese, not with the sulphur; and generally they could not make good cast iron with a low manganese content.

Melting Troubles.

Professor Campion said that the key to success with semi-steel was the cupola practice. Haphazard, unorthodox methods were useless. It was essential that everything entering the furnace be weighed or measured, and this was especially the case with the air. The early troubles with semi-steel were not caused by the steel being difficult to melt, but owing to unsuitable melting conditions and a failure to appreciate what really took place during the process.

As a matter of fact, steel melted very easily, and usually in advance of the iron in a properly designed and operated cupola, without necessarily first becoming heavily carburised. Recent experiments showed that carburisation did not take place until after the steel had fused, and the amount of carbon absorbed depended upon the depth of bed through which the molten metal passed.

An all-steel charge (mild steel 0.12 carbon) melted and passed through a coke bed having a depth equal to 12 per cent. of the cupola diameter absorbed between 1.9 and 2.0 per cent. of carbon. With deeper beds the amount was greater, as, for instance, when it equalled 23 per cent. of the diameter, the carbon was 2.37 per cent., and with depths equal to 70 and 110 per cent. the metal contained 2.60 per cent. and 2.76 per cent. of carbon respectively. These results appear to confirm the statements in Mr. Fletcher's addendum that "hot and rapid melting is necessary, so that the steel does not carburise too rapidly in its descent through the cupola," and also that "the depth of well or hearth below the tuyeres should not be too great."

The question of the size of test-bar in relation to casting size had been raised, and some of the previous speakers seemed to think that high tensiles could only be obtained in small cast bars, but he had recently tested bars cast 1½ in. dia., turned down to 0.798 in. dia., and obtained 18 tons tensile, and occasionally even higher results had been secured.

The Author's Reply.

Mr. Cameron, in reply, answering Mr. Flagg, said they had not used a receiver. They used an ordinary cupola. With a mixing ladle they could take every charge by itself, which would be impossible with a receiver. Regarding Mons. Ronceray's remarks, which were always interesting, he agreed that some of the tests and analyses given by Government departments were, to put it mildly, capable of improvement. He was pleased to hear from Prof. Turner and Mons. Ronceray that a high silicon content was not the dreadful thing that some of the ironfounders rather thought it was. As to Mr. Field's question whether semi-steel retained its properties after remelting, he believed some firms were using refined iron by a process of putting large quantities of steel chain into the blast furnaces. The practice of melting semi-steel mixtures in the cupola and remelting it had been followed with very good results, but probably if it was remelted too frequently it would deteriorate, as Prof. Turner said, and the sulphur would be absorbed. But to a limited extent remelting was useful in his experience. No doubt Prof. Turner's remarks about cast iron would go to the proper quarters. Turning to Mr. Fletcher's comments, he wished to emphasise that in 1918 ironfounders took whatever iron they could get; they were not allowed to use hematite. The great difficulty was that it was practically impossible to work to a uniform analysis; the chief thing being to produce these munitions at the necessary tensile strength, which was the Government test, and, he might also say, the ultimate test of these castings was fragmentation, as to which this metal gave excellent results. The Scotch irons used worked splendidly with steel scrap. Commenting on Prof. Campion's remarks, he hoped in the near future to make some real systematic research in regard to this material, particularly with respect to the relation of carbon to silicon, and so forth.

Regarding communication received since the Conference, the name semi-steel is likely to remain in general use until officially dealt with by the Cast Iron Research Association and the Institution of British Foundrymen.

The control of carbon within the limits indicated by Mr. Fletcher and Mr. S. G. Smith cannot be uniformly obtained in the cupola. Some other method of melting or after-treatment would be necessary.

The writer repeats that in his experience semi-steel gives superior results, both in ease of machining and finish, to any kind of cast iron he has made. It is admitted that the finish on a casting made from a permanent mould is superior to ordinary cast iron.

The writer agrees with Mr. Smith that physical structure is quite as important in cast-iron mixtures as in semi-steel. When cold-blast irons are used, the physical structure is practically identical with good semi-steel, and the benefit of the latter is that equal structure and strength may be obtained at a much lower cost.

Regarding M. Ronceray's later contribution, Mr. Cameron agreed that the tensile test was a very delicate one, subject to unexpected variations and requiring the greatest care with the test-bars. These had to be poured from the best of the metal when cupola was thoroughly heated and the bars accurately machined and polished.

With reference to phosphorus, the idea of a medium percentage was taken from 0.5 to 0.6 per cent. When the munitions in question were made hematite iron was not available, and it was sometimes difficult to keep to these figures. When phosphorus was over 0.8 per cent. the castings were inclined to be brittle under a severe test made by an official by trying to break them by throwing them on a steel rail.

The high sulphur bars referred to were found to be low in manganese. Mr. Young made clear reference to this in his remarks and in his Paper published on the subject.

The gradual deterioration in the set of four test-bars poured at intervals of 2½ minutes was fully investigated and described by Mr. Riddell in one of his Papers. Similar results would occur with cast iron, but semi-steel seems to be more sensitive to these holes and to other defects when pouring is unduly retarded in light castings. M. Ronceray has correctly given the solution of the steel scrap melting first. This scrap, in the writer's practice, was always placed on the top of the charge next the coke, and was in small pieces seldom over half an inch in thickness.

In conclusion, the writer has to express his thanks and appreciation to the speakers at the Conference and to those who sent written contributions later. The friendly reception and criticisms from eminent scientists and practical foundrymen of world-wide reputation have placed semi-steel in a position it had not previously been accorded in this country, and have undoubtedly led to increased interest and in many cases to trial and systematic research, which it is hoped will benefit the ironfounder's craft.

Written Contributions.

Mr. S. G. Smith, in a written contribution, congratulated Mr. J. Cameron upon the very able Paper dealing with added mild steel to grey cast-iron mixtures, and stated that the use of such mixtures is by no means modern. It is just 48 years ago during his foundry apprenticeship that his firm poured such castings as guides for wire mills and guide plates for small merchant mills. These castings were subject to very high frictional wear, and if made from ordinary cast-iron mixtures as was then used their life of service was very short indeed. The steel in the form of rail ends, plate scrap, etc., was put into the cupola with the last charges of metal. No record of percentages was kept at that time, as foundrymen in those days did things and said nothing, and he still had great admiration for foundrymen who were elderly when he was a boy for what was accomplished by them.

Mr. Cameron's opening statement truly says that the appellation "semi-steel" is misleading. He agreed with him. It is high time that this product should have a suitable name and specification. Text-books infer that iron containing more than 2 per cent. carbon is cast iron. The unsuitability of the name semi-steel brought an incident to his mind which occurred about five years ago. The engineers in a large engine-building concern, who had heard, or read, something about semi-steel being a good material for resisting superheated steam, inquired what should be the analysis of semi-steel. Without giving a thought for what purpose this was required, the analysis given was based upon the percentages of constituents of an average steel, and an average foundry iron put together and halved.

Shortly afterwards, a specification came from the engineers' office to the foundry that the analysis of certain castings must comply with the specification, which gave the total carbon a little above 2 per cent. Nothing more need be said, as it is common knowledge that it is very rare, regardless of percentages of steel put through a cupola, that total carbon will be less than 3 per cent.—more often it is well above that figure.

Whilst Mr. Cameron states that semi-steel does not displace steel or malleable cast iron, he thought there may be exceptions to this. There is a mixture of cast iron called "steel-alloy"—a much better name than "semi-steel." He knew of castings which were formerly made in steel and are now made in steel-alloy, the results being most favourable in every way. The castings referred to are comparatively thin—about half-inch section, and pass through an annealing process.

In the Paper it is stated that semi-steel is much superior to grey iron for machining. To this he could not agree. His experience with many mixtures of cast iron was that castings poured into iron permanent moulds (when not chilled) gives a perfect surface, regardless of the fineness of the thread. Also, this perfect surface can be obtained from suitable mixtures of cast iron not poured into permanent moulds. Additionally, a claim is quoted that semi-steel is a self-lubricating metal. This, he thought, was too good to be true. The quality of self-lubricating is more probable in castings containing a high total carbon, say 4 per cent., and a low combined carbon, say 0.04 per cent.

On page 90 the author states that semi-steel does not owe its qualities to chemical analysis so much as its physical structure. Surely Mr. Cameron will agree that those remarks apply to most mixtures of cast iron equally as well as steel-added mixtures.

Regarding the tests, he hoped that foundrymen were not making a lash to be whipped with. It is not often that the physical qualities of a test-bar clearly indicate the suitability of metal for castings they are supposed to represent. He would like to enlarge a little upon this aspect, but as the matter is now under consideration, and that he was serving on a branch committee, he did not propose to pursue the matter at present.

On page 94 reference was made to a bar cast from white iron and steel scrap being twisted after prolonged heating. He thought this was quite common in malleable-iron foundries.

The information given upon cupola practice he was quite in agreement with. Strange to say, the matter coincided in a remarkable way with an article prepared by himself upon that subject for THE FOUNDRY TRADE JOURNAL, and appeared in that paper twelve years ago.

The following are four results taken from numerous mixtures of cast iron and steel.

Mixture No. 7.—Steel 90 per cent., and No. 3 hematite pig 10 per cent. This gave a metal of the following analysis:—

C.C., 3.98; Gr.C., nil; Si., 0.13; Mn., 0.45; P., 0.034; and S., 0.171 per cent. The diameter of the cupola was 72 in. The steel scrap was composed of borings, turnings, billet ends, and miscellaneous material. The fracture was white.

No. 2 *Mixture.*—Cold-blast iron, 25 per cent.: No. 3 foundry pig, 25 per cent.; foundry scrap, 25 per cent.; and steel shells, 25 per cent.

On analysis this mixture gave C.C., 0.705; Gr.C., 2.80; Si., 2.031; Mn., 0.62; P., 0.23; and S., 0.124 per cent.

The transverse test gave 3,430 lbs. breaking load associated with a deflection of 0.09 in., whilst the tensile test registered 8.84 tons per sq. in. In this case the diameter of cupola was 60 in.

The object of this test was to attempt to minimise the growth and pitting in castings due to impinging of superheated steam. It should be pointed out that the low tensile test was probably due to the addition of steel to a strong iron, however the material was suitable for the purpose desired.

Nos. 3 *and* 4 *Mixtures.*—No. 3 foundry pig, 50 per cent.; steel scrap, 50 per cent. In this case the analyses were respectively: C.C., 1.58; Gr.C., 1.45; Si., 1.29; Mn., 0.36; P., 0.89; and S., 0.25 per cent. for No. 3, and C.C., 0.61; Gr.C., 2.70; Si., 1.90; Mn., 0.56; P., 1.05; and S., 0.13 per cent. for No. 4. Seventeen and eighteen tons per sq. in. were registered by Nos. 3 and 4 respectively, whilst the fracture of the former was steely and the latter dense.

Of course, castings from No. 3 mixture would be unmachinable, due to high sulphur, which influenced the combined carbon to rise to 1.85 per cent., caused probably by faulty cupola operation and condition.

Economy in steel mixtures will depend upon the price and availability of suitable steel scrap.

He thought no doubt existed that the addition of steel scrap strengthens denseness and toughens a soft, weak pig-iron; yet it should not be considered that for all practical purposes satisfactory results cannot be obtained without the addition of steel scrap. It has been shown many times that these results can be obtained with pig-iron mixtures without the use of steel scrap.

In connection with Mr. Cameron's Paper on "Semi-Steel." Mr. Thomas Bell wrote that he was very sorry so little time could be allowed for discussion of the very excellent Papers presented to the Conference. He had expected to hear some remarks from some of the practical men regarding the use of semi-steel for the heavy class of castings, and he was anxious to get some information as to its use for same. In the addendum some useful information is given; still, he could have wished for some information as to the method adopted in keeping the metal hot in the ladle when a large quantity is required and can only be drawn off in three or four taps. Another point which is always well discussed is the form of the graphite for high-tensile tests. It would have been of great interest to the practical men to have had some information how to get the graphite in this fine divided form. He supposed casting temperature would have something to do with it. Could this be regulated? He was delighted with Mr. Cameron's Paper, and if he or any of the members who took part in the discussion can offer any further information on these points he, as one of the practical men, would watch The Foundry Trade Journal with interest for same.

Mr. J. McEachen wrote in reply to Mr. Bell's query about heavy castings:—

"As a practical man, the methods I recently employed when manufacturing a 4-ton cast of semi-steel may be of interest to members.

"Considering that a good temperature is essential, I first ran through 4 tons of grey iron. This, of course, provided a good hot cupola. Then 2 tons of 20 per cent. semi-steel was put through, followed by a further 2 tons of 10 per cent. material. The casts were handled by four 12-cwt. bogie ladles. Though the weight of the castings ranged from a few lbs. up to 2 cwts., there would not have been the slightest difficulty in making a 5-ton casting, as the metal came down as quickly as it could be handled, and at a white heat. Under such conditions it does no harm to allow the cast to stand for a short time, but obviously it must be done with discretion. The cupola used is 52-in. dia. and provided with eight tuyeres. The semi-steel was all poured within 20 mins. and the moulds all cast up within 30 mins."

From Mr. E. Adamson, Sheffield:—

"Mr. Cameron is to be congratulated on his paper on semi-steel as much for the negative as the positive results which he gives. No doubt so-called semi-steel, or otherwise a mixture of steel, pig-iron and scrap gives a close grained material, and if melted under proper conditions the iron will give all the beneficial results claimed, but what adds to the value of Mr. Cameron's Paper are the difficulties connected with the use of semi-steel enumerated on page 97 of the Paper, for it is true to say that to ensure the best results it has to be handled on a fairly large scale, and when only a small quantity is required in, say, a jobbing foundry, the results are never so good, for in fact the steel does not get properly melted. It is chiefly because of these difficulties in small foundries that I have consistently advocated getting close grained castings from originally close grained metal.

"On page 86 Mr. Cameron states that No. 1 pig-iron was generally used as machinability was most desirable. No. 1 is, of course, a high total carbon and high graphite metal, but on page 98 it is stated that low carbon contents in pig-iron used for semi-steel is essential. In my opinion Mr. Cameron is right if it is intended to use a large percentage of steel scrap, one of the chief reasons being that the lower combined carbon with the No. 1 iron will make it difficult to melt, and consequently greater superheat will be required in melting, thus bringing the temperature required nearer to that which would be necessary to properly melt the steel used.

"In spite of care in using steel, difficulties still sometimes arise, and in one case I met with two large hard places on the flange of the exhaust end of a turbine casing, giving the impression that punchings had been used as steel scrap, and two of them had not become thoroughly liquid, but, in their plastic condition, had got into the ladle and from the ladle lodged in their natural position on the flange at the *top* part of the casting, which unfortunately had to be machined at this spot. The metal was made from a mixture of 25 per cent. steel, with pig-iron and scrap run first into pigs.

"It is delightful to hear men of practical experience making definite statements, that at one time were not believed. On page 88 an instance is given of 18 tons tensile with over 3 per cent. silicon, and further on it is stated that semi-steel does not owe its qualities to chemical analyses so much as to physical structure, that analyses are excellent in themselves, but must be considered in connection with physical structure. With these statements I have for many years been in entire agreement.

"It is further interesting to note on page 91 that Mr. Cameron recommends soft blast and a tuyere area of 1 to 4. Fifteen years ago I increased my tuyere ratio to 1 to 3½, and with a 10-oz. pressure attained excellent results."

A French Opinion of Semi-Steel.

MONS. E. RONCERAY, of Paris, in a written communication on Mr. J. Cameron's Paper on semi-steel, stated that he congratulated Mr. Cameron for his very interesting Paper, and thanked him for his too kind appreciation of his (Mr. Ronceray's) Paper on a similar subject given to the A.F.A. during the war.

He (the writer) was not very proud of his Paper, as he fell in a good many points into accepted errors of that time. His excuse was that it was then more urgent to help making shells than to argue.

Mr. Cameron considers the name of "semi-steel" as misleading, and he suggested that some translation of the French name, "fonte acierée," be used. Perhaps "steely cast iron" would answer the purpose.

So far as he could understand, the tests imposed by the British War Office were simply those of the French War Office translated in English measurements. The same criticism that he made in his Paper, "New Methods of Testing Cast Iron," applied. Those tests were valueless.

Colonel Prache mentions: "What has stopped possible improvements with semi-steel during the war are the tests imposed by the War Office. Those who have made semi-steel shells know that these tests had a very distant relation to the castings that were to be produced"; and also "War Office tests prevented foundrymen from making better shells." Portevin writes: "On the point of view of the quality of metal for projectiles, it was difficult to make a worse choice of testing methods."

The reasons were fully explained in his Paper, and he only wished to warn those who have not had a long experience of these tests not to put

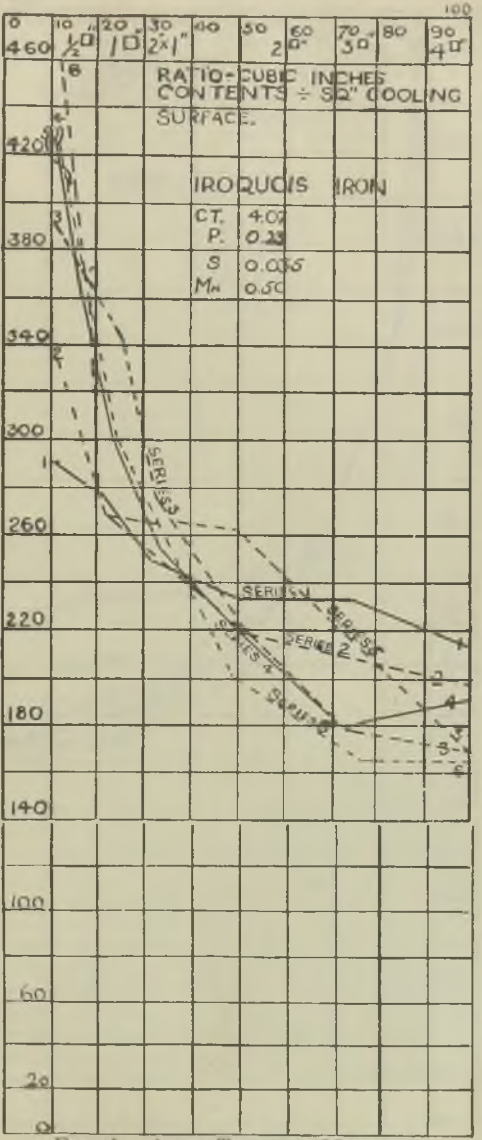


Fig. 1.—Acme Tests as Measured.

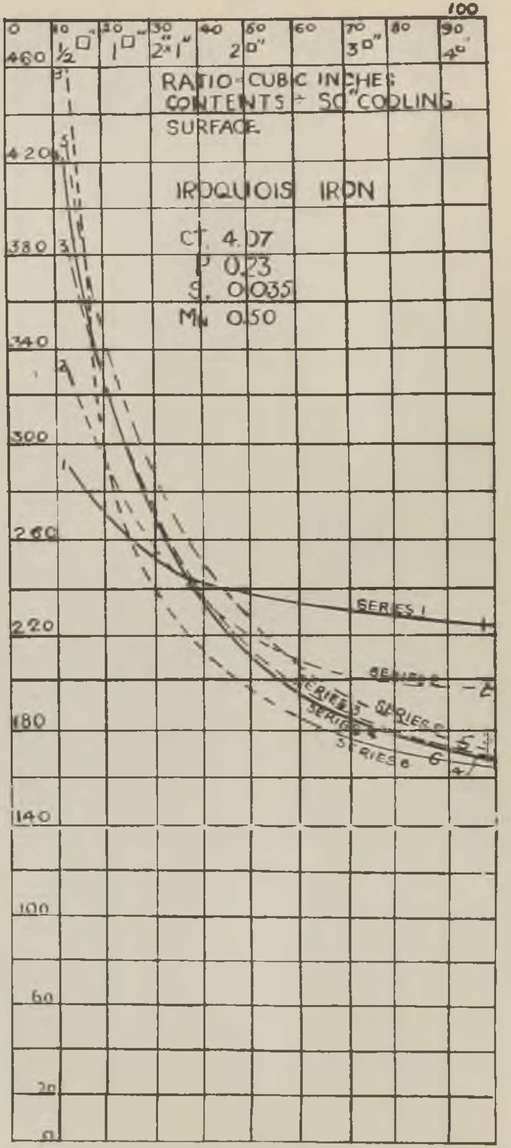


Fig. 2.—Curves Made Uniform.

the slightest confidence in them. Another proof of their unreliability is given by Mr. Cameron when he mentions that failures happened when the foreman had changed the moulder making the test bars. In fact, it is quite common that two bars cast in the same moulding box from the same gate give quite different results.

High Silicon in Cast Iron.

A point of Mr. Cameron's Paper which interested the writer considerably is his statement about high silicon test pieces. It refers to one of the writer's hobbies. Professor Turner did wonderful pioneer work when he investigated, more than 35 years ago, the influence of silicon on cast iron. He called attention to the importance of silicon on the condition of carbon, and gave a chart showing the influence of silicon on strength of cast iron. From this time the behaviour of silicon has been studied, and we are indebted to him for the considerable progress that has been made in the foundry in following the information given. About same time, on different lines, Gautier in France used silicon in cast iron to a great extent.

Professor Turner worked on what must be called artificial cast iron containing about 2 per cent. carbon, and used test pieces of only one size. Unfortunately, though Professor Turner mentions this point very clearly, many false ideas have been derived from the insufficient knowledge of these details.

After Professor Turner, Keep, the admirable American experimenter, made very important researches on the same question, dealing with commercial iron and using various sizes of test pieces, but he tested transversely, the most reliable of all tests for cast iron. He ventured to say that Keep was rather influenced by the results published by Professor Turner, for it seems that he did not dare to draw the full lesson from his tests. Fig. 1 shows the original diagram of pages 120-121 of "Cast Iron," by W. J. Keep, amended only in showing the zero line that Keep left out, beginning his diagram at 160 lbs. This was done only to save space, but it was rather misleading. Alongside of it (Fig. 2) is shown the diagram corrected by him to make nice curves, and amended by the writer in the same way as the preceding one. It is quite clear that in the first diagram there is a knot of all curves between ⅞ in. and 2 in. thickness, which the writer should translate by saying that between ⅞ in. and 2 in. thickness a percentage of silicon between 1 in. and 3½ in. makes no difference in the strength.

The writer has poured castings of about 1½ in. thickness and even more with cast iron intended to be used for thin work, and containing more than 3 per cent. silicon, and the work was quite satisfactory. He has done this now for more than four years, with the result that a hard casting is almost unknown when other conditions are normal in the foundry.

TABLE I.—*Composition of the Iroquois Iron used in experiments detailed in Fig.* 1.

Series	Per cent. nominal silicon.	Per cent. of silicon.						
		½" sq.	1" sq.	1" × 2"	2" sq.	3" sq.	4" sq.	Si. av.
1	1.00	0.83	0.79	0.78	0.82	0.72	0.88	0.81
2	1.50	1.09	1.14	1.70	1.33	1.10	0.88	1.20
3	2.00	1.73	1.73	1.70	1.50	2.17	2.50	1.88
4	2.50	2.13	1.69	1.60	1.80	2.17	2.07	2.01
5	3.00	2.42	2.65	2.40	3.36	3.67	4.67	3.19
6	3.50	2.74	2.69	2.70	2.62	4.30	3.22	3.04

Other conclusions could be drawn of a careful examination of Keep's diagram, but this is not the place to examine them. He hoped to be able to return to the subject later, but he was pleased to read in Mr. Cameron's Paper full support of what he had found when Mr. Cameron mentions that a gate 1¼ in. dia., containing over 3 per cent. silicon, yielded a tensile strength over 18 tons. At the same time, he mentions that semi-steel seems sensitive to phosphorus and sulphur.

Phosphorus in Semi-Steel.

Referring to phosphorus, he believed that we do not seem to speak the same language when we speak of high phosphorus in semi-steel in France and in Great Britain. In Mr. Cameron's Paper, in semi-steel analysis the P is from 0.39 to 0.73. It is when there is 1 per cent. phosphorus that one considers phosphorus high. In France, semi-steel for shells has always been made with hematite, and the question is to know if the limit of from 0.06 to 0.07, or exceptionally 0.12 per cent., can be passed. He sincerely believed that it would be a great mistake to insist upon such low figures, for up to 0.30 the strength and probably the brittleness of cast iron is not altered.

Colonel Prache is afraid that it will probably be brittle. Careful experiments must be made to determine if such is the case, for the price of commercial semi-steel would considerably rise if the lowest figures are insisted upon.

The Limit of Sulphur Content.

The sulphur in analyses given in Mr. Cameron's Paper (0.150 and 0.143 per cent.) was not balanced by a proper amount of manganese; this is probably the reason why the iron would not run in small bars. The manganese ought to have been at least 0.50 to 0.70 instead of 0.26 and 0.34. Thousands of tons of semi-steel shells have been made in France with such percentage of sulphur (see analysis in the writer's Paper on "New Methods of Testing Cast Iron," where the sulphur varies from 0.12 to 0.22). These high percentages of sulphur are not to be recommended, but this resulted from the poor material available during the war, and it is comforting to know that they can be occasionally accepted.

Blow Holes.

Mr. Cameron shows test-pieces with blow-holes due to retarding the pouring. Many reasons can be the cause of such blow-holes, either what the writer calls "Custer effect" (air entrained with iron in pouring), or slag inclusions, or gas from either the mould or the metal. So it is of no use to discuss this point, so long as no more details are available about the condition of pouring, but this is not special to semi-steel; under similar conditions common cast iron would behave similarly. Damp sand, when used for ordinary cast iron, will produce the same result.

Cupola Practice.

He quite agreed with Mr. Cameron as to the size of cupolas to be used and the general arrangement with only one row of tuyeres and the rate of 1 to 4, but he differed with him about the interest of small charges. He was at one time of this opinion, and he had altered it, because, when the charges are small—that is, corresponding to 4 in. thickness of coke as recommended by Dr. Moldenke—the coke takes fire through the charges of iron too easily, and after a short time the flame appears at the top of the cupola, which then is working as a gas producer burning a large amount of coke for nothing and rendering the working of the cupola very hard. He had come to the belief that a thickness of 6 to 8 in. of coke and a corresponding thickness of metal are to be recommended. It means that in a 40-in. cupola he would not use charges less than 14 cwts. iron for 12 per cent. coke ratio.

Referring to the melting of steel, Mr. Cameron says that steel melts quicker than iron, pig and scrap. He was very surprised to read that it is a fact that the melting of succeeding charges takes place more or less simultaneously, especially when the charges are small.

Dr. Moldenke gives evidence of such fact in his Paper of this year presented to the Rochester Convention of the A.F.A. But to admit what Mr. Cameron mentions needs more evidence than he gives. Very likely the pieces of steel melted first were of smaller section than the pig or scrap that he used. This would be a satisfactory explanation.

AMERICAN METHODS OF MANUFACTURE OF MALLEABLE IRON CASTINGS AND SOME DATA IN CONNECTION WITH THE FINISHED PRODUCT.

By Enrique Touceda (Albany, New York).

The author of this Paper would assure you that he feels highly flattered in having received your kind invitation to prepare an exchange Paper to be read before your body at this meeting, and deeply grateful as well in having been asked to appear in person as your guest. He has read with great interest and profit many of the valuable contributions written by your countrymen that have served so greatly to enrich the literature of the metallurgy and metallography of iron and steel, and he well remembers particularly during the early days of his career how profoundly he prized and was impressed by Sir Lowthian Bell's classic, "The Manufacture of Iron and Steel," which at that time he continually read and studied with indefatigable zeal and enjoyment. It served as a constant source of inspiration, and for it the author has an affection that has in no way been tempered with the passage of time. The author's one regret is that, having received so much from you, he has so little to offer in return. In the letters received from the Secretary of the Conference Committee, and the Secretary-Treasurer of the American Foundrymen's Association, Mr. C. E. Hoyt, it was requested that the subject of the Paper cover the manufacture of malleable cast iron as conducted in the States. Their suggestion was naturally prompted in large part by the knowledge that the author has had a very close association with this industry, particularly during the past ten years, and in part perhaps by sharing in the interest that has suddenly awakened in other countries in regard to this subject. During the past year inquiries pertaining to the practical details of this process have been received from France, Belgium, Italy, Australia, and Japan. The author has had the pleasure of receiving visits from a number of engineers from abroad who have seemed greatly interested in the practical rather than the metallurgical details of this industry. These facts have been entered into principally, because it is the author's thought that if he took as a guide the character of these inquiries and the various questions that have been asked him by the visitors referred to, he would not miss by much the ground that members would prefer to see covered, rather than attempt to enter into an academic discussion in regard to the mechanism of graphitisation and other controversial matter concerning which so much has been written of late, or in dwelling on other strictly metallurgical details that have been so ably covered by many others, and particularly by Mr. H. A. Schwartz, whose book, compiled from articles he has written for THE IRON TRADE REVIEW, is about to be issued. The author is assuming therefore that for the most part it is the purely practical end of the proposition that will prove of greatest interest to you; that what you desire mainly is a more or less brief reference to those points concerning which inquiry has been made both in the lay-out and operation of a malleable-iron plant of average capacity, and supplement this with some other matters that in some cases has not been touched upon by others.

The Lay-out of a Malleable Plant.

Starting with the lay-out of the plant, the details of which should have most serious consideration, it is obvious that its correct plan will be dependent upon the plant-capacity specified, and the shape of the building site. In connection with the latter high ground should be selected, if possible, while low ground that is naturally wet and cannot be successfully drained should be shunned as worthless, for if annealing ovens are erected in such a locality annealing difficulties will prove to be perpetual. Whether the plant is to consist of one or various working units, and even if the raw materials are to be handled by means of a crane, it is desirable that each kind be stored as near to the metallurgical apparatus in which it is to be used as is both convenient and possible. It is advisable that at the sidings where the raw materials are to be discharged, the tracks be elevated on trestles of a height and length that will admit of the rapid and cheap discharge of truck contents.

In the case of the moulding, face and core-sand, a saving will result if the roof of the buildings in which they are to be stored is flush with the tracks on the trestle, in order that the trucks can be discharged directly through roof openings into the building or sheds, which should be constructed with this end in view. Irrespective of the size of the plant, the various departments in each unit should bear such a relation to each other that the product from the very start of operations and at each step in the process should be continuously approaching the shipping room in the most direct manner possible, in order to avoid the retracing of steps. Economy in construction will result if each separate department is dimensioned strictly on the basis of providing not much room in excess of that which will occasion quite serious congestion when running at maximum capacity. Experience has convinced the author that, in rare instances only, are malleable-iron plants ever run at maximum capacity, for when business is booming labour is scarce and inefficient, and when labour is plenty and men are willing to do a fair day's work there is a dearth of business. A little crowding therefore in the various departments can be tolerated at times that prove exceptional. The one-storey straight-line plant of fair capacity (25 to 35 tons of castings per day) with core room and shipping rooms at extreme ends, and foundry, hard-iron shops, trimming room, grinding and sand-blast room, annealing room, and soft shops in between and located in the order named, will be found convenient, and can be arranged as to permit of considerable economy in construction, while admitting of considerable flexibility as to expansion. The character of building unit, very popular at the present time in the States, is the one-storey steel-skeleton type with curtain walls, brick pilasters, and concrete foundations, with either a saw-tooth roof, or one of usual construction with sufficient pitch, and 30 ft. wide, a monitor running the full length of the building with window sashes hinged at the top to swing inward, and sashes in the curtain wall pivoted at the centre, the roof covering being of slate, slag, fabricated cement-asbestos tile, or other fireproof material. The one-storey building of this type with either style roof possesses many advantages, in that maximum visibility within is assured, ventilation is facilitated, and fire risk minimised.

Ventilation.

One of the most important items to be considered is that of efficient ventilation, particularly in the foundry building and core room. Without a constant supply of fresh air, energy of body and alertness of mind are gradually deadened as the day progresses, and when activity and vigour are lowered the effect is always noticeable in increased foundry loss on late heats, while the hazard, due to accident, is augmented.

For effective ventilation dependence should not be placed wholly upon the monitor, but it should be supplemented by well-designed ventilators, positioned in such a manner that a steady discharge of air is assured. A popular and very efficient make rotates on ball bearings—the direction and extent of rotation being controlled by a vane—with the result that the exit for used air always faces away from the wind, which, in passing, creates an active suction. These ventilators, when installed by those who understand the ventilating problem. have proved to be worth many times their cost.

Heating.

The efficient and uniform heating of the foundry proper is a problem replete with difficulty, owing to the variable conditions that must be met. During the night there is the natural fall in temperature, coupled with the condition brought about by the wetting and cutting of the sand, that produces a clammy dampness rather hard to remove by the time the men report for work in the morning. In contrast to this condition is the state of affairs that exist after a heat, when the air is filled with hot steam and a great amount of heat is radiating from the stripped castings. Some foundries of even fair size still use the salamander, which while very cheap to install is expensive to run, takes up space of value, interferes somewhat with crane service, and occasions loss of time due to the men congregating around it if they feel slightly cold. One of the best and most approved systems is to force warm air into the building through pipes properly spaced to yield uniform heating by one of the many blower systems now on the market. Live and exhaust steam from the power house or from a separate steam source designed for heating only, or from such a plant supplemented by steam from waste-heat boilers. is used in some plants in manifolds hung in such a manner as to be out of the way but as near as practical to leakages of cold air from windows, entrances, etc., in order to heat this air as it filters into the building. The author has seen many plants where a waste-heat boiler-installation has proved to be a mistake. A waste-heat boiler has not been designed to date in such a manner that after furnace operations have ceased it can be hand-fired economically. In running but one heat per day, any saving would be offset by the huge amount of coal required to keep up steam for the balance of the time, when power or heat was required, while if the boiler is allowed to cool off and electric power and steam for heating derived from a small auxiliary heating plant substituted, the maintenance cost, due to the strains set up, would prove disastrous. The scheme works out very nicely in other cases, especially where the cost of electric power or coal is high; where two heats per day are run from the same furnace; where one boiler is used in common with two furnaces, and particularly when a great amount of power is required for sand-blasting purposes. Reference should be given to that type of boiler least affected by quick changes in temperature.

Foundry Floor.

The foundry floor is another item that is deserving of some thought. Some favour the concrete floor, but the writer believes that if a vote were taken of the moulders the decision would be in favour of almost any other type. The concrete floor is unquestionably hard to the feet, and dangerous in some particulars. When spills occur an eye can be lost or serious burns sustained due to the instantaneous generation of steam from the moisture on the floor surface, which invariably is more or less wet. Serious accidents have occurred in the carrying of iron through the moulder slipping on the rounded particles of metal that have been occasioned by spills. Even when the floor has been properly laid, it subsequently can be ruined through carelessness on the part of the moulder in shaking out the castings too hot. However, the worst feature of the concrete floor is its great tendency to transmit vibration. When bumpers or vibrators are used, the probability of shaking down dirt from the cope or the cope itself is great. A floor of hard-wood blocks properly laid on a sand foundation yields better all-round service, and is equally good for the gangways or, if protected with a little packing where the pots are dumped, for the annealing room; but when used in the annealing room a strip paralleling the front of the oven and 6 ft. wide should consist of square annealed iron plate about 18 in. by 18 in., with lugs on the under side, and set in concrete, or smooth granite block, set in concrete and well grouted. Molten iron has no other effect on wood block than to produce a surface char, which defects are very shallow, and when present become filled and well protected by sand. Black-gum, maple, beech, southern yellow pine, if well creosoted, give splendid wear. The blocks should be laid in straight parallel courses, with the grain of the wood vertical, care being taken to keep straight courses and close joints. All courses should break joints alternately by a lap of at least 2 in., and filled with a hot, low-melting-point pitch of a consistency that will flow like water, to the end that all crevices will be completely filled. Against the sides of the building and around all foundations expansion joints should be made by placing a 1-in. by 4-in. tapered board on edge against the sides of the building and around foundations, which boards subsequently should be removed after the blocks are laid and rolled in order that the void can be filled with hot asphalt to within $\frac{1}{4}$ in. of the wearing surface of the floor. The dirt, or clay, foundry floor is the safest, and the one that is most popular with the moulder. It is comparatively inexpensive, and, if given proper attention, can be kept level and in excellent condition, while if a standard travelling sand-cutter is used, there will be no danger of the floor being cut, provided precaution is taken to see that the treads of the wheels are made sufficiently wide to prevent their sinking into the ground.

Sand Cutting.

The author believes that if the moulder was asked what constitutes at the present time his hardest and most exacting task, if casting surface is a vital proposition, he would state, " cutting sand.'' In the States it is getting increasingly difficult to employ moulders owing to the all-round disagreeable nature of the work and the conditions under which the work is done, coupled with the fact that an equal wage can be earned in other occupations where the work is much less arduous as well as much cleaner. It is very noticeable after a lengthy shut-down that in general those moulders who have secured jobs in other lines refuse to return to the foundry on the resumption of operations. The fact is being recogised that something must be done to lighten greatly his labour and make his living conditions within the plant equal as far as possible, both in wage and comfort, with what obtains in the case of other industries, or, failing which, a very high premium will have to be paid to secure such labour. That the standard type of travelling sand-cutter has not been more generally used is due to the fact that moulding conditions in the malleable-iron foundry are different from those existing in foundries where other types of castings are made. As in malleable-iron practice, there are usually moulds on the floor between heats, it has been found impracticable in most instances to run the machine from pile to pile owing to the very short time available and the confusion that would result if this was attempted. In order to overcome this difficulty, a cutting machine has been devised to operate as a unit with a mono-rail hoist, to which it is attached by two hoisting cables, and by means of which it can be lifted to clear the ground. It also differs from others in that the operator rides on the machine, where he can easily control the cutting, piling, and traversing. Through this arrangement the operator can raise the entire outfit, himself included, and hop the machine from floor to floor without in any way disturbing the line of moulds already in place and located to one side of the pile to be cut, or encroaching in any way on the gangway space or interfering with the progress of other operations.

Lighting.

It would be difficult to over-estimate the importance of providing the foundry and other departments with proper and effective natural and artificial light. If the roof is of the saw-tooth type, the longitudinal axis of the building preferably should point to the north, while if the roof is provided with a monitor, the longitudinal axis of the building preferably should lay east and west. Not only should there be plenty of window space, but equally important means should be taken to secure a maximum amount of light from the space available. It is often found to be the case that considerable money will have been spent for the securing of ample window light, and is nullified in large part through subsequent neglect. Ribbed glass will transmit much more light per unit of area than will plain glass, while it will lessen, though at certain distances not wholly prevent, glare. It is perhaps slightly more difficult to keep clean than plain glass, but if given systematic and intelligent attention, no trouble will be experienced in this direction.

If accumulations of dirt are allowed to remain on glass of any kind for undue lengths of time the surface will become pitted and eventually more or less opaque. The matter of artificial lighting is one that, to be handled correctly, should be placed in the hands of an expert. In the States the problem is simplified by reason of the fact that all one has to do is to avail oneself of the opportunity offered by the General Electric Company, who, upon receipt of plans of buildings and working conditions within, will advise, free of cost, the most suitable installation. While the New York State Industrial Commission have rules relating to the artificial lighting of factories, these cannot be accepted as a guide, as their requirements fall short of what is recognised as being really proper and efficient illumination for the particular character of work covered in their specification. They have had in mind, for the most part, the safeguarding against accident rather than a scientific consideration of the illuminating problem. The General Electric illuminating engineers, depending upon the character of work to be done, recommend from 3 to 6 foot-candles, corresponding to a power requirement of 0.5 to 1.0 watt per sq. ft. of floor area, which is more than double that required by the State. The dominant object to be attained is the securing of uniformly diffused light free from flicker, and in which both shadow and glare will be reduced to the minimum. In the higher bays, a more concentrated distribution of light is desirable, and should obtain, than in the lower bays. These should be located at a height above the crane carriage, in the event that a crane is used, such as will admit of their being relamped and cleaned from it. The equipment that has given general satisfaction in the States for industrial lighting is that which is known as the R.L.M. standard dome reflector, bowl-enamelled incandescent-lamp, but a study of local conditions and building design and interior surface is essential in order to obtain the most efficient location and combination of overhead suspended and wall-bracket suspended units. All lights should be arranged as for quick re-lamping and cleaning, and for economic reasons too much attention cannot be given to the latter, and for the same reason the units should be so controlled that as few or as many lights can be turned on as are required at any time.

Handling Materials.

The following hints may prove of some value in the layout of a straight line foundry of medium capacity. A mono-rail crane so located that it passes from end to end of the foundry building and directly over two air furnaces symmetrically distanced as to moulding space and set crosswise of the building, in combination with an electrically-driven 2 or 3-ton transfer bridge of 30 to 40 ft. span that will admit of easy and rapid exit out of and entrance into the foundry, will pay for itself within a reasonable period. Through the latter arrangement the air-furnace charges can be placed on the floor space beneath the bridge at its entrance to the building, to be subsequently taken to the furnaces as needed. Such a scheme yields fairly complete crane service to both yard and foundry, while for a slight additional expenditure the mono-rail can be extended to the other departments if, as should be the case, a uniform overhead clearance of at least 15 ft. has been provided throughout the entire building unit. While the shortcomings of the mono-rail crane are due to its lack of flexibility in that the carriage is confined to one track, still, through appropriate special contrivances, it can be used to handle material surprisingly distant from its line of travel.

If it is deemed expedient to have a waste-heat boiler, the two air-furnaces can be placed in the middle of the foundry about 20 ft. between centres, their longitudinal axes lengthwise with the building and in the path of the transfer bridge, in order that they can, through this arrangement, be charged directly by it. One waste-heat boiler and stack can then be used in common by the two furnaces. In this design, however, the mono-rail can conveniently cover but one-half the length of the foundry building, owing to interference occasioned by the boiler and stack.

In one type of mono-rail a novel feature consists in the ability of the operator to raise or lower himself through means of a telescopical arrangement. The cables connecting the controllers for the various motors are all arranged with a flexible connection in order that at all times the operator has control of the travel and hoist motor and the motor for hoisting himself.

Through this arrangement it is possible for the operator to pick up any character of load in the yard without the aid of an assistant and bring it into the foundry, or, if in the foundry, do much work that otherwise would require the use of an additional man. In larger foundry units, it will be found that a more ambitious system of crane service not only should be adopted, but is demanded by conditions. The travelling-bridge crane service for the malleable-iron foundry differs in the majority of cases from what should obtain in the case of the grey-iron foundry, for it is rarely used for drawing patterns or for handling finished moulds. In some malleable-iron foundries, however, such as those making heavy railway work, while the requirements are quite similar, it is for a different reason. The large bottom-pouring ladle is now being quite generally and successfully used for the pouring of moulds for this class of work. The latter and former condition call for a creeping speed of from 1 to 5 ft. per min. Pouring metal through a nozzle from a large ladle suspended from a crane and passing from mould to mould necessitates quite careful control of the speeds. Consequently, the creeping and hook speed particularly should be adapted to the character of work to be done. In the absence of a specific design of building, it is not possible to indicate the best arrangement of travelling crane and supplemental crane installation. Such details are familiar to the structural engineer, and are not as serious as those to which reference has been made, if to these be added the fact that any crane should have a positive system of mechanical brakes, have electrical equipment as simple as possible, and so constructed as to prevent the admission of dust or dirt.

While, some few years ago, direct-current for crane service had numerous advantages over alternating current, electrical control equipment has been developed to such an extent that either D.C.

or A.C. current can be used with satisfactory results on slow speed. In the case of D.C. current, dynamic-braking is used for lowering, and with A.C. current regenerative-braking with solenoid load-brakes for creeping-speeds are used.

Lifting Magnets.

The lifting-magnet, used in connection with the crane, in the writer's opinion, is an indispensable accessory when the present labour situation is considered. Those who have seen labour sweat and toil in hooking-out hot castings from steaming sand, need not be told that this constitutes a very disagreeable task, and one, for reasons already cited, the men should be relieved of. Aside from this, when the castings are hooked-out and piled, much burnt sand is left in a heap on each floor that subsequently must be collected from all the floors in use. By means of the magnet not only can the castings be quickly removed, but the core wires, the cores themselves for the most part, and the chills are removed at the same time, and the entire mass deposited at one, or a few convenient places, from which the burnt sand can be easily and quickly taken to the dump, and the wire and chills recovered. Also, much time can be saved the moulder, particularly in the rapidity with which the sand cutter can get to work. It is needless to dwell on the many other uses to which the magnet can be put; in quickly loading the castings on to the trucks, that are pushed by hand, handled by the shop-mule or tractor, as the case may be, to the hard-iron mills, while its use for handling of pig and scrap is obvious.

In the event that the plot of ground is somewhat square, a rather convenient layout of building is in the shape of a very deep channel, one leg consisting of the foundry building, mainly, say, 300 ft. long by 136 ft. wide (1,300 to 1,500 sq. ft. of moulding space per ton of castings, the sq. ft. depending upon whether the work is heavy or light), the other leg containing, for the most part, the annealing room, say, 300 ft. long by 95 ft. wide, while the web, a building 300 ft. long and 50 ft. wide, connecting and opening into the two buildings that form the legs of the channel. The situation can be easily understood by reference to the arrangement of the departments as given for the straight line plant by simply considering that the straight line is bent in the form of a channel, the various departments following in the same order as in that construction. Through this design there would be a court about 70 ft. wide to provide light and ventilation, and in which a wash room can be built, easy of entrance from any of the main buildings.

Large Plants.

For a somewhat larger plant with more furnaces, where the shape of the plot approximates the letter "T," the entire foundry building can be built like a rather shallow, short-legged, long-webbed channel, the annealing room and other departments being contained in a building in the centre of the court at right angles to and opening into the web and extending considerably beyond it, thus giving the buildings as a whole the shape of the letter "T." The foregoing layouts are simply cited as cases that have proved to be convenient in operation and flexible for either low or maximum production.

Both the hard and soft mills should be so installed that they can easily be filled by hand or power, and high enough to clear a truck if placed directly under them to receive their contents.

Black-Heart Malleable Iron.

A description of the black-heart malleable-iron process has appeared in so many papers that have been written within the past few years that the author feels certain members must all be very familiar with it. On this account a very brief explanation only will be given. The castings, as cast, whether made in the cupola, air-furnace, open-hearth or electric-furnace, must not only consist of white iron in which no trace of primary graphite exists, but in order that the finished product, after heat-treatment, be of normal fracture and superior in mechanical properties its composition must lie between certain definite limits. The white-iron composition that the author would recommend for best all-round conditions, embodying facility of conversion, fluidity, shrink, static and dynamic strength, and ductility in final product, is of necessity and for obvious reasons a compromise. Such a composition is:—Silicon, 0.90; phosphorus, 0.20; sulphur, 0.060; manganese, 0.25; and comb. carbon, 2.35 per cent.

Later, some remarks will be made concerning permissible limits, but while at this point, the author desires to explain that the recommendations he will give in regard to both melting and conversion are based upon works conditions and not upon what can be accomplished by a scientist in laboratory apparatus of easy and positive control. In the States the cupola is little used except for castings for fittings. Melting the charge in the presence of coke in the ordinary cupola means not only high-sulphur but high-carbon. The mixture is one in which sprue and malleable scrap predominate; some steel may be used, and enough pig added to bring the silicon to the required point. The mixture as it enters the cupola will run from 0.70 to 0.95 per cent. silicon; the total carbon from 2.50 to 2.75 per cent.; the manganese in the neighbourhood of 1.00 per cent., the phosphorus under 0.18 per cent. The loss in silicon is but little, rarely as much as 0.12 actual, the loss in manganese about 2/5 the original content; carbon will be picked up to an amount that will produce an average of 3.00 per cent. in the product, while the amount of sulphur in the product will be a function of the fuel ratio, the quality of the coke, the amount in the original mixture and the size of the scrap. The smaller the scrap the larger will be the gain in sulphur. In the fittings examined by the author the sulphur will average around 0.25 per cent. While such iron, when annealed at a high temperature, will produce a free-cutting product, and while it is acceptable as a material for fittings, it would show a very abnormal structure in sections at all heavy, while it would be very low in elongation.

The Reverberatory Furnace.

The reverberatory, or air furnace as it is called in the States, is the melting apparatus mostly used for the production of white-iron castings. It is, as is well known, a very wasteful apparatus, having an efficiency ordinarily under 10 per cent. As numerous inquiries have been received in regard to its design the following remarks will prove pertinent. Under the assumption that bituminous coal and forced draft are to be used and that the furnace capacity is to be 15 tons, the first dimension to establish and lay-off is the length of hearth, that is, the inside distance between bridge-walls. Theoretically this should be such a distance that the charge will have absorbed all of the heat from the combustible gases just as these leave the hearth on the way to the stack. Such conditions are impractical, for this would imply an exceedingly long, narrow hearth with depth of metal so shallow that it presumably would be badly oxidised long before it became hot enough to pour. In order to obtain practical working conditions, therefore, the distance between the bridges must be such that a proper ratio of width, length of hearth and depth of bath must obtain, the former to provide for a workable hearth-size and the latter to avoid excessive oxidation. For this capacity furnace an inside distance between bridges of 22 ft. and an inside width of 6 ft. 6 in. will provide a mean depth of bath of 7 in., which will be about right. The top of the front bridge theoretically should be level with the molten metal, but if this were the case the furnaceman in rabbling the bath to hasten the melting of pig still partly solid and protruding above it would splash molten metal into the fire-pot. To prevent this the bridge should be some 6 in. higher than the level of the metal after the charge has entirely melted down. The top of the rear bridge should preferably be 3 in. lower than the top of the other. In order to lay off the hearth bottom, draw a horizontal line 6 in. below the top of the front bridge, which will hit the rear bridge 3 in. lower than its top. Draw another horizontal line 9 in. under this, and between these two lines, and limited by the bridge walls, lay off the bottom on a curve such that its lowest point, locating the tap hole, will be about 8 ft. from the front bridge. This is shown in Fig. 1. The curve or slant on each side of this point should have a pitch not much more than sufficient to drain properly the iron from the hearth, and such that as the metal is withdrawn, feathered edges of metal are not pronounced, that is, the average mean depth of metal should bo as great as possible when the hearth is full, and as it is being emptied. A tendency is to get the tap hole too near the front bridge. If this is done the brick surrounding the tap hole will wear unduly, owing to the wash of the metal and slag produced by currents induced by the action of the overhead blast used to provide air for secondary combustion. Next lay off the thickness of the bridge top which we will place at 15 in. Theory calls for the level of the coal bed to be flush with the top of the bridge, but if this were done, the forced draft would blow some coal into the hearth and recarburise the bath, which is particularly a matter that it is desirable to avoid.

For the general character of coal used in the States, it has been found that if the distance from top of bridge to the level of the coal is 15 in., there is little danger of this happening, which distance also will locate the bottom of the fire door or stoke hole. The next step to decide upon is the depth of fire bed, bearing in mind the fact that the use of bituminous coal is actually equivalent to the employment of two separate and distinct fuels; one consisting of coke and the other of gas. For this reason it has always been the writer's practice to approach as near to gas producer principles as possible, not only for the sake of economy, but for subsequent uniformity of operations as well. In his designs, therefore, he has provided for a deep bed of fuel. In the case of a thin bed, the burning of the fixed carbon left after the volatile matter has been distilled off, serves to heat the fire pot intensely and locally rather than the hearth where the heat is desired, while it has been the writer's effort to discourage this action and bring about as little combustion in the fire pot and as much in the hearth as is practically possible. If the fixed carbon on the grates can be converted into CO, then this combustible gas can be burned in the hearth, and we are transferring carbon from a location where its combustion does minimum good to the place where it is of maximum benefit. For this reason if a thin bed of fire is to be used, the percentage of volatile matter in the coal should be as high as possible, while in the case of a thick bed the volatile matter should preferably not exceed 25 per cent. It happens, also, that through this procedure another factor is accomplished of equal if not of more importance. Volatile matter is not driven from bituminous coal at a uniform rate. When such coal is stoked on a thin fire consisting of a glowing bed of fixed-carbon or coked-coal at a very high temperature, the gas instantly surges from the added coal in great volume. Inasmuch as no means have been found whereby the blast valve for the secondary air can be adjusted to deliver an amount at all times in theoretical proportion to produce complete combustion with the amount of combustible gas passing over the bridge, the following undesirable condition obtains:—The instant the stoker fires, more combustible gas is passing over the bridge than can properly be taken care of by the fixed amount of secondary air, provided the air supply, as it should be, is fixed for the average amount of combustible gases passing over the bridge from the time the stoker fires until it is time for him to fire again. This state of affairs lasts for a short interval of time, when for some moments there will be about the theoretical proportion of combustible gas and air, after which the air will be increasingly in excess until the stoker again fires. It is plain that if the amount of secondary air must of necessity be fixed, the more uniformly the combustible gas is evolved the less serious will be this handicap.

While there appears to be no practical method of accomplishing this object, the condition can be improved if arrangements are made whereby the fixed carbon of the coal is converted to CO, which will serve to transfer the carbon where its combustion serves but little good to the hearth where it is badly needed. Not only will this occur, but it will, at the same time, better the unbalanced condition referred to, because there will, at all times, be a more constant supply of combustible gas passing over the bridge in a unit of time.

In order still better to control the situation the stoker should be instructed to fire a small amount of coal at frequent, rather than a large amount at longer intervals of time. Since the level of the coal has been placed 15 in. below the top of the bridge, a distance 30 in. lower will give the location for the top of the grate bars, while an additional 30 in. will provide sufficient height for the ash pit. Since the width of the grate is established by the width of the furnace hearth, it remains to determine what should be its longitudinal dimension.

This obviously will depend upon the number of pounds of coal it is essential to burn per sq. ft. of grate per hr. Experience has demonstrated that for this size furnace a grate area of about 36 sq. ft. will prove to meet the conditions required, which is a compromise as between economy and speed.

Consequently if 5 ft. 6 in. is taken as the longitudinal length of the grate the area required will be obtained. If this distance is added to the other longitudinal distances cited, the total length from inside edge of rear bridge to inside of wall of fire pot will be obtained.

If this design were being laid out on paper as in Fig. 1, a perpendicular line of indefinite length should be erected at the latter point, the proper length of which will be determined subsequently by its intersection with the roof line. In order to determine the lines for the furnace roof curve, at a section passing through the longitudinal axis of furnace, it is essential to establish three points only. First, the perpendicular distance above the front bridge; second, the highest point in the roof, which is usually directly over the tap hole; and the last, the distance above the rear bridge. For this capacity furnace the first point should be about 23 in.; the second will depend upon the character of castings to be made, and for average conditions would be 42 in. If they are light the distance should be greater than if they are heavy, for in that case the sprue will occupy more room per ton, while the distance for the last point should be about 12 in. As the melting is chiefly accomplished by reflected heat from the roof it is desirable to have it as close to the bottom as possible and still admit of the placing of the charge in the furnace conveniently and rapidly. After locating these three points, on the paper, an easy curve can be drawn through these points with a flexible rule, taking the precaution of bringing the end of the curve that intersects the extreme wall of the fire pot as low as judgment indicates will not prove abnormal, in order to restrict the space in the fire pot, with the result that combustion will be discouraged in that compartment as much as possible, and combustion forced to take place in the hearth.

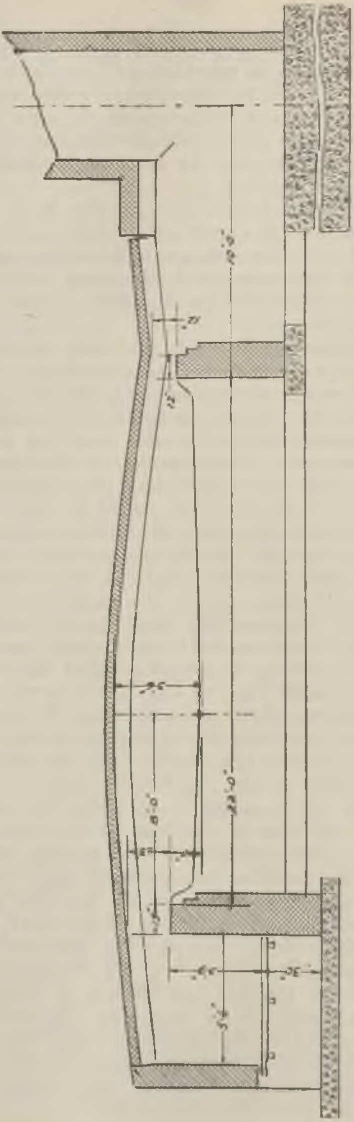
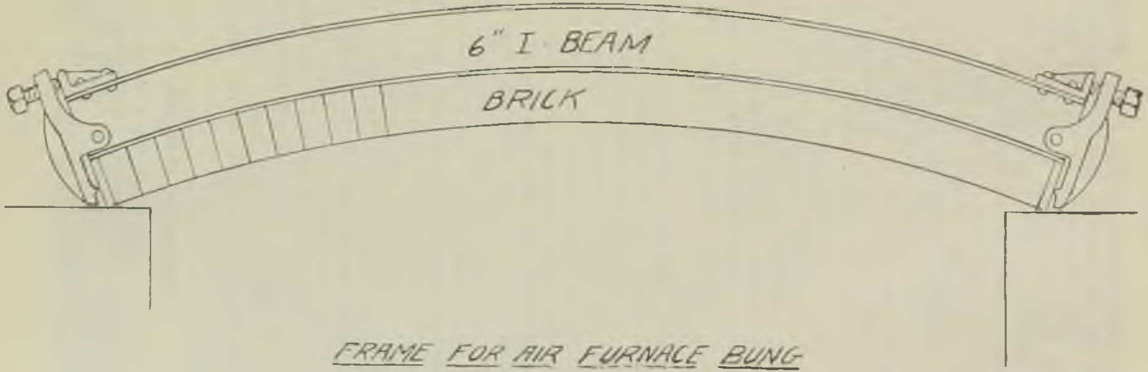


Fig. 1. Design for a Malleable Iron Melting Furnace.



FRAME FOR AIR FURNACE BUNG

Fig. 2.

All the inside lines needed for a longitudinal section up to the hearth side of the rear bridge wall have been obtained. It will be sufficient if the top of the rear bridge be 12 in. wide, which in the direction of the stack can be stepped off in accordance with usual construction. The distance between the rear bridge and the stack is called the neck of the furnace, and while its length in no way affects combustion it should be sufficiently long to prevent the rapid burning away of the lining of the stack as it is cheaper to repair the former than the latter. A distance of 10 ft. from rear bridge to stack centre will prove to be about right. Obviously with forced-draft, the stack requirement need be provided only for what is essential in order to prevent the smoke from proving a nuisance. The side-wall linings are usually 18 in. thick. The furnace is enclosed by iron plates, held in place by buck stays, conveniently spaced.

While there are many designs of bung-frames, the one favoured by the author consists of a 6-in. eye-beam, bent for a centre spring of 8 in., with clamp castings on the ends, that are hinged at a hole in the lower part of the web by means of a bolt that goes through this hole and one of equal diameter in the casting as shown in Fig. 2. The part of the casting that extends below the eye-beam to clamp the brick is provided with a knife edge, and a steel plate is placed between it and the first brick for a uniform distribution of pressure. Through this construction a heavy pressure can be applied to the bricks that will keep them securely in place, and not only is a very strong and stiff bung-frame provided, but as the webs are narrow a considerable part of the brick is left uncovered which will allow of heat being radiated off sufficiently fast to prevent damage to the roof. Another very good form of frame is shown in the design for a 20-ton furnace. (Fig. 3.)

Construction of Hearth.

While for the most part the ordinary fire-sand bottom is used in this country, the author favours the brick bottom, which can be made of old bats that otherwise would be taken to the dump or ground up for other use. The brick should be laid on edge on a cushion of fire sand about 2 in. deep, and spaced about ⅝ in apart on all sides. A very dry fire-sand, having enough impurity, in the form of bases, to flux tightly with the brick should then be poured into all the crevices, after which more sand should be thrown on the surface, and this swept around by means of a stiff road-cleaning broom, until every crevice is completely and tightly filled with sand.

A bottom laid in this manner can be relied upon to give much longer life than the regular bottom of fire sand.

The Tuyeres

The tuyeres should be located about a foot in front of the grate bridge, and inclined at an angle of about 45 deg. While the general practice is to use from four to six pipes for tuyeres, the author prefers the continuous type that goes practically across the roof, which, instead of jets, delivers a thin sheet of air that cuts and completely mixes with the stream of combustible gases passing into the hearth. The ends of this continuous tuyere should be constructed so that the air will not impinge upon the side walls in order to prevent the erosion that would otherwise follow.

A direct connected motor-driven fan installed at the side of the furnace will prove to be more economical than one that is belt-driven and located at a rather distant point necessitating somewhat lengthy piping, while it is better practice to have a separate fan for the secondary air supply, as through this means both the volume and pressure can be better regulated. About 120 cub. ft. of air per lb, of coal seems to give good results for under grate supply, rate of oxidation and other factors being considered, and about one-third of this amount provided for secondary air supply. While only a few of the plants at the present time make use of a CO_2 recorder, gradually the wisdom of using this instrument more generally is being recognised.

Grate Bars.

If a deep bed of fire is to be used it is quite essential to have properly designed and spaced grate-bars. If the grate does not shed ashes with facility, the stoker will shortly find that instead of a deep bed of coal he has a deep bed of ashes, with the result that little if any CO will be generated, while if the bars are too widely spaced, a happening that is less frequent, the bars will quickly be destroyed and trouble will be experienced from clinker with a coal that would not perhaps cause that annoyance under other conditions. The author has designed a grate-bar of kite-shaped section, as a stiff bar can be made in this manner that will produce but minimum clogging as compared with rectangular bars of equal depth. It is clear, that as soon as ashes are deposited on such bars, they must either fall through with facility or clog only as far down as one-third the depth of the bar, which is the distance at which the kite-section is of maximum width. Beyond this depth the section gets narrower and the space between the bars wider, and consequently the ash must fall free from this point down. The ends of the bars where they rest on the grate bar supports are of rectangular shape, the dimensions depending upon how far apart the bars are to be placed; these ends being proportioned to act in part as spacers. While certain forms of the shaking grate have given satisfaction, their adoption has been slow. It should also be stated that, once the fire pot has been filled, it is a mistake to allow the stoker to disturb it except to level the bed. He seems to be obsessed with the belief that, if he is not continually poking the fire, he is remiss in his duty, in spite of the fact that this method of procedure will result in the formation of clinker, making the conditions worse in a coal that has that tendency, and inviting the trouble in one that has not. While various types of automatic stokers have been tried, none has given satisfaction.

Oil and Powdered Fuel Firing.

In some instances where the cost is not prohibitive, oil is used for fuel, and in other cases powdered coal. An average of 58 gall. of oil per ton of iron melted and a ratio of 4.5 of iron per ton of coal used, can be counted upon in the case of good installations, as against an average ratio of 2.5 of iron to one of coal in the case of regular air-furnace practice. The installation for oil is very inexpensive as compared with that for powdered coal, unless provision is required to safeguard against strikes or for other causes that would necessitate a very large storage capacity. In the case of powdered coal, its adoption by a plant of small capacity would be prohibitive, unless it was the intention to use this system for annealing also. Where conditions warrant, powdered coal is the fuel to use, due to its flexibility; but, if installed, provision should be made whereby it is not essential to run the entire installation in the event that the plant is running on quarter- or half-capacity.

Metallurgy of Melting.

All the author's correspondents and visitors appeared to be very familiar with the reactions that take place in the air furnace. Covering the ground very briefly, it can be stated that the carbon is eliminated mainly as CO. Neither the sulphur, nor the phosphorus, are permanently oxidised, while there will be an increase in the former that may amount to little or much, depending upon the amount of sulphur in the fuel. The silicon and manganese are in part oxidised to silica and manganous oxide respectively, while, unavoidably, some of the iron is being oxidised at the same time, with the result that double silicate of iron and manganese is formed, which, if the lining and bottom were inert and no dirt or sand accompanied the charge, would constitute the slag. As there is more or less erosion of both sides, walls and bottom, and invariably some foreign siliceous matter introduced with the charge, the slag consists of mixed silicates of iron, manganese, alumina, lime, magnesia, soda, potash, etc., in which the silicates of iron will predominate. In a normal heat the elimination of that part of the silicon, manganese and carbon which is lost, takes place mostly while the charge is melting, and in the absence of very small or thin scrap, will amount to about 28 per cent. of the silicon, from 15 to 19 per cent. of the carbon, and from 40 to 50 per cent. of the manganese, all based upon their original content in the mixture. If it is expedient to use small thin scrap, owing to its lower cost or because it is a by-product of the plant, it should be charged in the molten bath in order that it will be protected from excessive oxidation. While the composition, to which reference has been made, is the one recommended for general use, it is not to be understood that quite wide departure cannot be taken in the case of most of the elements. Some ten years ago attention was rarely, if ever, paid to the carbon content in the product, principally because its importance was not recognised. Inasmuch as the carbon content in pig-iron must have averaged at least as high as 3.35 per cent., and, inasmuch as the sprue must under these conditions have been exceedingly high in this element, it was imperative to run on a low-silicon mixture in order to secure a silicon-carbon ratio that would yield white iron in sections of even medium thicknesses. While to-day it is in no sense unusual to run both thin and heavy castings from the same furnace, at the time referred to this was not considered practical. As a general proposition little thought was given to manganese, which was frequently too low or too high, with the result that many heats of low-silicon, accompanied by low manganese, resulted in the production of a "picture-frame" product, by which is meant a finished product that shows upon fracture an outer surface ring or frame ranging in thickness from 1-64 in. to 1-16 in., or even deeper in exaggerated cases; wholly different in appearance from the metal which it surrounds and separated from it by a sharp line of demarcation. As a matter of fact, this character of fracture, whether resulting from this or other frame-producing mixtures, was so general that the name black-heart malleable iron was given to the finished product, and there is ample evidence to show that it was the aim to obtain this character of fracture.

The author's reason for placing the silicon at 0.90 per cent. and the carbon at 2.35 per cent. is because these figures call for a silicon-content of about 1.25 per cent. and a carbon-content of about 2.70 per cent. in the mixture—limits sufficiently high, on the one hand, to produce a product whose mechanical properties will still be excellent, even if the oxidation of these two elements exceeds their

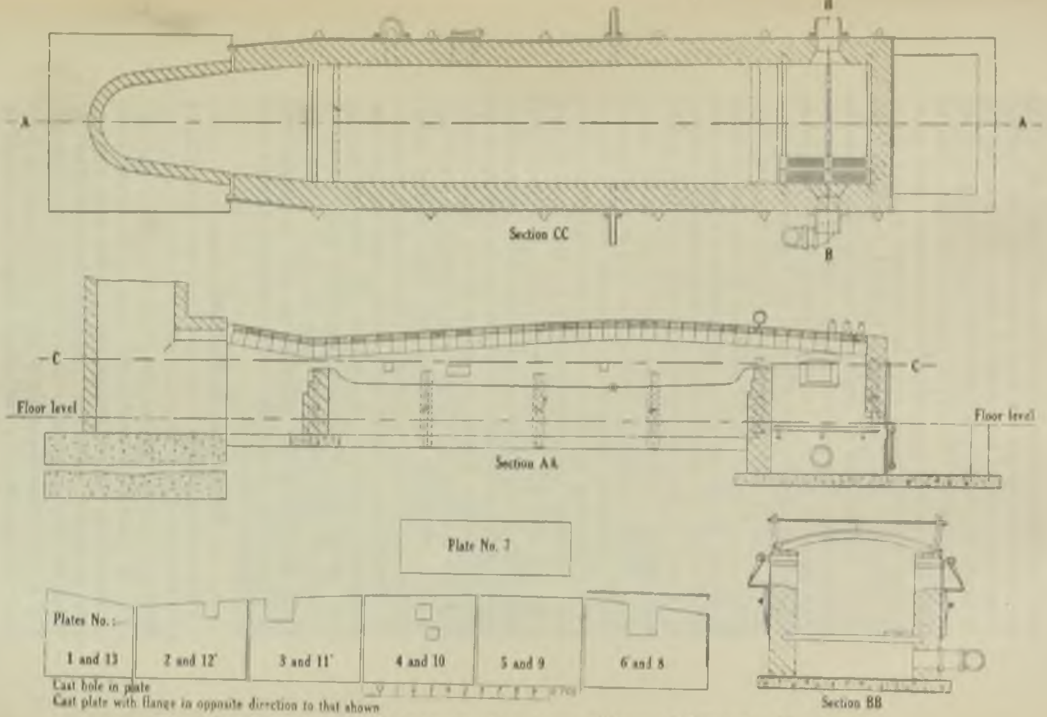


Fig. 3.—Details of Construction of a 20-ton Melting Furnace.

average elimination by a substantial margin; while on the other hand, in the event that the elimination is somewhat less than the average, neither are so high that the product will suffer deterioration in consequence. The fact must not be lost sight of that the percentage of silicon, carbon, and manganese recommended for the mixture is at a point at which, if the furnace is worked normally, the metal will be hot enough to pour by the time the molten bath has arrived at the hard-iron composition decided upon. As has already been indicated, not only is the best design of air-furnace a rather crude affair, but it is not operated by metallurgists. In Fig. 3 is outlined a 20-ton air-furnace designed by the author, that seems to have given satisfaction. Consequently, for commercial reasons, it is well to aim for that composition which safely will admit successfully of reasonably wide variation. With a sulphur content of 0.06 per cent., and other elements balanced, it makes but little, if any, difference at all in either the tensile or shock test, whether the manganese is as low as 0.22 per cent. or as high as 0.30 per cent. While further reference to manganese will be made, the author would point out that, as far as he is aware, there are still some things to learn about this element and the manner in which it is capable of existing. It is a generally accepted fact that, if the manganese is in excess of the amount necessary to unite in theoretical proportion with sulphur to form manganese sulphide, the excess will unite with carbon, and a manganiferous-cementite will be formed instead of the single carbide of iron. However, when graphitisation takes place and is completed, in what form does this excess manganese remain in the finished product?

Phosphorus in Malleable Iron.

Concerning phosphorus, the limit has been placed at 0.20 per cent., because, when in this amount, it does not appear to produce an abnormal appearance of fracture, even in the case of thick sections, at annealing temperatures around 900 deg. C., nor does it appear to lessen strength or ductility. It happens, however, that the limits for the impurities are so interdependent that, for economic reasons, prudence calls for what might be termed a metallurgical safety-factor in the balancing of the different elements. For thin-sections like stoveplate it is well to work on a phosphorus-content of about 0.26 per cent., due to the increased fluidity resulting therefrom, coupled with the fact that the fracture is in no way undesirable.

Slag Conditions.

Leaving this matter as it stands, for the present, there are some hints that may prove of value in connection with the operation of the furnace. The author has already pointed out that the coal-bed should be left undisturbed except to level the bed. He would make the same recommendation in connection with the molten bath of metal, except the necessary disturbance that takes place in hooking into the bath partly exposed pig or sprue, to expedite fusion during the melting-down period; while removal of the slag should be postponed as late as is practical. If machine-cast pig can be purchased as cheaply as the sand-cast, this should be used in preference; while it will be found, if the sprue is partially broken up by means of a light-weight sledge, that, owing to its brittleness, not only can this be done quickly and cheaply, but through this practice much of the adhering sand will be knocked off that otherwise would find its way into the hearth, with the further advantage that the sprue can be charged much more compactly. Every effort should be exercised to prevent foreign siliceous material from entering the hearth, when this can be accomplished at such little cost. In a test on twelve heats, amounting to a total of 192.8 tons, the slag from these heats, weighed on the same scale, amounted to a total of 12.7 tons, or 6.62 per cent. From this slag there was recovered 5,140 lbs. of metallic iron. At this plant no special precautions had been taken to prevent foreign siliceous matter entering the hearth. It will be found, if such precautions are taken, that a very substantial benefit can be effected by the end of the year through a saving in fuel, in better furnace-control, less slag to wash, and free from iron, etc. If, due to lack of business, it is essential to run the air-furnace at considerably less than capacity, the hearth should be shortened by filling-in with bottom-sand at the rear-bridge, for such a distance as will leave the bath, when molten, almost as deep as when the furnace is being run at capacity; otherwise, due to a shallow bath, the elements will be oxidised to a greater extent than under normal operations.

In determining the space between rear-bridge and roof, to regulate flame-travel, it is advisable at the start to build the top of the bridge slightly too low, securing the final adjustment by bricking-in at each end between bridge and roof, through which procedure the correct area, more quickly and conveniently, can be ascertained, after a trial or two, than through adding or removing a course of brick from the top of the bridge.

Sampling.

In following the progress of the heat it is the general practice to cast what are called test sprues at intervals of about half an hour after the charge has melted. These are broken and the fracture examined, in order to ascertain the rate at which graphitisation is diminishing. In the cooling of these test sprues the practice varies, and it is possible that the fracture, far from enabling one to approximate closely the correct story, can be very misleading. Two precautions must be taken. First, the centre section at about where the sprue should be broken should not be less than about $1\frac{7}{8}$ in. dia., and the cooling should not occupy less than about 20 mins. As soon as the sprue has solidified it should be removed from the sand, which should be scraped from the surface. It should be cooled in the air for 10 mins., and then quickly plunged in water and almost instantly removed, this procedure being repeated about every half-minute, allowing the sprue to remain in the water for a slightly longer interval at each dip, and this continued until when again dipped it ceases to create any visible agitation. At this temperature, if broken, it will have the same appearance as if it had not been fractured until actually at atmospheric temperature. If instead of one sprue two are poured at the same time, one being allowed to cool normally in the mould, in order that its fracture can be subsequently compared with the sprue that was cooled in the regular manner for test purposes, it will not be long before an observer can closely estimate and allow for the effect produced by the drastic cooling. If the cooling of the test-sprue be carried out in this manner it can be stated that for castings with sections as thick as $\frac{7}{8}$ in. no danger need be anticipated that primary graphite will be present if in the sprue last taken the fracture shows clear, except for the presence of a few minute specks of graphite very sparsely disseminated throughout.

At this point a few words in connection with the castings as cast may prove pertinent. If owing to the use of a poor consignment of fuel, to neglect or bad judgment on the part of the furnacemen, a heat is delayed and an undue amount of silicon, manganese, and carbon eliminated, this can be detected by the sudden stickiness and sluggishness shown by the metal as it is being poured from the test-ladle, also by the appearance of pin-holes at different places on the periphery of the very thin rim of the test sprue. While castings from such a heat would, when annealed, have a picture-frame or an all-steely fracture, dependent upon how badly oxidised is the metal, the heat can be saved if promptly treated by a silico-spiegel addition, or an addition consisting of a combination of ferro-silicon, ferro-manganese, retort-carbon, and iron-borings bonded in briquette form, the borings being added to give increased weight to the mass in order that it will sink into the molten bath as far as possible. It can be stated that, through close observation, almost any over-oxidised heat may be saved in this manner.

But whether the castings are derived from a heat of the composition recommended, from a heat from which a greater amount of the oxidisable elements have been eliminated than in the case of the former, or from one in which the carbon particularly borders on the higher limit, there are certain practices concerning which the author would hesitate to make mention were it not for the serious losses sometimes occasioned through neglect to observe precautions of so obvious and commonplace a nature. At times complaints have been received concerning the heavy losses resulting from the checking and cracking of castings. With the knowledge possessed by the foundrymen that the lower the carbon the less fluid, and the higher the contraction of the molten air-furnace iron, he is prone to attribute such losses when extraordinarily heavy, wholly to the fact that in the effort to obtain high-tensile and ductile metal, the fluidity and contraction of the iron have been adversely affected through the use of a low-carbon composition.

In his examination of some of these complaints, the author has found conditions, entirely apart from composition, that have actually invited this character of trouble. Owing mostly to failure on the part of the engineer-designer to co-operate with the foundry engineers, the foundry is called upon to make castings from patterns of intricate design and of unreasonably disproportionate sections and not infrequently from poor pattern equipment.

Hard-iron castings of this description must be in a state of severe strain even when allowed to cool in the mould, and much more so, when cooled as evenly as is commercially practical, while the design may be so unnecessarily faulty, that even under test conditions of commercial practice the loss from cracks and checks may prove prohibitive in certain cases, and much too high in others. If the foregoing is true, what can be expected in the many cases that have been seen in which the castings have been stripped a few moments after solidification, with half of the castings buried in the still very hot sand and the other half exposed to the draughts of the foundry atmosphere. Not infrequently a labourer will be seen wetting-down the sand on a floor adjacent to the one where the castings have just been stripped, and as he playfully looks around, the nozzle of the hose will partially swing around and drops of water will be sprayed over the red-hot castings, with the development perhaps of a check where each drop fell. Obviously, as the carbon is gradually lowered, both fluidity and contraction are adversely affected, but the author believes that there will be found to be little difference in these properties as between a carbon content of 2,50 per cent. and 2.35 per cent., but a more consequential and serious difference between a content of 2.35 per cent. and 2.00 per cent. While no manufacturer aims to run as low as 2.00 per cent. carbon, this figure accidentally may be reached when aiming to run on a content of 2.35 per cent. The point the author would bring out, is that from complaints investigated, he is forced to conclude that carelessness has contributed more to heavy crack and check loss than a low carbon-content has.

In the foregoing remarks on the air furnace, no efforts have been made to cover anything aside from the "high spots." With few exceptions, this is the furnace used in the States, owing to its cheapness and its simplicity of construction and repair. The open-hearth is much more costly to build, with the net result that no fuel economy results from its use owing to the fact, not that it is not a more efficient melting apparatus, but that it must be kept hot when not in operation in order to prevent the spalling of the silica brick. The author does not believe that the use of the electric furnace is warranted, except perhaps in very large installations. There is no advantage to be gained in running on a very low-sulphur-phosphorus content, but quite on the contrary many disadvantages.

The Annealing Process.

In order to prepare the hard-iron castings for heat-treatment they are barrelled until free from adhering sand and then trimmed. They are then placed in receptacles called pots or rings of the shape of a band in that they have neither top nor bottom. A ring is placed on a stool of solid iron about 3 in. thick and somewhat larger in perimeter, on the bottom of which are lugs about 5 in. high that serve as feet, and which are so spaced as to admit of the lifting fork of the charging truck being introduced beneath the stool. This ring is then filled with castings which are surrounded with a packing, the nature of which will be entered into later.

Another ring is placed upon the first one, and the process continued until four or five rings have been used, the entire assemblage being called a stand. These stands are then picked up by the charging truck, the best and most convenient form of which is the electric, and taken to the heat-treating oven, where they should be placed in straight rows, the row nearest the side wall being spaced at least 5 in. from it, and a space of 4 in. between the other rows. No mistake could be greater than to jam the stands close together, as it is of prime importance that heat circulation be given its greatest opportunity. The castings are surrounded with a packing for the purpose of preventing kiln-warp, and for the purpose also of furnishing an oxidising pot-atmosphere that will facilitate the decarbonisation of the metal. The

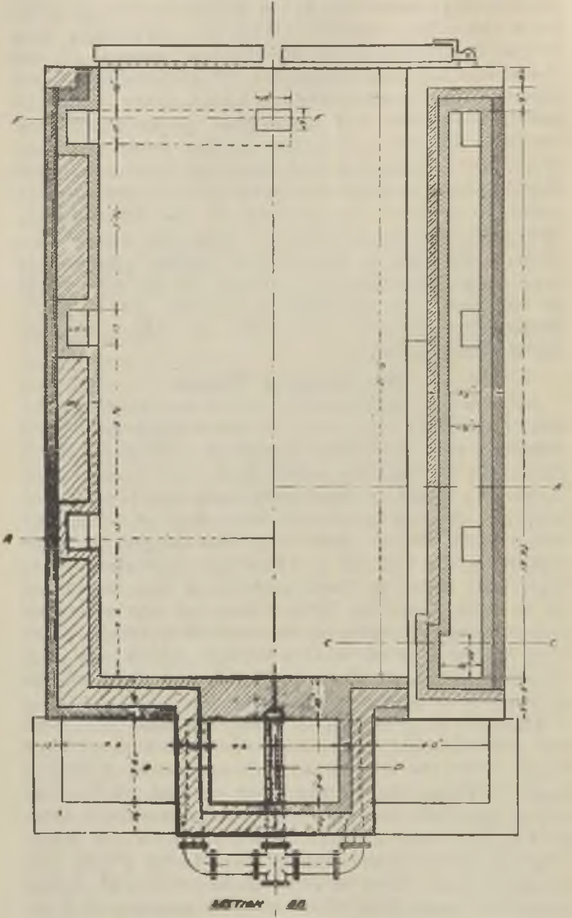


FIG. 4.—DETAILS OF CONSTRUCTION OF ANNEALING OVEN.

latter object has been given an exaggerated importance as far as present-day practice is concerned.

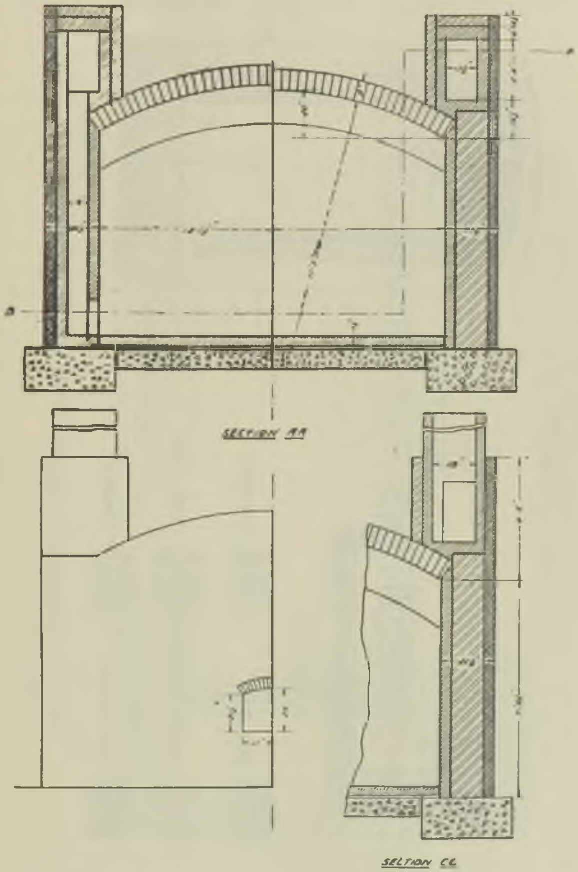


Fig. 4.—Details of Construction of Annealing Oven.

In the old days, with castings having a carbon content of 3 per cent. or over, this may not have been the case, but with the carbon content now present a very strong packing is a mistake rather than otherwise. Even a packing of sand, if properly sized, will hold enough air to admit of all the oxidation necessary to produce a superior product. The really important matter is to have a packing preferably containing about 10 per cent. of iron oxides, the balance being of an inert character of the nature of slag, or other material that will have

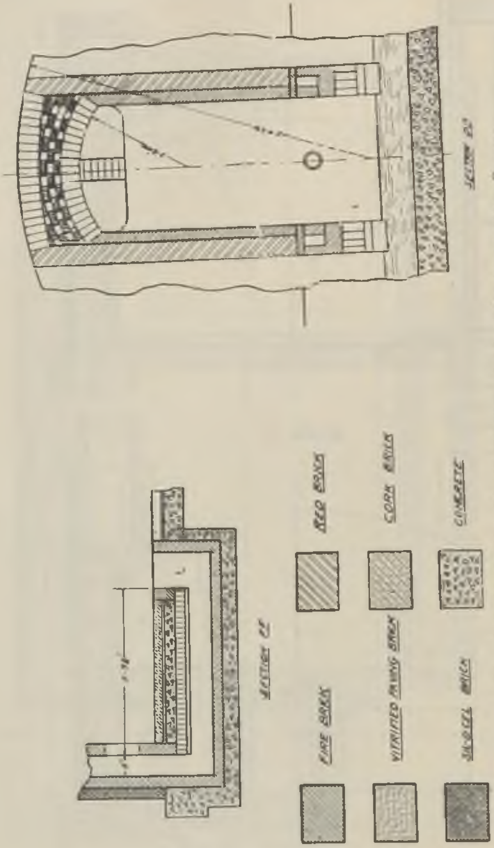


Fig. 4.—Details of Construction of Annealing Oven.

little tendency to combine with the oxides of iron at the temperature of anneal. The latter condition is important in order that there will be no tendency for the packing to lump, and in order that the

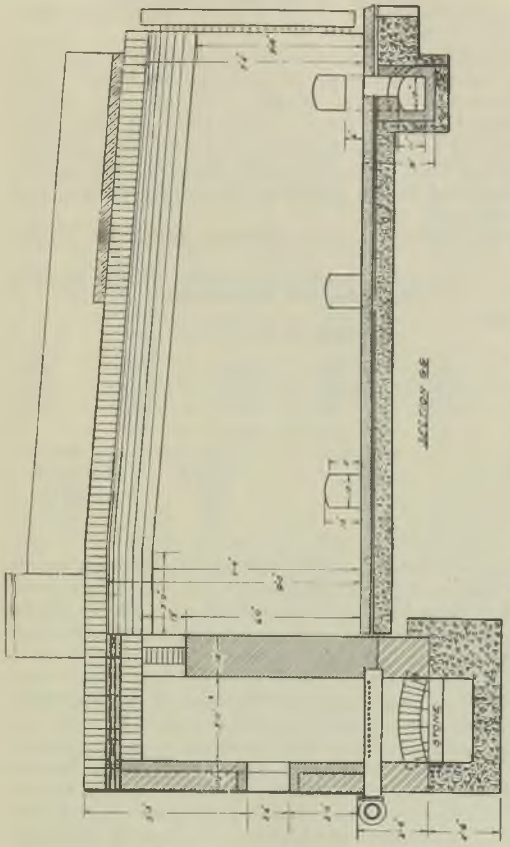


Fig. 4.—Details of Construction of Annealing Oven.

casting can readily be shaken out clean and free from adhering packing. As a matter of fact, in muffle ovens of the very tightest construction, in which castings are packed solidly, so that the only unoccupied space in the muffle results from the voids occasioned by the castings, the decarbonisation is as complete as in the case of the strongest packing now used, as can be seen from Table I., which has reference to three test-bars selected on the author's last visit to a plant where no other type of oven is used.

If castings are being made that are not liable to warp, the muffle-oven is the type to build. The best construction of muffle is by the use of the Manion type of brick. This brick is thin, but reinforced by webs that serve for the most part to carry the load, with the result that the heat can be transmitted to the inside of the muffle quickly and economically.

If the muffle is made of carborundum-brick a very strong and lasting muffle will result, through which the heat can be transmitted some six times more quickly than through a clay-product. These bricks are very expensive, and many have been deterred from their use on this account. A number of those who have consulted the author have been very sceptical in regard to the character of product that can be derived from the muffle oven. In order to satisfy any who may feel likewise it can be stated that in the Association of which the author is consulting engineer one of the members makes use of the muffle-type oven only, and their record for quality is amongst the highest. As can be gathered from the tensile tests quoted in Table I., which happen to be considerably higher than their average, their product is not excelled by that of any of the other. These particular results are quoted simply by way of illustrating what can be accom-

TABLE I.—*Showing the Analysis and Physical Tests of Malleable Irons treated in a Muffle Furnace.*

ANALYSIS OF HARD IRON.

Mark.	Si.	P.	S.	Mn.	C.C.
1	0.76	0.193	0.050	0.200	2.13
2	0.88	0.180	0.051	0.230	2.26
3	0.80	0.190	0.049	0.200	2.37

PHYSICAL TEST.

Mark.	M.S., tons per sq. in.	E., per cent. on 2 in.	R. A. per cent.
1	26.5	36.7	38.0
2	26.1	35.9	33.2
3	25.8	25.7	30.1

plished in the muffle oven. The product made by this particular concern will average about 24.1 tons per sq. in. ult. strength and run somewhat over 20 per cent. in elongation.

The Heat Treatment of Malleables.

As stated, in order to obtain a product high in tensile strength and ductility, the composition of the hard-iron castings must be restricted to within certain limits. Assuming that castings are being heat-treated that correspond to these composition requirements, it can be stated that, in order that their conversion into a product that is both strong and ductile, be complete and satisfactory as far as structural conditions are concerned, the castings preferably should be held at a temperature about 100 deg. F. (37 deg. C.) above the critical-range for a period of not much less than 60 hrs., and cooled at a rate of 10 deg. F. (5 deg. C.) or less per hour, until their temperature has fallen to about 100 deg. F. (37 deg. C.) under the critical-range, after which the cooling gradually can be accelerated. It is one thing, however, to possess an accurate knowledge of exactly what should be done in order that the best heat-treating results will follow, and another to construct commercial apparatus in which a large quantity of material can be heat-treated in conformity with the rules that are prescribed. Some few years ago not only were most of the plants lacking in a metallurgical knowledge of the process, but the apparatus was of such a faulty character that it was impossible to carry out in an effective manner what research had shown was essential if the superior product was to be obtained. In short, it often is much easier to indicate than to achieve, and while general instructions can be sent out as to the proper temperature at which to convert, the length of time to hold at temperature, and the rate at which the cooling should take place, this will prove of little avail if the heat-treating ovens are so constructed that proper thermal conditions exist in only a restricted area of the oven. and that the oven as constructed cannot be cooled at the rate designated.

Essential Features of Annealing Ovens.

Space will not be used for recounting the conditions that prevailed, but a brief attempt will be made to cover certain facts that must be considered in annealing-oven design. First of all, each oven should be self-contained in all particulars. The general method, almost universal some few years ago and in no sense uncommon to-day, of building a battery of 8 or 10 ovens with common side-walls and a common stack is a serious mistake from many points of view. One can well imagine the unbalanced thermal conditions that must obtain when, as very frequently happens, two contiguous ovens are under fire, but one at their side remains cold. In such cases the common side-wall of the two under fire is not exposed to the atmosphere, and consequently is radiating no heat to it, while the other side-wall is doing so at a rapid rate. Without wasting words to prove the general worthlessness of such construction, it can briefly be stated that from the standpoint of cost, maintenance, and control, this system could not be worse. Rigidity of construction is one essential that is fatal to overlook. If the ovens are not rigidly built cracks will develop and it will be difficult, and perhaps impossible, to cool the oven from temperature at the rate desired. The walls should be at least 22½ in. thick, encased on the outside with steel or iron plate, and the whole reinforced by a system of buck-stays set about 30 in. between centres where this is possible.

The walls and doors should be so thoroughly insulated that when the oven is at temperature the hand can be pressed against the plates without undue discomfort. The floor as well should be insulated and, for reasons to which we will refer later, so should the front half of the roof. The fire-pot of an oven should be on its outside and not within it, as the oven proper is designed to heat-treat castings and not for the purpose of burning coal. With the fire-pot on the inside and, as frequently is the case, located at one corner only, it is not an easy task, if at all possible, to obtain heat uniformity within the oven, which statement holds true even in the event that a fire-pot is placed within the oven at diametrically opposite corners. The floor should be built solid, with no underground flue system beneath it. The latter construction is of no benefit as far as a saving of fuel is concerned, and with a complicated under-floor flue system—now being generally discarded as new ovens are being built—the cost of this part of the oven equalled if not exceeded that of the rest, while owing to the jar produced by the loaded charging truck and the combined weight on a floor subjected to such a high temperature the maintenance cost is heavy. No underground flues are necessary aside from one small stack-flue on each side of the oven, which preferably should be located on the outside, as close as practical to the side-wall footings. In the last few ovens designed by the author he has placed one stack-flue and one small stack on top of each side-wall, the bottom side-wall flue-openings being connected with these stack-flues by a vertical flue built within the side-wall.

In this manner not only is all underground flue work avoided, but as the entire system is exposed the flues can easily be kept clean and tight. The ovens are built in rectangular form, width and length in the ratio of about 3 : 4. The fire-pot is located on the outside, midway between the side-walls, and is constructed on the gas-producer principle, that is, there is a water seal, air bungs through which about 400 cub. ft. of air per min. against a 5 oz. pressure is admitted, a more or less deep bed of coal resting on ashes that reach from the floor of the seal to about 1 ft. above the bungs. Between the actual roof of the fire-pot and the fire is a false arch, and between it and the roof chequer work of brick through which hot secondary-air for combustion of the combustible gases is drawn. These details are set out in Fig. 4. The opening from fire-pot to oven, that is, the bridge, is located as high as possible in order that combustion will start to take place right in front of the chequer work and at the point where the roof of the oven proper slants towards the front. Through the use of a slanting roof the bridge can be located so high above the top of the stands, where the temperature is obviously the hottest, that no danger exists in over-heating the castings in the top ring of the stand, while as the flame advances towards the front of the oven and its temperaturo drops by the amount imparted to the castings at any section, the roof is lower, and consequently a very close heat balance is maintained until the front of the oven is reached.

There are three side-wall flue-openings at the floor-line, leading into the vertical flues that go to the stack-flue, with openings so proportioned that the heat of combustion is drawn to different parts of the oven in a very uniform manner, the adjustment being made by means of a draft-gauge in such a manner that the draft in the two front flue-openings is strongest but equal on each side, the next two less strong and equal on each side, and next still less strong and equal on each side. By means of this gauge and a pyrometer the adjustments can be made after some three or four anneals have been run.

Oven Control.

The ovens are controlled by means of a recording pyrometer, the element of which should be inserted in the centre of a pot, located close to the side-wall, as it is the temperature of the castings that is desired, and not that of the oven atmosphere. If this procedure is not adopted there is no certainty as to when the castings have arrived at temperature, and consequently the time at which the castings are held at temperature will be an approximation instead of a certainty. This design of oven has given every satisfaction, and is being installed quite generally as new ovens are needed, or the principles embodied in the design are adopted in so far as practical in the remodelling of old ovens.

Electric Heating.

For some years the author has endeavoured to find some manner in which temperature control could in some way be made fool-proof. The electric resistance oven seemed to be the only solution, but the cost was found to be prohibitive. The thought finally took root that it would prove to be perfectly practical if instead of using electricity alone, to use a combination of any fuel, supplemented at certain times by electric heat. In operation the oven and contents are to be heated in the ordinary manner by coal, and the firing continued during the period at which the castings are to be held at temperature, but so regulated that the temperature produced through this means and during this period should be some 150 deg. F. (83 deg. C.) lower than required, the deficiency in temperature being supplied by electric current controlled by a potentiometer. It was thought that through this procedure not only could the temperature easily be maintained within a range of 10 deg. F. (5 deg. C.) or less if need be, and lowered at the rate desired, while through the proper proportioning and location of the resistance-ribbon the temperature could be maintained practically the same throughout the entire oven at the particular period when this is essential. In order to prove out the practicability of this scheme an oven was rigged-up quite recently with the necessary number of grids of resistance-ribbon and the other necessary details, in which two anneals have been run through. While a little trouble was experienced during the first anneal, owing to some of the hanger-block, on which the ribbon rested, parting, this was corrected in the second trial, which was carried through without a hitch. The author believes that in the future electric heat will be used in the oven to supplement carbonaceous fuel of any character. These trials have demonstrated that by means of an electric current controlled by a potentiometer the heat can be maintained in practically a straight line while the castings are being held at temperature, and that the rate of cooling can be controlled with exactness by means of the same instrument without any attention on the part of the heat-treater. The cost of current is but nominal, and it is expected that the resistance ribbon will last for a period of at least 15 months. This scheme permits of the use of electricity in any oven, almost irrespective of its design, and actually makes possible the assurance that the most uncertain step in the process can be made fool-proof. In all other methods of heat treatment the heat is applied at the top of the oven, and it is a problem to induce it to come downward and towards the corners in the manner desired. With the resistance coils properly spaced and placed near the floor this trouble vanishes. Another advantage resulting from the use of the gas-producer principle is the fact that very cheap grades of coal can be used. The author is confining his remarks to the coal hand-fired ovens, as these are the ones in general use.

Oil and Natural Gas Firing.

Where oil and natural gas can be had cheaply these successfully can be used in properly-designed ovens. In using these two fuels, however, the author believes that the oven should be designed in such a manner that the firing will take place at each end alternately at intervals of about 20 mins. In this manner better control can be had than if the oven is fired at one end or at both ends at the same time. If castings are being made that are not liable to kiln warp, the muffle oven is the type to build. The best construction of muffle is through the use of the Manion-type of brick. This brick is very thin in the direction in which the heat is to flow, but is reinforced by webs designed to carry the load, with the result that the heat can be transmitted to the inside of the muffle quickly and economically owing to the thinness of the brick. If the muffle is made of carborundum brick a very strong and lasting muffle will result, through which the heat can be transmitted some six times more quickly than through a clay product. These bricks are very strong, have a low co-efficient of expansion, and, under the conditions to which the muffle is subjected, would never spall.

Grinding.

Concerning the matter of grinding, the practice at the present time is evenly divided between grinding in the hard or grinding in the soft, with a tendency to the latter method and the use of the rubber-bonded wheel. Unless there is a good exhaust system in use with the grinding apparatus the odour imparted by the rubber wheel is quite objectionable, but otherwise not. Many plants grind the light castings in the hard with a vitrified wheel, but all heavy work in the soft. When the gates exceed a certain size the pneumatic tool is used to advantage.

Sands.

There is little to be said about the moulding sand except that the problem is one of increasing difficulty. Many are troubled owing to their inability to obtain a sand sufficiently free from bases to avoid the fusion of the sand to the surface of the castings so tightly that cleaning is made difficult. It is interesting to note that in cases of this kind in which, in spite of drastic tumbling, a crust of sand still adheres, particularly at fillets or recesses, that a very short application of the cutting torch will speedily remove it, owing to the difference in the rate of expansion of the crust and the iron.

Foundry Losses.

Regarding foundry losses the following is representative. In general automobile work the hard- and soft-iron losses will approximate 15 and 4 per cent. respectively. While the latter may seem high, inspection is extremely rigid and the losses that result from straightening are not inconsequential, while defectives returned by the purchaser will often run as high as 2 per cent. It is safe to say that 20 per cent. of the castings poured are rejected at one stage or another. In the case of railway work the losses are not as heavy, and will not exceed a total of about 9 per cent., and while the inspection to which these castings are subjected also is rigid it is not so exacting as in the case of the other. In agricultural work the average loss will approximate 5 per cent. In addition to the foregoing it is well to estimate that the loss due to grinding will prove to be about 1 per cent.

Runners and Risers.

The author believes that losses due to misruns and defective casting can be minimised through a study similar to the one he has undertaken, and which he believes is new. The idea is illustrated in some accompanying photographs, and to which reference will be made in due course. Some years ago the author was called in consultation in connection with a heavy foundry loss on certain sizes of piston rings. The rings were nested and gated together and poured in multiple moulds. On analysing the situation it was found that the loss was confined mostly to two sizes. The manner in which the problem was attacked was to take five single moulds and short-pour them, that is, pour a very small amount of iron in the first mould, a little more in the second, a little more in the third, and so on to the fifth. In this manner the travel of the iron could be followed exactly, as if the mould had been made of glass. Briefly, the problem was solved by a change in the gates and runners in a manner that was contrary to the precepts that were heretofore considered orthodox. To conserve space, and because members are as fully able to analyse the situation as is the author, photographs are submitted without comment, which show some interesting examples of what short-pouring will disclose. In the case of all of these tests the moulds were carefully levelled in two directions before the molten metal was poured into them. Lack of time has prevented the author securing such patterns as might have illustrated in a more exaggerated manner what he has attempted to set forth, while also he regrets the fact that he was unable to secure photographs of short-poured castings of a larger and more complicated design; but he believes that, in spite of this, the cases he is submitting to show the value of the information that can be obtained from a study of this character are sufficient. (See Figs. 5, 6, 7, 8, and 9.) The vital necessity of having the gate leading to all patterns on both sides of the central runner exactly of the same shape and area as far as each pair is concerned; the area of the gates of each pair changed in accordance with what is disclosed by the short-pouring test, and the runners so tapered that the flow of metal will be more evenly distributed to each individual pattern in the flask, to the end that each one will be taking the metal as rapidly as the other. The casting shown

Fig. 5.—Showing Examples of Short Pours.

Fig. 6. Another Example of Short Run Castings.

in Fig. 10 is an eloquent testimonial of the length to which the founder is willing to go in his effort to insure the integrity of the casting. In this case the risers weigh more than the casting, but in

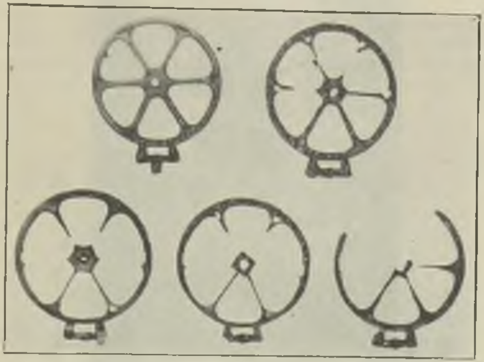


Fig. 7.—Small Wheels which have been Short Run.

addition to this expedient permission was obtained to place a strap on the casting shown at A, leading from the gate of each of the four heads upward towards the fillet, whereby a wide channel, for the metal to reach the top of the casting, is assured, and in this manner the formation of a shrink such

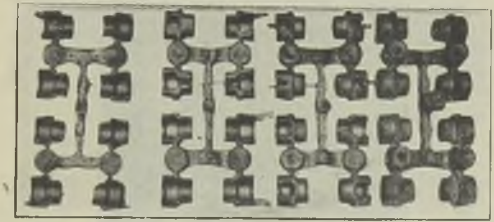


Fig. 8.—Another Group showing the Same Defect.

as can be seen in Fig. 11, at the fillet, where the smallest diameter swells gradually into the larger one, is prevented. Even with the precautions referred to a very light shrink will be seen in the

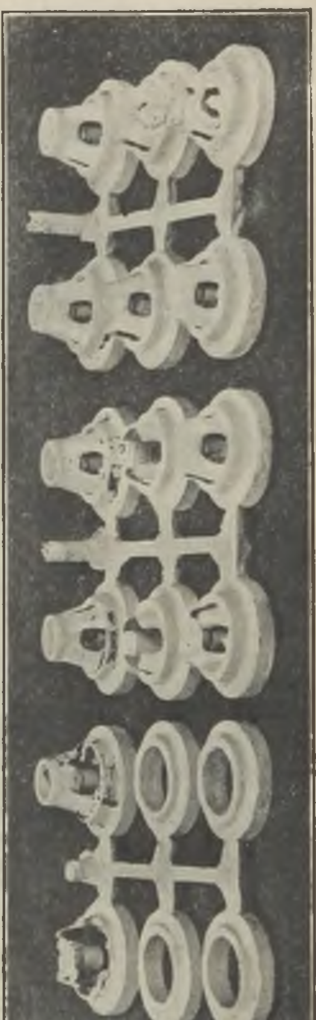


FIG. 9.—A TYPICAL EXAMPLE OF SHORT RUN CASTINGS.

etched section right opposite a very sharp corner. If permission could be obtained to round off this corner it would result in the disappearance of this shrink. In taking on new work the founder should not only experiment with the pattern until he has satisfied himself, through the breaking up of the hard-iron castings in many small parts, that shrink is absent and that he has ascertained the best method of gating and heading the casting, but after he has finally arrived at this decision he should anneal some of the castings in order to confirm this conclusion. Slight porosity is difficult to discover in a fracture of hard-iron, and it oftentimes happens that upon breaking up the annealed casting, which in its hard condition was supposed to be perfectly sound, it is found to contain some shrink. It might be well to note that in the author's experiments on shrink he has found that

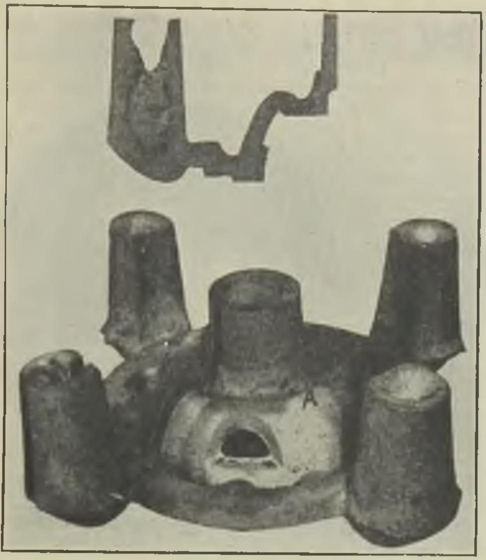


Fig. 10.—An Example where Risers Weigh More than the Casting.

whether the iron was poured hot, medium, or fairly dull can be told by the colour of the shrink. When poured very hot it is black, when poured at medium temperature it is more or less very dark grey, while the shrink resulting from metal poured fairly dull is very light coloured.

Composition Limits.

What are the permissible limits for the various elements in the hard-iron is a question the author has been asked with frequency. Owing to the inter-relations of these elements the answer on its face appears to be complicated. While admitting the complexity of this inter-relation, actually as far as practical work is concerned there exists little reason why this fact need necessarily complicate the proposition. As previously set forth, with all other elements balanced a silicon-content of 0.90 per cent. in the hard-iron yields very desirable properties, for when heat-treated it is resolved into a silico-ferrite matrix that, considered alone, is strong and ductile and of spendid machinability.

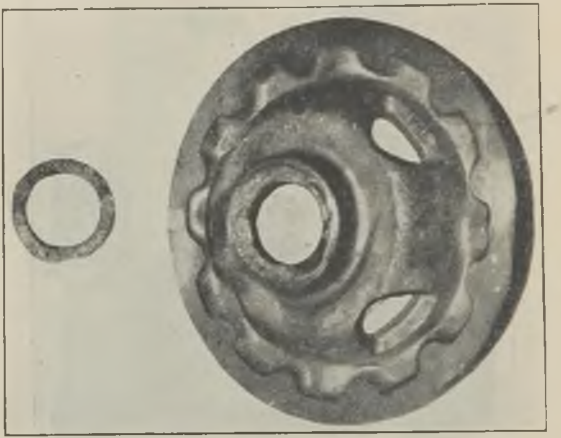


Fig. 11.—An Example of the Shrink Defect.

It has been established that the strength and ductility of this matrix is weakened by high total-carbon, and that improvement takes place as this element is lowered. The limit to which this safely can be carried without detriment to the fluidity and life of the molten metal, or increasing the tendency of the castings to crack or check on cooling to an objectionable extent, may be assumed to be, say, 2.35 per cent. The phosphorus appears to be in no sense detrimental up to 0.20 per cent. Inasmuch as no difficulty exists, nor is any expense attached to the adjustment of these three elements at these percentages, they can be eliminated from the problem and the disturbing elements considered to be sulphur and manganese only as far as these five elements are concerned, or consider the silicon, carbon, and phosphorus to be the datum, and work from there as a start. While it is not difficult to purchase low-sulphur pig and fairly low-sulphur scrap, it is getting increasingly difficult to secure low-sulphur fuel. Also in some localities it is rather difficult to purchase pig with manganese as low as is desirable.

The question, then, really resolves itself into what are the permissible limits for the sulphur and manganese. While it is generally conceded that these elements should be present in atomic proportion to form manganese sulphide, the author has seen many instances in which the product was excellent where this was not the case. Based upon data obtained from the testing of many test bars, the author would state that with a sulphur content between the limits of 0.05 and 0.08 per cent. it is safe to use a manganese content between the limits of 0.20 to 0.30 per cent., with the recommendation to avoid using, coincidentally, the high-limit for manganese with the low one for sulphur, and contrarywise. The manganese should be increased with increase in sulphur, and with the latter at 0.12 per cent. it should lie between 0.34 and 0.40 per cent. It happens, however, that at this percentage of sulphur the metal has a frame-producing tendency, by which is meant that upon annealing the carbon, instead of diffusing out of the iron in a manner that will leave a decarbonised surface-rim of ferrite, surrounding a core of normal structure, there will exist between the ferritic rim and normally-structured core a partition ring of pearlite. Just why a very low-silicon-manganese mixture will produce an iron having this tendency, and just why a high-sulphur iron with insufficient manganese will do the same, the author does not know; but he does know that such is the case, and that when the metal is in this condition not only is the material hard to machine but that probably it will fail in service. In the absence of a decarbonised surface ring it does not appear possible to obtain a true frame, while, on the other hand, the presence of a decarbonised surface rim does not appear to act to produce a frame except under certain conditions that will be touched upon. The conclusions that follow may be correct, and they may not. It is not possible in regular practice to heat an ordinary ferrous metal in a heating furnace or annealing oven atmosphere without decarbonising the surface to a certain depth, whilst the same thing takes place when a grey-iron, a hard-iron, or a steel casting is stripped from the sand and exposed to the air while still red-hot, and, to some extent, even if they are not stripped at that temperature, for, as there is air in the mould, some decarbonisation will take place on that account.

Frame-Producing Mixtures.

Assuming then that all hard-iron castings have a partially-decarbonised surface prior to being heat-treated, it is quite certain also that the hotter the iron as it enters the mould the more complete and the deeper will be this decarbonised surface. If the practice is such that the molten metal is given a high degree of super-heat in order that it can be distributed in large ladles, the moulds first poured will have a deeper decarbonised surface than those last poured, and are liable to develop "frames."

Now, while it is essential that a decarbonised surface must be in existence before a frame can be produced, it is the author's belief that it is the rate at which the carbon in the core tends to diffuse into the decarbonised rim and the completeness with which the carbon continues to be removed from this rim that determines whether or not a localised carbon-content will be built up and maintained in equilibrium at the junction of the two while the fact that test-wedges from the same heat, but annealed in different pots, have been found in which one wedge was framed and the other not, must lead to the conclusion that the rate of diffusion referred to plays an important part in the story. Then again the author has proved that the depth of frame is a function of the temperature, for in the case of wedges poured from the same ladle in the same flask, and heat-treated at different temperatures, the heaviest frame in every case accompanied the highest temperature. In the case of frame-producing mixtures the composition must be such that the rate of diffusion favours the building up of the pearlitic ring. The author is inclined to believe that this attitude towards the frame-producing mixtures is entitled to some weight. It is a problem that the author has endeavoured to obtain time to investigate properly, but without avail to date.

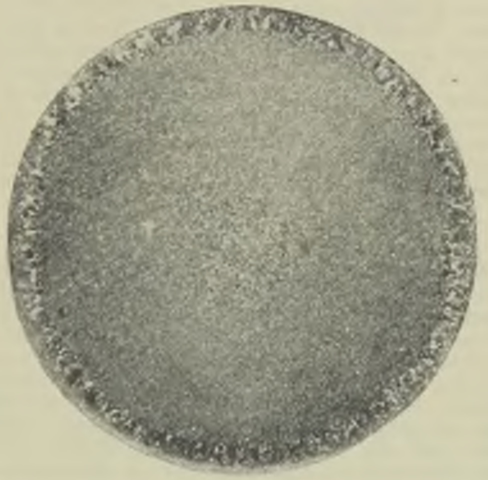


Fig. 12.—Micrograph of a 1 per cent. Carbon Steel Subjected to the Same Heat Treatment as Malleable Iron.

An Experiment with Steel.

Fig. 12 is a micrograph taken at about 4 dia. of a sample of steel containing 1 per cent. carbon. The sample was placed in a pot, together with the hard-iron castings that were about to be heat-treated, and given the same treatment as is ordinarily given the product of that company. A well-defined pearlitic-ring that is located between the surface border and core can be seen, exactly as happens in the case of framed malleable cast iron. There is another kind of frame in which, instead of the pearlite being at the junction of the decarbonised area and the core, it is directly at the surface. This, it is believed, results from a casing-action due to the particular pot-atmosphere existing at the time, and such as would favour the casing of the surface, which condition may be brought about in various ways, particularly when ashes that contain unconsumed coal are used for a packing. The latter condition is the worst form of frame, both from the standpoint of machinability as well as untrustworthiness under shock.

Machining Properties.

It can be stated that the ease with which malleable cast iron can be machined is its most valuable asset, and any defect in the product that operates to retard the speed with which it can be machined is fatal. The two worst defects are the framed-casting, to which reference has been made, and the shrink. Of all of the troubles to which these castings are heir, the shrink is by far the most troublesome and the hardest to combat. Whilst at one time the really-hard casting—the one that was hard throughout, due to an improper heat-treatment—was a source of constant anxiety to the manufacturer, such castings are now rarely produced. It happens, however, that silicon, sulphur, phosphorus, manganese, and carbon can all be present in ideal proportion in a hard-iron casting, and the heat-treatment conducted in an entirely efficient and normal manner, and still castings may under certain circumstances be produced that will have a steely fracture and be hard to machine. Just what operated to bring about such a condition remained a mystery to the author for a long time, owing principally to the fact that in many instances in his experience he found that when it was claimed that all details of works practice had been correctly carried out it was discovered that, unintentionally, he had been misinformed. In the particular case now referred to it was suggested by the management that if this was the author's thought he had better assume the responsibility for a trial air-furnace heat and subsequent heat-treatment. This suggestion was adopted, with the result that, in spite of all precautions, no improvement was found in the fracture. While the author had been acquainted for a long time with the effects of chromium on the structure of annealed castings, he had not suspected until this occasion that chromium was the offender, owing to the supposed rarity of this element in pig-iron in an amount that was in any way harmful; but as soon as it was ascertained that, notwithstanding the fact that

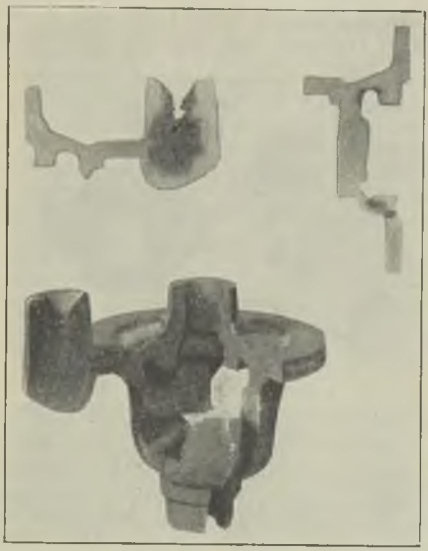


Fig. 13.—A Casting Difficult to Manufacture Owing to the Varying Thicknesses of Metal.

every detail of the process had been safeguarded, the castings still were abnormal in fracture, the product was examined for this element, and his suspicions confirmed.

Chromium is Deleterious.

Hard-iron castings, therefore, can be produced by the presence in the mixture of very minute percentages of this element, particularly if the annealing temperature is higher than normal. Not only will less than 1/10 of 1 per cent. produce an abnormal fracture, but this will be accompanied by a phenomenon the explanation of which proved very baffling until quite recently. Some years ago one of the manufacturers was engaged in the production of some railway castings. One of the kilns was poured late in the day, and as the superintendent was anxious to ascertain the quality of the product he broke the test-lug on a number of the castings that were still quite warm, and as the fracture was normal he felt satisfied that all was well. On the following morning the railway inspectors started their examination, and not only did they find that the fracture of the test-lugs was steely, but the other test-lug on the castings from which the lugs were knocked off by the superintendent on the preceding day were steely. In the case of these particular castings it appeared as if one end had been pro-

FIG. 14.—OTHER SECTIONS OF THE CASTING SHOWN IN FIG. 13.

perly heat-treated but the other end not. The author was called to the plant, and as there happened to be available some test-bars from this heat that positively could be identified, these were heated to a temperature about 300 deg. Fah. (148 deg. C.), and, when broken, showed a perfectly normal fracture, but when cooled to the atmosphere and again broken the fracture was steely. From this time on a few other cases of this kind came to the author's attention, but the cause of the phenomenon remained a mystery. Some time ago it occurred to the author that, in view of the curious effects of chromium on the fracture, possibly this element was the cause of this phenomenon also, and without entering into detail as to the complete investigation made, it can be stated that the author has been unable to bring about this condition in the absence of chromium, but that when exceedingly small percentages are present this peculiarity exists. It also appears that the evil effects of chromium are made more manifest the higher the temperature. From the foregoing it appears that at atmospheric temperature the effect of chronium is to embrittle ferrite, while at a somewhat higher temperature—say in the vicinity of 400 deg. Fah. (205 deg. C.)—the ferrite regains its ductility.

Shrink Troubles.

The casting with shrink, however, still persists, although now that the engineer-designer is co-operating with the foundry to a much greater extent than ever has obtained in the past, while everyone in the foundry connected with moulding operations are on their toes in an endeavour to minimise this trouble to the greatest possible extent, it is still with us to an alarming degree. As has been pointed out so frequently in Papers written by the author, shrink not only can prove to be the sole cause for the failure of a casting in service, but even should it occur in a part of a casting that subsequently is to be removed by machining it can cause a damage not suspected by one who is ignorant of the cause. Very early in his investigations the author discovered that, irrespective of how efficient and complete the heat-treatment of a casting might be, free-cementite invariably exists in the area occupied by a shrink, that is, wherever a shrink occurs a hard spot will be found. Such hard spots had always been attributed to segregation, with phosphorus as the culprit. Even to-day authors of Papers talk of the liability of segregation, simply because this element is in the vicinity of 0.20 per cent., notwithstanding the fact that for the most part malleable-iron castings will not average $\frac{5}{8}$ in. in thickness of section, and solidify so quickly that opportunity for segregation is denied. While undoubtedly there may have been rare cases of phosphorus segregation, none have ever been called to the author's attention.

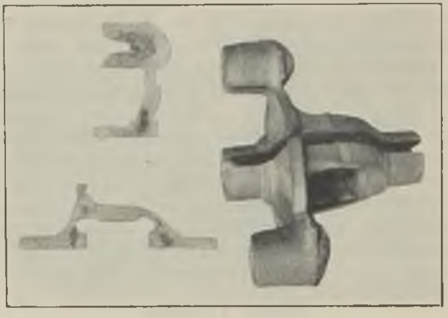


Fig. 15.—Further Illustrates the Necessity of Refusing Badly-Designed Castings by the Foundryman.

Anyone who has seen a Bullard Multiautomatic machine tool at work taking cuts $\frac{1}{4}$ in. thick at 150, and light finishing cuts at 250 ft. per min., machining a casting as fast as the operator can put one in place and remove another that is finished, will appreciate what it means if by chance one of these castings contains a shrink in the path of the tool The tool set-up on one of these machines cannot be accomplished short of some three or four hours, a loss of time that will not be tolerated. In order that the difficulties of the situation may be appreciated, Fig. 13 is reproduced, showing a casting from which two sections have been cut. One cut is in line with the centre of the head, and through a section of fairly uniform thickness. In the etched section, shown above the casting, it can be seen that there is an entire absence of shrink. About 90 deg. from this another section was machined from a part of the casting whose sections are very disproportionate. The various shrink spots are plainly visible, and to those who have made a study of shrink the cause for their presence should be clear.

This particular casting could be gated and headed in almost any manner, with almost any amount of metal, with little hope for complete soundness in this particular section, while a slight thickening up of the narrow neck, just above the largest shrink, and the removal of some metal from the very-heavy section to which it is attached, would enable the founder to make a solid casting, provided also some slight modification in the case of other sections was made. Fig. 14 refers to a similar casting, but cut at other sections. Fig. 15 further illuminates this matter, as well as the fact that it is up to the malleable-iron founder to protect himself and his industry by refusing to make castings that are designed in a manner such as actually inhibit soundness. In Fig. 16 is shown the etched section of half of a casting fed by two risers. In this case complete soundness is apparent. In order that the case will be fully understood it should be noted that a strap was also used in this case leading from the heads to the fillet at the neck of the casting, which facilitated and made perfect the feeding at the fillet. The section from A to B is consequently thicker by the thickness of the strap at this point than would be shown in other similar sections of the casting.

Fig. 16.—Half of Casting Fed by Two Risers and Made Sound by the Introduction of a Strap.

For the purpose of making certain deductions in connection with an investigation that it was intended would be introduced in this Paper, and on which considerable work has been done, some bars of wrought iron and soft steel were annealed with malleable iron castings under the usual heat-treating conditions, and in the belief that, although space is lacking to include these experiments, the results of these mechanical tests may be of use to some reader of this Paper in some other connection.

It is unnecessary for the author to encumber the Paper with remarks in connection with the results; they are obvious upon inspection.

As inferred in the introduciton of this Paper, the author has touched upon those questions concerning which he has received inquiry, while he has endeavoured also to avoid dwelling, in so far as possible, upon items that are usually found in papers covering the malleable-iron process. Pressure of work, frequent absences from the city, and other complications have prevented the taking up of a few other items that are, at least, of equal importance to any of which he has made mention, but which owing to lack of time to obtain the samples for illustrations and the making of the necessary micrographs.

In conclusion, the author would state that the future for this industry in the United States is most promising. The manufacturers are determined that they are going to get all out of the product in the way of tenacity, ductility, and shock resisting properties that investigation and improved apparatus can make possible. Any metal possessing the best machining properties of any ferrous product and having an average ultimate strength exceeding 23.6 tons per sq. in., a yield point approximating 14.75, accompanied by an elongation that easily can be made to average, day in and day out, at least 20 per cent., a figure that to-day is somewhat higher than the average of the American Malleable Castings Association's product as a whole, has a future that is very inviting. The author feels certain that, should British foundrymen enter this particular field in a large way, that Americans will be obliged to look after their laurels as far as quality is concerned. Americans would all welcome the aid and co-operation of the many noted British metallurgists. While very early in the game, and since, the author has experimented with most of the ferrous additions, no results were obtained that have given promise of an improvement of product. All the deoxidisers have been tried, and in no case has any improvement followed their use. It is the American hope that British scientists may in the near future develop some improvement in the process that will serve to make an excellent product still better.

TABLE I.—*Comparative Tests on Annealed and Unannealed Samples of Wrought Iron and Mild Steel Bars.*

WROUGHT IRON.

Mark	04	05	06	01	02	03
Treatment	U	U.	U.	A.	A.	A.
Dia.	0 637	0.665	650	0.662	0.657	0.655
Actual elastic limit (tons)	4.6	4.8	4.8	3.5	3.3	3.4
Elastic limit (tons per sq in.)	14.4	13.3	14.5	10.1	9.8	10.3
Actual ult. strength (tons)	6.7	7.3	7.0	6.4	6.2	6.2
Ult. strength (tons per sq. in.)	21.0	21.2	21.2	18.5	18.4	18.3
Elongation (on 2 in.)	38.0	39.0	39.0	43.5	40.0	42.5
Reduction of area	52.4	51.6	51.2	49.7	50.4	40.2

MILD STEEL.

Mark	44	45	46	41	42	43
Treatment	U.	U.	U.	A.	A.	A.
Dia.	0.665	0.637	0.667	0.651	0.660	0.672
Area	0.347	0.319	0.349	0.333	0.342	0.354
Actual elastic limit (tons)	6.8	6.5	7.2	5.2	5.4	5.9
Elastic limit (tons per sq. in.)	19.8	20.5	20.9	15.5	15.7	16.7
Actual ult. strength (tons)	10.1	9.4	10.2	8.6	8.8	9.6
Ult. strength (tons per sq. in.)	29.2	29.4	29.3	25.8	25.8	25.9
Elongation (on 2 in.)	41.5	41.5	42.5	43.5	43.5	43.5
Reduction of area	64.6	65.5	65.2	64.6	63.7	63.6

In concluding, the author desires again to thank the Institution for their graciousness in having invited him to be with them as their guest. He also desires to thank the following manufacturers for samples of castings that have been used to illustrate this Paper and for others that were to have been used had time permitted:—Eric Malleable Iron Company, Fort Pitt Malleable Iron Company, Frazer & Jones Company, Marion Malleable Iron Works, Troy Malleable Iron Works, and York Manufacturing Company.

Discussion.

Dr. P. Longmuir welcomed the author of the Paper on behalf of the Institution, and congratulated him on the very complete records that he had given of American foundry practice.

American Malleable Iron Practice.

Mr. F. J. Cook (Birmingham) added his testimony, having just returned from the States, as to the high efficiency of the malleable products of that tremendous country. He must say, however, that his experience with regard to grey iron was most disappointing. Still, the pleasure and interest it gave him to see what the malleable industry was doing more than compensated for any loss in other directions, and the improvement of the malleable iron industry was mainly attributable to the work of Professor Touceda.

Mr. O. Stubbs (Manchester) thoroughly agreed with what Mr. Cook had said. Production in the States was enormous. He had the privilege of going over the biggest malleable iron foundries in America, and the first he went through had a weekly production of 2,000 tons. They were very much in front of British foundrymen as regards malleable iron. The question of interior transport was also a matter of first consideration out there. They did not find a workman wheeling a barrow; everything was done mechanically, and this principle was carried right through. There was no doubt that the Americans were producing a very fine malleable casting. He had the pleasure of meeting Professor Touceda in New York, and he could assure him that they all felt very much honoured by having the opportunity of welcoming him now in person. Indeed, he might say that they had with them that day the highest brains in the malleable iron industry.

Mr. S. Flagg (America), as a member of the Association of which Professor Touceda directed the technical side, said he could not refrain from giving evidence of the high value they put upon Professor Touceda's services. Those familiar with recent published tests of elongation would be interested in his work in this respect. Early in 1914 he saw tests in this country giving 17 per cent., but in work done under the Professor's direction

17 per cent. was considered very low. They would see in his Paper 25 to 30 per cent. elongation as an actual accomplishment under his direction.

Prof. Turner (Birmingham) joined in welcoming Prof. Touceda, and said it had been his pleasure for the last seven or eight years to read Papers, particularly in the Proceedings of the American Foundrymen's Association, contributed by him. No doubt this succession of Papers had contributed very largely to their knowledge, and Prof. Touceda, by these published results of investigations, had been instrumental in greatly improving the quality and uniformity of the product in the United States. He did not now propose to discuss the technical matters embodied in his Paper, but he might say he had been struck by the fact that he referred particularly not only to the lay-out of the plant, but to the heating of the foundry, the comfort of the workmen, and the lighting conditions. These were matters which did not receive the proper amount of attention very often in this country. If they were to get the best work out of the men they must be able to work under conditions which were comfortable, and to see properly what they were doing. Part of the Paper, which he had not heard before, touched on a matter relating to the effect of chromium. This raised an extremely interesting theoretical and practical question. There were many pig-irons that contained small quantities of chromium and of nickel, especially those melted from Cuban ores and other ores from the States.

Scientific Gating Advocated.

Mr. Retallack (Willenhall), speaking of the means of transport in American foundries, said the way they handled material up to 60 and 70 ton loads was remarkable. He also urged the adoption of a policy of scientific gating, relative gating according to the section and size of the casting.

Mr. Miller inquired if Prof. Touceda had considered the use of English irons with regard to making black heart castings. A good deal of work was done there in the making of cycle fittings, which in this country were braized.

Mr. Wilkinson (York) said some of the results obtained by Prof. Touceda were an eye-opener as to the possibilities of malleable iron. Nothing approaching them had come under his notice before in regard to elongation. Alluding to pages 48 and 49 of the Paper, as to the elasticity of castings (headed "Composition Limits"), he said that, having made many thousands of these castings, he must admit that the practice in America differed considerably from the practice here.

Mr. J. E. Fletcher (Dudley) described the Paper as wonderful in its information and scope. The diagram of a melting furnace (Fig. 3) on page 22 of the Paper reminded him of the practice in America of melting heavy masses of metal for malleable cast iron. He thought they were often forgetful of the fact that their American friends were able to follow that practice because of their tremendous output, and these methods placed them in this country at once in quite a different position from the States. Looking at the details of the furnace shown in the diagram, they would see that here the flame effect was able to carry out its purpose efficiently; whereas in their British foundries, even though making black heart malleable, their output was so small that they had to use shorter furnaces, and could not obtain that efficiency of melting that undoubtedly was possible in America. He considered that they ought to be specially grateful to Prof. Touceda for pointing out these phases of malleable iron manufacture. Here they were confined to small crucibles or cupolas, or in some cases small gas melting furnaces; but they were on entirely different lines from those used in America. He assumed that Prof. Touceda would tell them that during the process of melting in these large furnaces a considerable amount of oxidisation took place, which helped towards refining it; it assisted in getting a low carbon metal. Another point which might be noticed by practical men was the position of the running spout in the air furnace. Those who had used furnaces knew how vital this point was, and how serious was the mistake of putting the spout in the wrong position. Emphasising the difference in output of American and British foundries, Mr. Fletcher said that as long as they had small furnaces it was going to be very difficult indeed for them to obtain those high elongations which Prof. Touceda had mentioned.

HISTORY OF LOAM MOULDING IN THE PROVINCE OF LIEGE.

By J. Varlet (Liege).

(Belgian Foundrymen's Exchange Paper).

The origin of loam moulding dates from 1846, in which year it was practised for the first time in the Gomree Foundry—thanks to the enterprise of a working patternmaker named Pirson.

He was faced with the necessity of moulding a roll for which it was not convenient to make a pattern. Pirson conceived the idea of making the mould by striking up in a loam and using a spindle and strickle boards; these latter were for a long time called " Placards."

It was not till 1870 that loam moulding began to be generally adopted and that many large foundries decided to produce engine cylinders, condensers, and a number of parts for steam engines by this method. At this date the foundries of John Cockerill, John Roos, and A. Ketin already specialised in loam moulding, which they carried on in a systematic manner, and it was from this foundry that the science of loam moulding was disseminated. At that time there were only available a few exceptional workmen, such as the Marechals, the Galasses, Doyen, and Baguette.

These men, who were real artists, were the actual professors of the period, and it was with an almost fatherly interest that they taught young workmen this art of loam moulding, which is the most intellectual part of foundry work, and which requires the most complete knowledge of engineering design.

In this occupation the artist is revealed by the facility with which he handles the loam and by his insight and capacity for organising his work.

About 1880 loam moulding began to attract still more attention. Many young workmen interested themselves in this branch of foundry work, and there was a veritable rush into the new profession, which was considered a justifiable title, as being much superior to other sections of foundry work.

Course of Training for Loam Moulders.

The young men who had taken up foundry work had learnt sand moulding or perhaps coremaking; there were young coremakers who followed their inclination and their aptitude for the craft, and took up loam moulding after five or six years' apprenticeship to coremaking. Each of these young men had to go through a course of mechanical design, and in 1880 there was in the City of Liège only one professor, Monsieur Rosa, who taught mechanical design with special reference to moulding, and he never had less than 40 pupils. These lessons were given each Sunday for three hours, and the pupil paid 1 franc per lesson.

When the young coremaker was equal to reading his drawing and of making all the sections and views of a cylinder, condenser, pump, etc., and if he had the aptitude already mentioned, he made application with a view to entering the loam moulding department. There he was attached as assistant to a leading moulder, under whose tuition he perfected his workmanship, and in time became a leading loam moulder himself.

Notwithstanding this system of tuition there was not less than 60 to 70 per cent. of failures; that is to say, workmen who never rose above assistant loam moulders or were obliged to return to coremaking.

It was in 1890 that the number of loam moulders reached its height; large important foundries had 10 to 25. The work was at this period perfectly executed, and the cost of production reached its lowest level. In addition, it was not uncommon to see castings struck up in loam which had previously been moulded in sand. The general appearance and skin of these castings was much superior, and extraordinarily enough, cost of production was lower than in the case of the same castings, sand moulded (to-day the contrary would certainly be the case).

The Life of the Leading Loam Moulder in the Workshop and After the Day's Work.

If one examines the life of these workmen one cannot help being astonished to notice how much we have gone backward from the point of view of love of work.

The leading moulder was animated by a sincere love for his profession; he had the respect of his chiefs; he respected himself, and, above all, he conducted himself as an artisan of an intellectual profession, who had the right to everyone's consideration.

The loam moulder worked with his hands in the foundry and with his head at home. When he received from his employer the drawings for an important casting, he sometimes took them to a corner of the foundry for a preliminary study, but in any case he studied the drawings at home and organised his work for the next day.

Methods of Working.

At this period various works had adopted two methods differing widely from each other.

The first consisted in the moulder making a full-sized drawing on large wood panels of the casting he had to make. The second consisted in the moulder sketching out, after a preliminary study of the drawings handed to him, all the strickle plates and grids which he would need to make the casting.

The second method was much superior to the first. It required of the workman a deeper knowledge of the construction of the moulds, and the work was considerably more rapid.

In the method of making a lay-out to actual size a great deal of time was required by the moulder for the execution of these drawings. After that the workman familiarised himself with his drawings, which he consulted continually, and as in these views he saw all the mould faces, his comprehension and execution of his work was greatly facilitated, but his labour was less intellectual than in the other method. This process developed the workman but little, but tended to mechanical labour, and it is noticeable that the workmen who practised it were much less capable than others in the art of loam moulding and were less intelligent, whilst, in particular, they were slow in the production of their castings.

By the other method, on the contrary, the workmen very quickly conceived the complete construction of his mould, and one may say that when he had studied his drawing for an hour he could see the casting on all its faces. To quote here the old proverb:—

"One is only a loam moulder when one can see the completed casting one hour after having received the drawings." This means that after an hour of study a moulder should be able to foresee all that is necessary for the successful production of the casting.

The workmen practising the latter method were much more valuable than those of the other school, who were never able to compete with them either from the point of view of quality of work or speed of production.

Equipment.

In considering the tools employed by the loam moulders of that period one is forced to feel respect for these artisans and to recognise their exceptional ability in being able to produce such perfect results with such primitive tools, or almost none at all.

Whilst now we have available such modern tools as travelling cranes, jib cranes, forced draught mould dryers, special mould tubs, and numerous strickles—most of which are patented—machined plates, pneumatic tools for ramming up large castings, there was available, even in 1890, only crude equipment; the workman had to cut a centre with a chisel in a cast-iron plate so as to form a strickle, with a spindle often weighing 140-150 lbs. These strickles were fixed and had to be constantly checked with a plumb line; mould tubs did not exist. Instead, a hole was dug in the foundry, and in order to make sure of the work, the moulder made the hole much greater than the mould itself, so that there was always the space of about 3 to 4 ft. which had to be filled in with sand and rammed by hand. This great thickness was indispensable, seeing that in order to resist the pouring pressure of the metal, it was necessary to arrange a layer of pig-iron in the form of a grid so as to stiffen the walls of the mould. It was not uncommon for the cooling of a casting made in loam, such as the cylinder of a steam engine, to require three or four days to complete. The loam and the sand, in the condition of mortar, were mixed in a heap with a shovel and crushed with the feet or with a bar of iron, whereas to-day there is at our disposal sand mills and mixers of excellent design.

Loam Moulding at the Present Day.

Nowadays loam moulding is not so much practised, owing to the disappearance of certain types of steam engines. Foundries still have loam moulders, but these are employed as much on core-making as on moulding. Only some of the large works who still make occasionally steam engines, turbines, etc., have a section for loam moulders.

On the other hand, methods of work have changed; they are quicker when the work is convenient for repetition production, and as often as possible a duplex method is practised, part sand and part loam, as will be seen from the drawings which follow.

Loam Moulding.

A loam mould is composed:—(1) Of a base upon which the mould is built (this base is furnished with a strickle spindle when the casting in question is round). (2) Grids which follow the shape of the casting, which strengthen the mould and allow the parts to be lifted. (3) Red bricks and loam bricks, which form the bottom and the sides. (4) Loam (slurry), which forms the first layer covering the bricks. (5) Sand (slurry), which forms the last layer and constitutes the skin of the mould before the layer of blacking.

The loam and sand mixtures are generally made up as follows:—

Loam Mixture.—Waste core sand and loam bricks 50, clay 20, old foundry sand 10, tan (tannery waste) 20 per cent., and water *ad lib.*

Sand Mixture, No. 1.—Quarry sand 75, horse manure 25 per cent., and water *ad lib.*

Analysis of Sand.—Silica 93.3, iron oxide 0.90. alumina 3.5, magnesia 0.10, lime 0.60, and calcination loss 1.50 per cent.

Sand Mixture, No. 2.—Quarry sand 68, horse manure 10, hard coke grindings 12, waste firebrick grindings 10 per cent., and water *ad lib.*

Sand mixture No. 1 is used for general purposes and No. 2 specially for castings of large area and great thickness.

Slag Ladle for Steelworks.

When a foundry is attached to steel works it has to make slag ladles regularly, for which the mould should be constructed as in Fig. 1, where (1) is a wrought or cast-iron shell; (2) a base bolted to the shell; (3) a core-iron bolted to a cover plate: (4) a bottom plate for core-iron, which must be

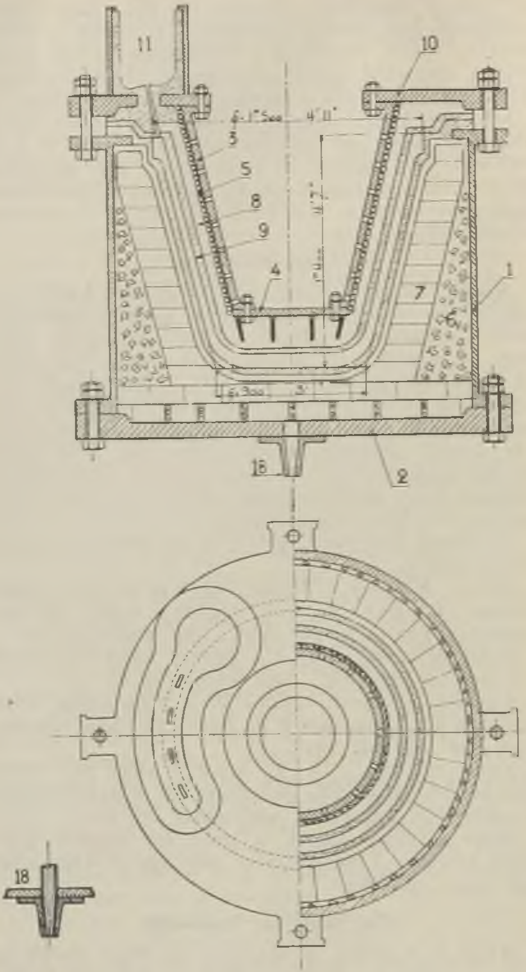


Fig. 1.—Plan and Section of a Loam Mould for a Slag Ladle.

unbolted before removing the core-iron from the core; (5) straw rope; (6) layer of sand; (7) red bricks; (8) loam mixture; (9) sand mixture, No. 2; (10) cast-iron cover; and (11) runner bush.

When a casting is poured, it is possible the same day or the next morning to lift the core-iron, which does not stick to the mould, the straw ropes being burnt. In cases where straw is not interposed between the sand and the core-iron, it is impossible to lift the latter owing to the contraction of the casting, and the labour of chiselling the core-iron free is very slow.

In cases where there is only one casting to make, the outside of the mould is made in sand and the core in loam without a core-iron, the latter being replaced by red bricks but still using straw rope as indicated. For repetition work it is sufficient after having lifted out the casting to remove the top layer of sand from the mould and sweep up again directly. In the case of the core, the straw, a layer of loam, and a layer of sand must all be replaced.

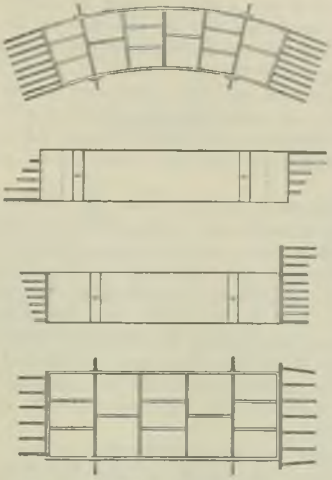


FIG. 2.—BOX PARTS, ETC.

The maximum labour for this class of casting is

15 to 18 hours for one man. The weight of the casting is about 3 to 4 tons.

It is noticeable that the slag ladles have a longer life when moulded in loam than when moulded in sand, the iron being closer where in contact with loam surfaces. It is also noticeable that the interior is better finished by moulding in loam than when sand is used.

Composite Moulding of Large Flywheels, part Loam and part Sand.

Formerly heavy flywheels of large diameter (18 ft. to 23 ft. dia. or more). which were too large to be made in a single moulding box, necessitated a very great amount of labour, and occupied a large area of the foundry over a long period; often six to eight weeks passed by before valuable space thus occupied (90 to 110 sq. yards) could be recovered for the moulding of other castings. This slowness was due to the system of using small box parts for the rim and the arms and to the necessity of working up patterns for these parts and the enormous quantity of gaggers required to keep the sand in position in the small box parts, etc., shown in Fig. 2.

These box parts for the rim and the arms had to be finished at each end with grids, having wrought and cast iron pins, which were adjusted according to the shape to be followed at the hub and the rim, which required considerable labour, as the box parts had to be tried on the mould many times before they could be definitely fixed in place.

The New Method.—The new method of moulding these large castings consists in making one part in loam, such as the top part mould of the rim and the arms.

The labour is greatly reduced, and it is possible to strike up the shape of the flywheel directly. Once the rim is strickled, and the hub made, it only remains to make the arms; one pattern will obviously enable these to be moulded in a minimum of time.

The loam part consists in making slabs to cover the rim (four or six according to size), a plate for the hub, and a slab for each arm. This work is very rapid; a coremaker can finish the whole in ten days.

For the arms, a pattern is made in tarred loam.

The slab follows the contour of the arm, the rim, and the hub. These slabs are worked up in a very

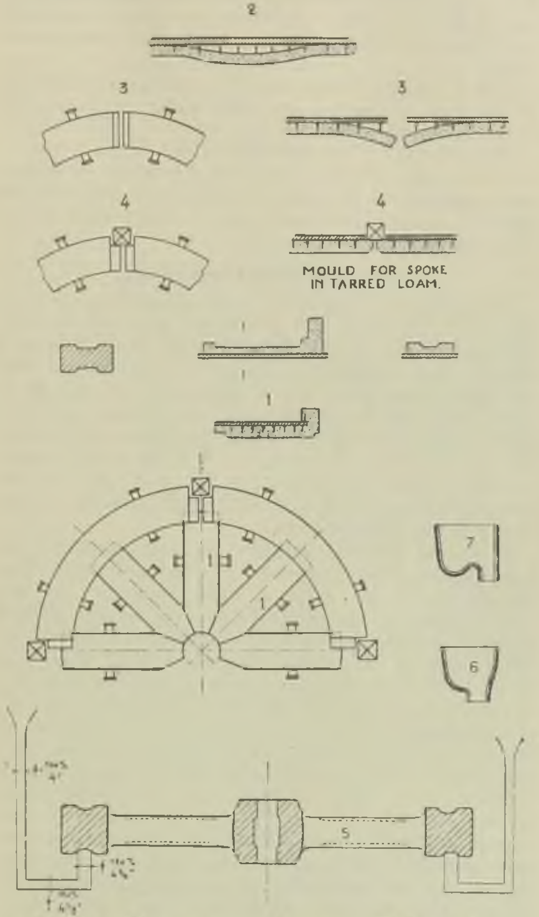


Fig. 3.—Details for Flywheel Moulding.

short time (Fig. 3, No. 1). After remaining a night in the drying stove, the first arm is lifted from its pattern, and the second is made, and so on. By this process two moulders and one coremaker can easily finish a 20-ton flywheel in three weeks and a 30-ton flywheel in four weeks, the comparison being:—

Old Method.—Three moulders and a labourer for 30 days of 10 hours, say, 300 hours × 4 = 1,200 hours, plus 80 hours for the cores = 1,280 hours.

New Method.—Two moulders for three weeks = 2 × 3 × 48 = 288 hours; one labourer, 80 hours; one coremaker, 120 hours; making a total of 488 hours. Taking 500 hours as a round figure, the ratio is 1: 2.4.

Chief Difficulties Encountered.

The periphery finished, the assembling of the rim and arm slabs was proceeded with, afterwards the mould was dried by portable hot-air mould driers. As a result, the top part of the mould (the parts in loam) absorbed a large part of the moisture from the lower portion and became spongy; some of the thin layers of loam buckled and formed air pockets (Fig. 3, No. 2), and were washed away by the metal; the blacking did not stick to the spongy surface, and thus the casting had a rough and scabbed appearance.

A second trouble occurred at the joints of the loam slabs, often caused by slow pouring. The expansion of the sand on the periphery of the wheel, due to radiation from the metal, caused crushing at the joints and formed gross defects at these points. It often happened also that the slabs, half an hour after pouring, having absorbed the maximum amount of heat from the casting and expanding several inches, broke the sand at the joints still further, which forced its way into the pasty metal and thus formed a large cavity at each joint (Fig. 3, No. 3). To cure these serious defects, the following method was employed:—(1) It is sufficient to dry the bottom part mould in the early stages, perhaps the first day, or by the labourers of the night gang, covering the rim and arms with sheet iron; after blowing through hot air for seven or eight hours, the moisture is driven off, the sheets removed, and the assembling of the rim and arm slabs proceeded with; the mould drier is again used for about the same period; the loam part does not then receive the moisture from the sand. (2) The edges of the slabs at the joints are bevelled, wedges are driven between them, iron to iron, and their expansion has then no effect on the joint. In addition, the speed of pouring, as will be seen later, only allows a slight expansion of the sand before the mould is completely filled (Fig. 3, No. 4).

Pouring.

The casting is bottom run at the rim (see Sketch 5) and with an expanding ingate, which causes the metal to flow easily on the sand of the runner. To pour quickly at constant pressure through a constant area runner causes sand washing, the speed of the metal increases heat radiation, burns the facing, and gives rise to scabs, etc.

It is well established that it is possible to pour a flywheel by using a system of expanding runners, or in other words, a reduced pressure system (Fig. 3, No. 5). The author believes that a 20-ton flywheel ought to be poured in one minute, and he has often poured flywheels of 10, 12, and 15 tons in 44 to 50 secs.

It is important that the upper of the mould be subjected to radiation from the liquid metal for as short a time as possible. The metal is poured from two ladles holding 10 to 15 or 20 tons according to the weight of the casting. The metal is decanted from one ladle to the other to ensure a homogeneous mixture, otherwise, as already mentioned, there is a possibility of unequal stresses being set up during contraction which may cause cracks, particularly in the arms.

In order to enable a large body of metal to be emptied into the reduced pressure runners, funnel-shaped runner bushes are employed (Fig. 3, No. 6), as skimming bushes similar to No. 7 will not take the metal quickly enough.

Loam Moulding a Sugar Cane Calender.

Large calenders (Fig. 4) of 8½ ft. dia. × 6½ ft. to 9½ ft. high and of generally thin section (not more than 1 in.) are castings which require great care to ensure success. It is impossible to guarantee success with a sand mould, owing to the friable nature of the sand, and especially of the large surface of the mould, perhaps 22 to 27 sq. yards. In addition, the great height and the speed of pouring cause disintegration of the sand, the metal scouring the walls of the mould strongly as it enters. Loam moulding, therefore, offers a more certain chance of success.

Mould faces in loam are not disintegrated by the scouring action of the flowing metal, and they are not burnt so quickly when Mixture No. 2 loam containing coke, which has a minimum expansion, is used.

This sand is very refractory (notwithstanding its high calcination loss of 20 per cent.), it has a very hard surface, very open at a thickness of $\frac{1}{4}$ in. to $\frac{3}{8}$ in., and more so at a thickness of $\frac{5}{8}$ in., which is the thickness that should be used.

The gases easily escape, and it is unusual for the sand to wash in the runner, even in the case of high pressures, large bodies of metal and great heights. The sand withstands the force of the metal without crumbling.

For this kind of casting, loam moulding is much quicker and, as a general rule, may be taken as little more than 60 per cent. of the time occupied for the same mould in sand.

Two essential features need to be observed:—

(1) The cast-iron rings in the core (Fig. 4, No. 5) must be in one piece and not cut on one side for expansion. These rings made in one piece greatly strengthen the core, but in order to permit of the contraction of the casting (2) they must be faced with straw rope (Fig. 4, No. 6). This is absolutely necessary, otherwise the resistance to contraction would crack the casting, whereas when the straw is burnt a space is formed between the ring and the outer layer of sand which permits free contraction.

Pouring the Calender.

The casting is poured from the top by means of small ingates, well separated (Fig. 4, No. 8), the metal being poured into a trough (No. 9). It is necessary to keep the runner-bush full and to pour as hot as possible, as the ingates (No. 8) should not be larger than 3-16 in. × $2\frac{1}{2}$ in.

The core should be rammed hard with a pneumatic rammer, in the lower portion, to a height of about 20 in.; in order to avoid a run-out at the bottom joint a weight of 5 to 7 tons, with a fairly large area, is placed on the layer of sand rammed

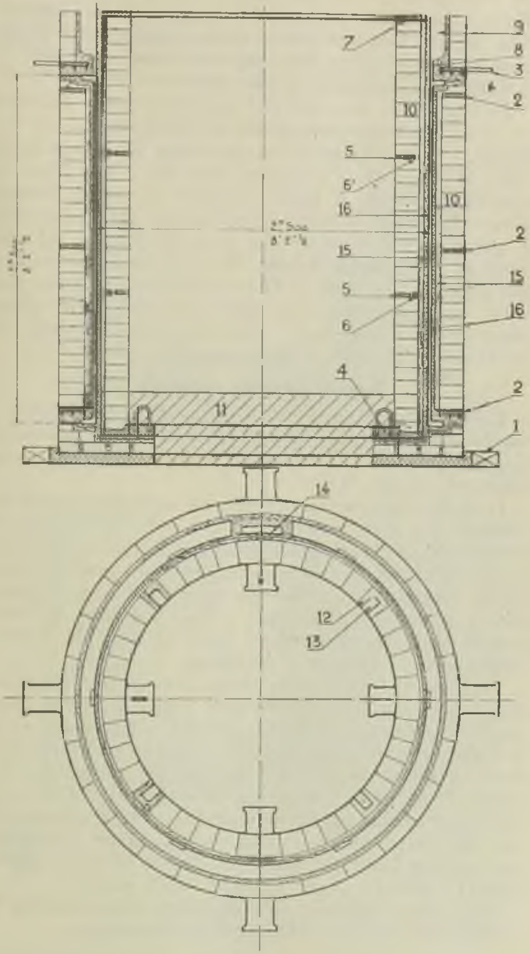


Fig. 4.—Plan and Section of a Calender Loam Mould.

at the bottom, the rest of the core being left free. This makes an appreciable economy in labour. The escape of the gases takes place with great rapidity, which, in the case of thin castings, is a factor of primary importance.

In regard to the core the cast-iron rings inserted in it make it very resistant to the pressure of the metal. Three hours after pouring the sand layer (No. 11, Fig. 4) is removed, and the rings (No. 5) are rapped with a light hammer so as to detach from the layer of sand; five hours after pouring a groove is cut from the top to bottom of the casting in the loam bricks (No. 12) inserted for the purpose in the core. This operation reduces the total core thickness by half (No. 13), and gives elasticity to the core, allowing the casting to contract naturally without strain.

Special Recommendation.

The bottom ring (No. 4, Fig. 4) should be entirely contained in the print, at least 2 in. below the casting, so as not to interfere with the contraction of the latter.

It is imperative that the core and the mould be bolted to the baseplate, or otherwise heavily weighted, as the height from which the metal falls produces a serious head of pressure, enabling the metal to penetrate into the base, forming a flash, which may lift the core. The outside of the mould must be rammed as hard as possible, otherwise there is danger of bursting.

In Fig. 4, 1 is a base ring; 2 covering ring for the collar and reinforcement ring; 3 cover ring and support for pouring trough; 4 bottom ring for the core; 5 intermediate rings to reinforce the core; 6 straw ropes; 7 top ring for clamping the core; 8 runners; 9 pouring trough; 10 red bricks; 11 layer of sand; 12 loam bricks; 13 grooves cut in the loam bricks three hours after pouring: 14 feeding head or riser; 15 layer of loam (open grain); and 16 layer of sand with coke.

The time required for moulding this casting is 70 hrs. for one moulder and an assistant.

Moulding a Large Marine Engine Cylinder.

Moulding a large cylinder in loam has for its object production of casting of regular thickness and free from defects. By moulding in loam it is possible to arrange the joints of the mould in all the necessary planes, so that assembling and coring up can be carried out with the certainty of correct thicknesses being attained, the various

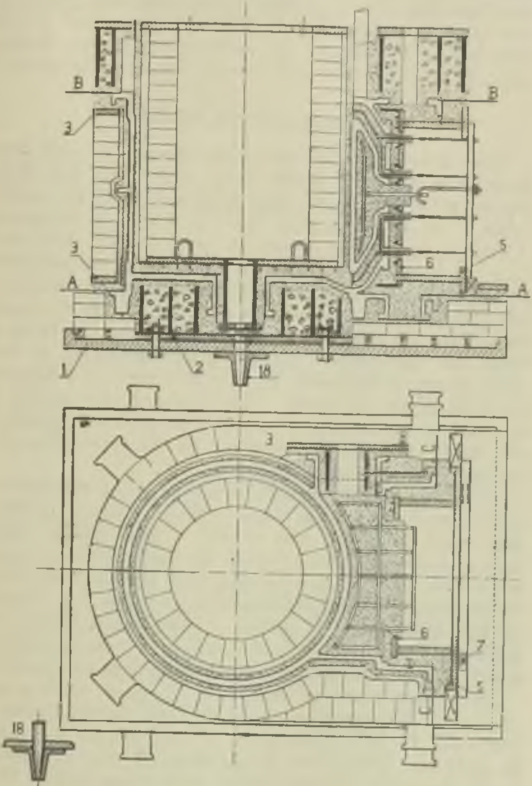


FIG. 5.—DETAILS OF MARINE ENGINE CYLINDER MOULD.

cores being secured by iron wires or bolts. In a loam mould (Fig. 5) holes can be cut for certain cores, such as for the pipes (No. 8, Fig. 5), of which the core can be inserted from the outside of the mould so as to unite with the exhaust core, fixing it by a joint and a wedge on the outside, which takes a bearing on one of the mould grids.

The cylinder shown here would be jointed in the following manner, so as to secure the maximum facility for locating the cores and the parts of the mould, adjusting the thicknesses and fixing the whole by means of galvanised hooks, wires, etc., to the interior and the exterior of the mould.

Contraction of the Mould.

The mould would be built up on a cast-iron baseplate (No. 1) made very solid, not less than 2½ in. to 3½ in. thick, and with a rim on the outer edge. A case-iron grid (No. 2) would be attached to the base, having wrought- or cast-iron pins cast into it, this grid serving to hold all those portions of the loam and sand which project on account of pipes, bosses, etc. This part of the grid would have the interior filled with coke, so as to form a vent for the gases. Care must be taken to see that there is at least 2½ in. of loam, in addition to ¾ in. layer of sand. This part of the mould is swept up by means of a conical pointed spindle, the bush of which is fixed on to the base (No. 18) at the joint shown by line A. A.

The body of the mould is built up of red bricks and loam bricks on a frame (No. 3), which carries the main body of the mould. This main body forms, following the lines B. B. and C. C., a joint with the top part covering the steam-chest, the outer flange of the steam-chest and the top flange of the cylinder. A collar of the same shape as that shown at No. 3, but thinner, is placed underneath the top flange so as to strengthen the mould.

The riser part is made on a grid with pins (No. 4). The steam chest is then formed along the lines D. D. This part of the mould is made to pattern, and after being marked out and filed to fit the parts of the mould above and below, the thickness of sand left by the pattern is placed in position. The steam chest is made on a plate (No 5) fitted with a grid (No. 6). The inlet and exhaust port cores are made in false moulds of loam (tarred when there are many cores to be made). All these parts of the mould are made separately, so that the work can be quickly carried out.

Coring Up and Preparing the Runner.

The baseplate is placed level and in a position which allows free access all round. The body of the cylinder mould is placed on the baseplate exactly central, and checked to the datum lines

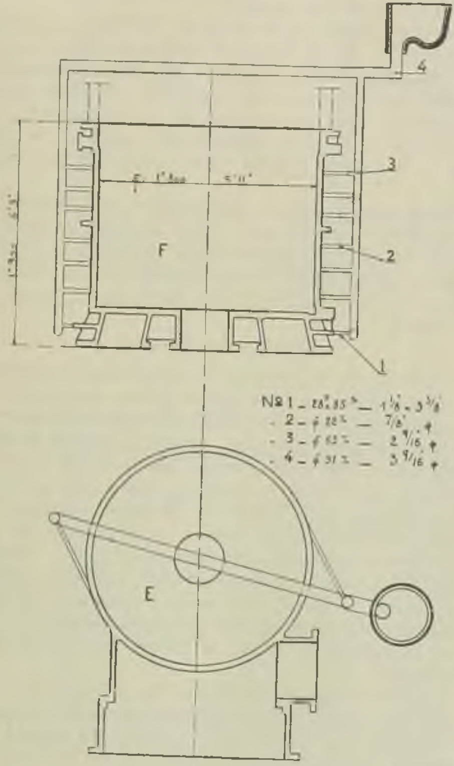


FIG. 6.—THE ARRANGEMENT OF THE RUNNERS AND RISERS.

which are marked out when these two parts were tried together before blacking up.

The inlet and exhaust port cores are fitted in the steam chest core, and after making sure that they are correctly located they are fixed by means of small bolts (as shown in the illustration). All being fixed, this part is removed by two lugs in the coreplate (No. 5), and thus there is the steam chest, as shown in the vertical section drawing. There remains little difficulty in fixing this securely in the body of the mould.

Having made certain that all is in place, a wedge (No. 7) is inserted between the coreplate and the lower mould grid. By this process it is possible to examine the position of each part of the mould, and to correct it, if necessary. The barrel core is then introduced, and it is easily seen if it makes a good joint with the port cores, etc.

There only remains the header, which is placed in position last of all, after having wedged and bolted up all the parts of the mould. It is necessary to replace the closed mould in the stove, so as to dry the joints which have been luted with wet loam.

Pouring the Casting.

The method of pouring is of primary importance for the success of castings of great mass and varying thicknesses. Also, for larger cylinders, the author favours pouring from a single ladle, to ensure homogeneous metal, but through a number of small ingates ½ in. to ¾ in. dia. and in number 12 to 14 for a cylinder of 12 tons weight.

The runners are attached tangentially on either side of the casting (as shown in Fig. 6). They are calculated so as to ensure rapid running (10 secs. per ton). One of the most important factors is to secure the flow of the greatest volume of metal into the casting in the shortest time, but at low pressure.

A cored casting should not be subjected to metal pressure, as the metal circulating under these conditions in the mould will attack the mould faces, whereas if the casting is poured at reduced pressure even a large quantity of metal will flow easily over the mould surface without burning and erosion. In order to reduce pressure, the area of the main runner (Fig. 6, F., No. 4) should be 30 per cent. less than the total area of runners 1 and 2; for example, the area of runners 1 and 2 is 9,360 sq. mm., less 30 per cent., which equals

6,560, and this corresponds to a main runner 91 mm. dia.

This method has always given the best results, and the author uses it for all castings above ½ ton

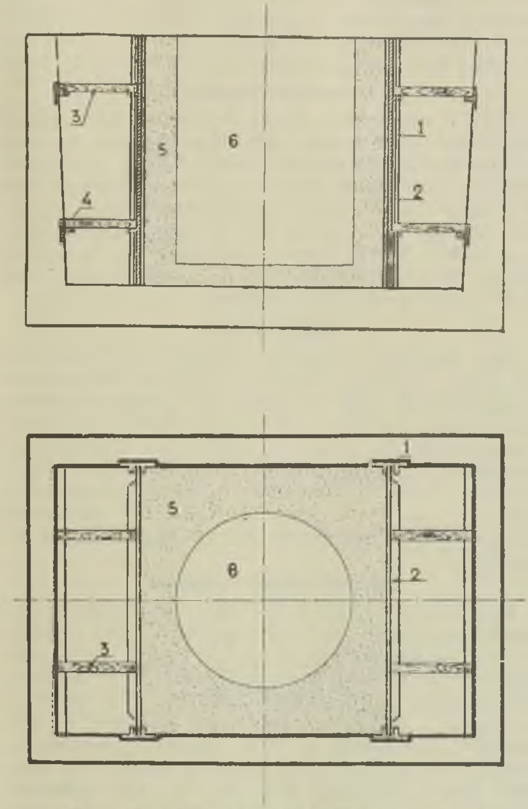


Fig. 7.—A convenient Casting Pit.

The author considers the double tangential runners the best for cylinders, as the circular motion of the metal floats up into the riser all sand, slag, scum, etc. In the bore of a cylinder the metal surrounding the barrel core, if not enlivened by a circular movement, brings about inequalities of temperature, which may give rise to cold shots; sand and slag may stick to the core by the pressure at the surface of the metal, whereas by giving the metal a circular movement it washes the core and mould, and one is certain to get clean metal, which will give a perfect bore.

A Convenient Casting Pit.

Fig. 7 represents a pit furnished with plates supported with props. By this system, as soon as the casting is poured, and before the sand hardens, the plates (No. 2) can be withdrawn and the sand (No. 5) may be easily removed, as can the casting. In Fig. 7, No. 1 represents the cast-iron slides; No. 2, cast-iron plates; No. 3, wooden props; No. 4, brackets; No. 5, rammed sand; and No 6, the mould to be poured.

DISCUSSION.

Dr. Longmuir, having thanked M. Varlet for his Paper, said he supported all the statements made therein with the exception of the statement that loam moulding was introduced in 1846. Throughout the whole of mediæval Europe and mediæval England loam moulding was in use. Prof. Turner, in his " Metallurgy of Iron," referred to the first cast-iron made in Sussex. The early Sussex ironfounders were in all probability loam moulders.

Apprenticeship Problems.

Mr. Gallon (Newcastle) said in England they would be glad if they could get such boys to train as M. Varlet portrayed in his Paper, boys who would take an interest in the principles of machine construction and pattern-making, and then in moulding. They had not had such boys in this country. It would be their greatest pleasure to teach such boys all they possibly could. In England boys were put into one of the different branches of the trade, therefore they could not teach them now as M. Varlet would have them taught. He did not know a boy in the whole of England who could design a casting. He meant a young fellow who was brought into the foundry to learn the trade. He did not know one such that was taught to design a casting from the very beginning. He took notice, as he read the paper, that the men of Liege were not afraid to work. They could turn out this large slag ladle in 18 hours. He would be glad to see it done in that time in this country. He did not know whether they worked 10 hours a day in Liege, but if they worked 8 hours it would be a very difficult thing to do the job in three days. M. Varlet described the chiselling of the centre hole out of a plate for the centre pin to work upon. He (Mr. Gallon) would like to ask if that was not a mistake. Forty-five years ago, when he was an apprentice, they used to cast those centre holes in the plate. They secured a pin vertically in the sand bed, and cast the plate around it. He considered that was very much better than boring a centre hole into the cast-iron plate. He would like to hear something as to other methods of casting cylinders. The Paper appeared to him to be a great one, and the greatness of it was its simplicity and honesty; it conveyed something they could carry away.

Mr. Young said he thought every foundryman attending the Conference ought to go to the Birmingham Technical School. They had not anything like it in Newcastle. He thought if other institutions went on the same lines as the Birmingham Technical School they would get the educated boy they wanted.

Mr. Wilkinson congratulated M. Varlet on the excellence of his Paper and the clearness of his drawings. He (Mr. Wilkinson) totally disagreed with Mr. Gallon's remarks. It was quite possible to get young men in England to take a keen interest in their work. Personally he could recall several who came under his own charge. Showing a little aptitude for the work they were taken in hand, and they made very rapid strides. He coached one or two in the laboratory, and he was very much surprised by the interest they took in their work. He knew from personal experience that lads in the South of England, in the North and in the Midlands would take a keen interest in the work if there was the human touch to encourage them. If they tried to get at the lads on their own level a good percentage of them would try to use their brains as well as their hands. They must do a great deal more to encourage brain work among the youths in their foundries. Unless they very carefully trained the youths to follow in their predecessors' steps and improve on their often defective work, they could not hope to hold the position they had hitherto held. It seemed to him the human side was being applied to the problem in Liege with very considerable success.

The President said M. Varlet would have an opportunity of seeing the discussion after it had been translated into French, and his reply would be published in due course.

Written Communications.

Mr. S. G. Smith, in a written contribution, stated that M. Varlet's historical notes upon the loam moulder are interesting. On page 184 M. Varlet refers to an early period of loam moulding, when the cost of production was lower by that method than in the case of the same castings made in sand, adding that to-day the contrary would be the case. Personally he did not altogether agree; so much, if not all, depends upon the way adopted, outlay, tackle, etc. There are expensive and economical ways of loam moulding.

A few years prior to the war he (Mr. Smith) produced plain repetition loam work as low as 7s. 6d. per ton, 54-in. 60-in., and 66-in. socket and spigot pipes 9 ft. 6 in. long for 10s. per ton, 40-in. and 50-in. dia. double flange Gee pipes 9 ft. 6 in. long for 12s. 6d. per ton. Internal flange cylinders 4 ft. to 8 ft. diam., and from 4 ft. to 8 ft. long, were made regularly for 20s. per ton. A medium size of the latter, three men would make one casting in two days. The above compares favourably with M. Varlet's figures which he gives later on in the paper.

On page 187, under the sub-heading of "Loam Mixture," the tannery waste referred to was, he assumed, cow-hair?

"Sand Mixtures No. 1," consisting of new sand and horse manure, would be a rather extravagant mixture. Why not some floor sand?

On page 190 the maximum labour given for slag pan is given as 18 hours. Does this include both skilled and unskilled labour?

Page 191, Fig. No. 3, deals with a fly-wheel. He (Mr. Smith) did not think that the best method was adopted for making these wheels. Forty-five years ago he used to strike the outside of the rim up in loam, the arms were formed in dry sand cores, the rim and hub were covered with loam plates.

He had made fly and grooved rope wheels various ways, but the cleanest, quickest, and most economical way was to make and assemble the whole in dry sand cores. Such wheels, or half-wheels of any diameter or weight can be made in the minimum time and cost. A brief reference to this method and procedure appeared in THE FOUNDRY TRADE JOURNAL, May 25, 1922, in which a fly-wheel problem was dealt with.

On page 195, Fig. 4, calendar cylinders are dealt with. This is a very plain external-flange cylinder. No provision appears to be made for the dross head, which he thought is necessary to obtain a clean top flange. The method adopted in making this casting involves breaking-up the brickwork for each cylinder.

If this is a repetition job, it can be obviated by making suitable tackle. He (Mr. Smith) had given a full detailed description of method and procedure of making external flange cylinders without removing the brickwork, or rather, without breaking up the outside brickwork. This appeared in THE FOUNDRY TRADE JOURNAL about 1913. M. Varlet will find this a most economical method of producing such castings. Upwards of 50 cylinders can be made without re-bricking, or ramming the outside of the mould.

This contribution will be unduly long if reference is made to other castings in the Paper. It is an open question regarding the superiority in skill of the loam or sand moulder. It is said that moulders, like poets, are born, not made. There is little in common with the methods of the two, and a combination of both is like the old-time fitter, very rare.

A loam moulder's daily routine is with spindles, plates, bricks, strickles, etc. A sand moulder's daily routine is with various kinds of patterns, rammers, etc., to which he has to apply his intelligence as well as his weight.

The risks of the sand moulder making faulty work is greater than the loam moulders.

The Author's Reply.

M. Varlet, answering Messrs. Gallon and S. G. Smith, writes that he thanks these gentlemen for the interest they have taken in the Paper which he read at the Birmingham Conference, and desires to place on record his deep regret that he was only allowed twelve pages in which to deal with so exhaustive a subject, for he would have liked to have outlined the subject in all its phases instead of being limited to four types of casting. With regard to Mr. Gallon's remarks, he would say that the workmen of the Liège district are undoubtedly very clever, especially as regards loam moulding. It is perfectly true that one man can make a $3\frac{1}{2}$-ton slag pot in 18 hrs. This period is quite average when, say, three are ordered. It should be mentioned that the mould and core are made in masonry and last for three castings as set out in the paper. As regards the hole, chiselled out of the base plate for taking the strickle, a translation error has crept in. This plate is cast around the stem of the strickle, which is first doped with tar. This stem is suspended in the mould with iron wire. As soon as the metal is frozen, the arm is lifted out and given a quarter turn twisting motion, this being

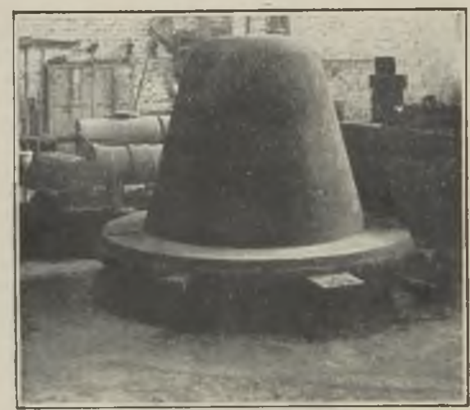


Fig. 1.—Finished Core for Slag Pot.

done before the contraction of the casting takes place.

Dealing with Mr. S. G. Smith's discussion, M. Varlet states that he is in agreement with him that loam moulding can be either cheap or expensive according to the methods adopted and the type of casting to be made. He remarked in his paper that the old loam moulders, who had little equipment, were quicker than present-day workers, and that certain castings were more quickly made in loam than in sand. Mr. Smith will perhaps be astonished when told that in 1890 the St. Léonard concern of Liége made a series of six locomotive cylinders in loam, and that the cost price was lower than when made in sand. But as stated in the paper, the contrary is often true.

FIG. 2.--THE CORE REMOVED FIVE HOURS AFTER CASTING.

Composition of Loam.

As regards the pipes made by Mr. Smith, he regretted that he could not enter into a discussion on this question, especially as to length of time taken. He found Mr. Smith's figures excellent, but he wished to state that the subject of the Paper presented was "The Origin of Loam Moulding in the Province of Liége" associated with its actual methods of working, and is not, to his mind, a comparison with those of other countries. Tannery waste, mentioned under the heading of "mixtures," is bark, either oak or chestnut, which when reduced to small lamellæ of 2 to 5 cm. long is used for the tanning of hides and skins. Sand No. 1 (mortier de sable) is a mixture normally used in Belgian foundries. It includes horse litter, and not exactly dung. Horse litter has quite special properties. It is above all an excellent binder, giving high plasticity to the sand on account of the fatty and ammoniacal materials present. Further, because of the considerable straw and oat content, a high degree of porosity is given to the sand allowing of the easy escape of gas. It should be stated that it is rather expensive, and when, as it occasionally happens, it is replaced by sawdust, different results are given.

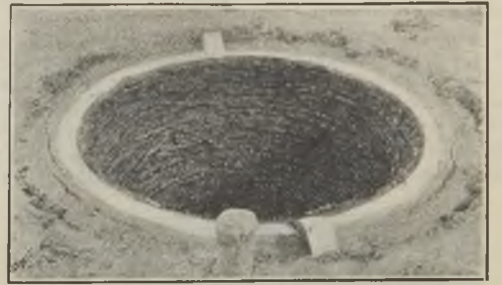


FIG. 3.—THE CASTING PHOTOGRAPHED AFTER THE WITHDRAWAL OF THE CORE.

Flywheel Moulding.

He was again in complete agreement with Mr. Smith that the best method of mould flywheels is to assemble the whole in a box, and that is what is always practised in Belgium for flywheels up to 5 metres dia. But for larger wheels he insisted that the method outlined in the paper is more rapid, for no boxes are used for such large diameters. Moreover, consideration should be given to the small number of reinforcements that are used for a flywheel of 6 to 7 metres dia. compared with the method outlined by Mr. Smith in THE FOUNDRY TRADE JOURNAL of May 25, 1922.

Unfortunately, he has not one of these castings on order; it would be a pleasure for him to invite Mr. Smith to do him the honour of visiting Belgium and ask him to compare the two methods of moulding outlined. Mr. Smith could then judge for himself as to whether the method of working was the most economical, the quickest and easiest, and also could examine the numerous details mentioned as to the success of the casting.

Cylinders.

Having dealt with the loam moulding of a cylinder of 2½ metres dia., 22 mm. thick, and 2½ in. high, he affirmed this was an easy casting to mould, but its complete success requires some amount of care. Mr. Smith must excuse the author if he has forgotten to say that this type of mould does not apply to repetition work, but only to an isolated casting. Up to now, he

Fig. 4.—The Withdrawn Core Remade with Straw Rope and—on the Top—Coke. It is now Ready for Strickling.

had only turned out three, and these of different diameters. They were not for an outside order.

It is probable that for repetition orders special equipment would be devised, and it is quite understandable that Mr. Smith has cast 50 cylinders without remaking the masonry. Regarding the feeding head, this is quite well explained in the sketch (see Fig. 4, No. 14) by an arrow. One alone is sufficient.

In praising the superiority of the loam moulder, he referred to those he had known in the past and those he desired to see in the future—that is to say, a man to whom one can confide a plan of a casting of the highest importance and who moulds it perfectly without having recourse to the help or the advice of anybody. He found that the moulder had to apply himself with all his power to imagine the construction of the mould, whilst the dry-sand moulder is usually provided with a pattern for the production of his casting. It was not possible for the writer to compare the British and Belgian moulder, for he had not

FIG. 5.—LOAM MOULD FOR A GAS PRODUCER GRATE TO BE CAST IN STEEL.

the opportunity to visit a foundry during his stay in Birmingham. This is to be regretted, for he imagined that some very interesting methods of working are practised in England, and he further thought that all foundrymen ought to spread the knowledge of any methods which they find advantageous and to help foundry progress by every possible means.

When the Congress and Exhibition was held in Liège in 1921, all the visitors were invited to inspect the four most important Belgian foundries: Messrs. John Cockerill, A. Ketin, Compagnie des Conduites, and Esperance-Longdoz. The visitors expressed themselves as delighted with the opportunity afforded.

Generally speaking, Belgians are always happy to show their work, for they consider all foundrymen as friends. They looked upon the recent visit of Mr. V. C. Faulkner, the honorary secretary of the London Branch, when passing through Liège, as a distinct honour, and he hoped on the occasion of the next Belgian Conference to see the members of the Institution of British Foundrymen, who, he assured in advance with all possible sincerity, would be accorded the same hearty welcome which he had received in Birmingham, and which is one of his most pleasant memories.

[In sending his answer to the criticisms on his Paper, M. Varlet enclosed five photographs which are distributed amongst the text, being self-explanatory, except perhaps Fig. 5, which has reference to a mould for a gas-producer grate. This mould was struck up in loam, no pattern being available. It was closed up and taken a considerable distance to another part of the works to be cast in steel.]

SOME INFLUENCES OF LOW TEMPERATURE ON THE STRENGTH AND OTHER PROPERTIES OF CAST IRON.

By A. Campion, F.I.C. (Falkirk), and Mr. J. W. Donaldson, B.Sc., A.I.C. (Greenock).

Introduction.

James Watt only succeeded in producing a working steam engine after obtaining the assistance of John Wilkinson to show him how to cast and bore the cylinders, and from that time to the present the engineer has always been largely indebted to the iron founder.

Modern engineering progress involving the use of high speeds, temperatures and pressures, together with the increase in the size of engines, has been facilitated in no small degree by the exertions of the ironfounder. The limits have not yet been reached, and it appears probable that in the immediate future the engineer will make still further demands upon the founder and metallurgist for castings of even greater complexity, and to meet more stringent specifications as regards strength and reliability.

Although cast iron is one of the most extensively employed, it is at the same time the most complex of the ferrous materials used in engineering construction, and the one least understood as regards its constitution and properties under varying conditions and treatment.

The engineer requires material which possesses considerable strength and reliability not only at ordinary temperature and pressure, but which also retains its strength, shape and size when submitted to the action of higher temperatures and pressures.

It must be frankly admitted that metallurgical progress in regard to cast iron has not kept pace with that of engineering design, but it is of the utmost importance that this deficiency be made good at the earliest possible opportunity, and that cast iron receive full and careful attention and investigation of its constitution and properties.

The future progress of engineering design and construction will largely depend upon the ability of the metallurgist to produce material capable of withstanding more severe conditions of service, and of the founder to cast it. During the last ten years the authors have given very serious and careful consideration to the manufacture, selection and testing of iron castings for use in internal combustion engines and other positions where the material is submitted to the action of high pressures, temperatures, superheated steam and other severe influences.

The object of the present paper is to set out some of the results of tests which have been made on irons of different qualities and compositions in the hope that they may prove of interest to the members, provoke a discussion from which some suggestions for further work may arise, and at the same time stimulate interest in this very important question.

Material.

Three irons have been selected from amongst a number which the authors have examined as representing widely different classes of material, and for which fairly complete sets of figures are available as regards:—(1) Change of volume after repeated heating and cooling to and from (a) 450 deg C., (b) 550 deg. C. (2) Tensile strength after annealing for constant time at temperatures between atmospheric and 700 deg. C. (3) Tensile strength at temperatures between atmospheric and 500 deg. C.

The chemical analyses of the materials are shown in Table 1.

Table I.—*Chemical Analyses of Materials Used.*

	A1.	A2.	A3.	A4.	A5.	A6.
Total C.	3.286	3.144	2.845	3.377	3.382	3.295
Gr. C ..	2.716	2.334	1.950	2.647	2.662	2.599
C. C. ..	0.570	0.810	0.895	0.730	0.720	0.696
Si. ..	1.745	1.840	1.447	1.560	1.237	1.716
S. ..	0.110	0.110	0.155	0.073	0.061	0.072
P. ..	1.541	0.868	1.036	0.950	0.751	0.766
Mn. ..	0.155	0.510	0.460	0.540	1.080	1.660

A1 is an iron used for stove plate and other light castings.

A2 is a strong iron used for steam turbines and other marine work.

A3 is a semi-steel used with marked success for dies for tube drawing.

The first two are somewhat similar in composition so far as total carbon, silicon and sulphur are concerned, but have very different percentages of manganese and phosphorus. Although the quantity of total carbon is nearly the same in both irons there is an appreciable variation in the manner in which it exists.

In addition to the three irons referred to above there are given changes in volume, weight and tensile strength after repeated heating from 1 to 20 times, at (a) 450 deg. C. (b) 550 deg. C. and cooling of other three irons whose compositions are shown also in Table 1.

Experimental Methods.

The necessary number of bars 12 in. long and 1½in. dia. were cast from the same ladle, all at one time and under identical conditions of irons A1, A2, and A3. The bars were then rough-machined before treatment. Bars 1 in. dia. by 9 in. long were cast for irons A4, A5, A6, and machined to size before treatment.

Change of volume.—Cylindrical test pieces exactly 1 in. dia. and 6 in. long were prepared from A1, A2 and A3, and approximately 0.625 in. dia. and 5.25 in. long from A4, A5 and A6.

The specimens of the first three were placed in an electrically-heated furnace with closed ends and through which a current of coal-gas passed. The test pieces were gradually raised to the desired temperature, maintained at it for 7 hours and then allowed to cool in the furnace. The dimensions of the bars were measured after each five heatings by means of a vernier reading to a ten-thousandth of an inch.

The A4, A5 and A6 bars were heated for 6 hr. periods without the coal-gas passing through the furnace, being simply bedded in asbestos wool. The dimensions in these experiments were taken by means of micrometer calipers reading to ten-thousandths of an inch.

The temperatures of heating (450 deg. C. and 550 deg. C.) were chosen because the experiments were originally made to determine the most suitable material to use in the liner and piston of a type of internal combustion engine in which the average temperature of the metal had been found to be between 400 deg. C. and 500 deg. C. All further experiments have been made at the same temperatures for comparison purposes. The fact that the results of the tests were found to agree very closely with those obtained in actual practice indicates that the temperatures were well chosen.

Some results are also given for irons A4, A5 and A6 heated to 550 deg. C. after having been previously submitted to 21 treatments at 450 deg. C. and cooled in air. These results are of interest inasmuch as they give an indication of the possible effect of occasional overheating, such as might occur in the event of the cooling medium running short or circulation interrupted.

Annealing.—The test bars, 6 in. long, rough-turned and screwed, 1⅛ in. Whitworth thread at the ends, were placed in an electric muffle-furnace, maintained at the desired temperature for 4 hrs. and then allowed to cool in the furnace, precautions being taken to reduce oxidation to a minimum in all experiments. The bars were then machined to exactly ½ sq. in. area in the parallel portion.

Strength at High Temperatures.—The test pieces were of the same dimensions as those employed in the annealing experiments. They were screwed into the sockets of long holders, and surrounded by an electrically heated furnace which was attached to the machine. The holders themselves were surrounded for a considerable distance by the furnace in order to ensure thorough and uniform heating of the test pieces. Thermocouples were clamped to the test pieces, so that the actual temperature of the metal and not of the furnace was determined. The bars were slowly heated to the desired temperature and when it had become constant, was maintained for half an hour and then tested. Special precautions were taken to ensure that the rate of loading of the specimens was the same in all cases, and as a further check an autographic record was taken of every test.

Each of the materials was tested in the condition as cast and also after having been annealed, by heating to 400 deg. C. for 4 hrs. and allowed to cool in the furnace, in order to remove strains due to casting or machining.

Strength after Repeated Heating and Cooling.

The growth test bars of irons A1, A2 and A3 after treatment were prepared and tested for tensile strength. Materials A4, A5 and A6 were tested more fully as the necessary number of previously machined test pieces were treated and tested after each treatment. Ten sets of bars were placed in the furnace and one set taken out after each of the first 6 heatings and one each after the 9th, 15th, and 20th heating and then tested. The test pieces were 8 in. long by ½ sq. in. area in the parallel portion and screwed ⅞th Whitworth thread at the ends.

Consideration of Experimental Results.

The average results of all the experiments are given in Tables II. to XII. and graphically in Figs. 1 to 6.

Changes in Volume Consequent upon Repeated Heating and Cooling.—A1 shows by far the largest variations when heated in a non-oxidising atmosphere of any of the materials considered in the present paper. The results of the 450 deg. C. heatings are erratic and exhibit no tendency to change in any particular direction. The maximum growth is found after 10 heatings, when the volume decreases until after 20 heatings where a slight increase is again registered, but it appears that this material never attains a constant volume. Heating to 550 deg. C. causes a continued growth and even after 55 treatments there is no indication that constancy will obtain. It is evident that this material is most unsuitable for use in positions where permanency of size or

TABLE II.—*Change of Volume After Repeated Heating to* 450 *deg. C. and Cooling.*

Condition.	A1.		A2.		A3.	
	Volume cub. in.	Change %	Volume cub. in.	Change %	Volume cub. in.	Change %
Original	4.7124		4.7124		4.7124	
After 5 heatings	4.7162	+0.0806	4.7156	+0.0679	4.7147	+0.0488
,, 10 ,,	4.7184	+0.1274	4.7178	+0.1145	4.7167	+0.0912
,, 15 ,,	4.7176	+0.1103	4.7261	+0.2907	4.7197	+0.1549
,, 20 ,,	4.7170	+0.0976	4.7263	+0.2949	4.7187	+0.1359
,, 25 ,,	4.7171	+0.0995	4.7263	+0.2949	4.7187	+0.1359

TABLE III.—*Change of Volume after Repeated Heating to* 550 *deg. C and Cooling.*

Condition.	A1.		A2.		A3.	
	Volume cub. in	Change %	Volume cub. in.	Change %	Volume cub. in.	Change %
Original	4.7124		4.7124		4.7124	
After 5 heatings	4.7273	+0.3160	4.7193	+0.1460	4.7176	+0.1103
,, 10 ,,	4.7396	+0.5770	4.7196	+0.1530	4.7227	+0.2185
,, 15 ,,	4.7556	+0.9170	4.7202	+0.1660	4.7227	+0.2185
,, 20 ,,	4.7692	+1.2050	4.7205	+0.1740	4.7227	+0.2185
,, 25 ,,	4.7892	+1.6290	4.7205	+0.1720	4.7227	+0.2185
,, 30 ,,	4.8006	+1.8720	4.7205	+0.1720	4.7227	+0.2185
,, 35 ,,	4.8183	+2.2480	—		—	
,, 40 ,,	4.8309	+2.5140	—		—	
,, 45 ,,	4.8437	+2.7860	—		—	
,, 50 ,,	4.8479	+2.8750	—		—	
,, 55 ,,	4.8531	+2.9860	—		—	

shape is required, especially if, as is so often the case, the material is subject to oxidising influences. The effect of the treatment is to reduce seriously the strength of the iron.

A2 shows a maximum percentage of growth at 450 deg. C. which is in excess of that of A1 after 20 heatings, but the volume has then become permanent. The maximum growth of this sample at 550 deg. C. is also attained after 20 heatings, but is less in amount than shown by the same material at the lower temperature, and in this respect it differs from the other irons with which the authors have so far experimented, for they have all shown a greater increase at 550 deg. C. than at 450 deg. C. This iron shrinks a little between 20 and 25 heatings, but then remains constant. The effect

TABLE IV.—*Change of Volume After Repeated Heating to* 450 *deg. C. and Cooling.*

	A4.		A5.		A6.	
Condition.	Volume cub. in.	Change %	Volume cub. in.	Change %	Volume cub. in.	Change %
Original	1.6118		1.6900		1.6972	
After 1 heating	1.6146	+0.170	1.6921	+0.006	1.6995	+0.130
,, 2 heatings	1.6193	+0.460	1.6944	+0.260	1.7017	+0.260
,, 3 ,,	1.6195	+0.480	1.6919	+0.112	1.7012	+0.230
,, 4 ,,	1.6130	+0.070	1.6890	—0.059	1.6983	+0.060
,, 5 ,,	1.6124	+0.040	1.6890	—0.059	1.6978	+0.090
,, 6 ,,	1.6119	+0.010	1.6878	—0.030	1.6967	—0.030
,, 9 ,,	1.6149	+0.190	1.6897	—0.017	1.6967	—0.030
,, 12 ,,	1.6164	+0.280	1.6897	—0.017	1.6961	—0.060
,, 15 ,,	1.6137	+0.120	1.6864	—0.213	1.6931	—0.240
,, 18 ,,	1.6134	+0.100	1.6864	—0.213	1.6928	—0.260
,, 20 ,,	1.6134	+0.100	1.6864	—0.213	1.6928	—0.260

TABLE V.—*Change of Volume After Repeated Heating to* 550 *deg. C, and Cooling.*

	A4.		A5.		A6.	
Condition.	Volume cub. in.	Change %	Volume cub. in.	Change %	Volume cub. in.	Change %
Original	1.7642		1.6967		1.7754	
After 1 heating	1.7577	—0.362	1.6834	—0.783	1.7681	—0.411
,, 2 heatings	1.7568	—0.413	1.6844	—0.724	1.7666	—0.495
,, 3 ,,	1.7637	—0.002	1.6887	—0.471	1.7672	—0.461
,, 4 ,,	1.7653	+0.068	1.6892	—0.442	1.7675	—0.444
,, 5 ,,	1.7662	+0.119	1.6925	—0.247	1.7693	—0.343
,, 6 ,,	1.7667	+0.147	1.6928	—0.229	1.7686	—0.383
,, 9 ,,	1.7670	+0.164	1.6931	—0.212	1.7681	—0.383
,, 12 ,,	1.7679	+0.215	1.6920	—0.277	1.7681	—0.383
,, 15 ,,	1.7682	+0.232	1.6914	—0.312	1.7681	—0.383
,, 18 ,,	1.7679	+0.215	1.6914	—0.312	1.7681	—0.383
,, 20 ,,	1.7679	+0.215	1.6914	—0.312	1.7681	—0.383

of the repeated heating is to reduce very considerably the strength, although in a less degree than A1.

A3 shows a much smaller percentage of change than either A1 or A2 at 450 deg. C. The maximum increase is reached after 15 heatings, which is followed by a reduction until 20 heatings when permanency of size is attained. Heating this material 10 times at 550 deg. C. produces an increase of volume greater than the maximum obtained under 450 deg. C. treatment, but it shows no further change even after 30 heatings. It would appear from these results that semi-steel is a more suitable material to employ when alteration of size or shape is to be avoided than ordinary cast iron, as the casting could be heated

TABLE VI.—*Change of Volume After Repeated Heating to* 550 *deg. C. and Cooling After Previous Treatment at* 450 *deg. C.*

	A4.		A5.		A6.	
Condition.	Volume cub. in.	Change %	Volume cub. in.	Change %	Volume cub. in.	Change %
After 20 heatings at 450 deg. C.	1.5430	—	1.6864	—	1.6927	—
After 1 heating	1.5430	—	1.6836	—0.166	1.6930	+0.018
,, 2 heatings	1.5450	+0.129	1.6866	+0.012	1.6944	+0.100
,, 3 ,,	1.5460	+0.194	1.6905	+0.243	1.6956	+0.171
,, 4 ,,	1.5470	+0.259	1.6916	+0.308	1.6970	+0.254
,, 5 ,,	1.5460	+0.194	1.6930	+0.391	1.6959	+0.248
,, 6 ,,	1.5470	+0.259	1.6890	+0.195	1.6944	+0.100
,, 9 ,,	1.5480	+0.324	1.6897	+0.195	1.6944	+0.100
,, 12 ,,	1.5480	+0.324	1.6908	+0.261	1.6944	+0.100
,, 15 ,,	1.5480	+0.324	1.6903	+0.231	1.6944	+0.100
,, 18 ,,	1.5480	+0.324	1.6903	+0.231	1.6944	+0.100
,, 20 ,,	1.5480	+0.324	1.6903	+0.231	1.6944	+0.100

TABLE VII.—*Changes of Weight After Repeated Heating at* 450 *deg. C. and Cooling.*

	A4.		A5.		A6.	
Condition.	Weight Grams	Change %	Weight Grams	Change %	Weight Grams	Change %
Original ..	189.220	—	198.690	—	199.320	—
After 1 heating	189.220	—	198.690	—	199.320	—
,, 2 heatings	189.225	+0.022	198.695	+0.002	199.320	—
,, 3 ,,	189.242	+0.011	198.705	+0.007	199.340	+0.010
,, 4 ,,	189.240	+0.011	198.715	+0.012	199.340	+0.010
,, 5 ,,	189.240	+0.011	198.715	+0.012	199.340	+0.010
,, 6 ,,	189.245	+0.013	198.715	+0.012	199.345	+0.012
,, 9 ,,	189.295	+0.039	198.790	+0.050	199.390	+0.035
,, 12 ,,	189.310	+0.047	198.812	+0.061	199.410	+0.045
,, 15 ,,	189.320	+0.053	198.815	+0.063	199.420	+0.050
,, 18 ,,	189.340	+0.063	198.820	+0.066	199.435	+0.057
,, 20 ,,	189.355	+0.071	198.835	+0.073	199.450	+0.065

and cooled a few times before being put into service and, further, the strength is comparatively little affected by the treatment.

A4 reaches its maximum size at the third heating, then steadily contracts until the sixth, increasing again to the 12th, and then shows no further change. The total amount of growth is greater than that of either of the first three irons with the exception of A1 at 550 deg. C. Although the effect of treatment at 550 deg. C. is to cause a quicker attainment of constant size the amount of the increase is greater than that at the lower temperature, and curiously enough the first three heatings produce a diminution instead of an increase of volume. The effect of treatment at 550 deg. C. on the material after it has been heated 20 times at 450 deg. C. is a steady increase of size for nine heatings, when no further change takes place.

TABLE VIII.—*Changes of Weight After Repeated Heating to 550 deg. C. and Cooling.*

Condition.	A4.		A5.		A6.	
	Weight Grams	Change %	Weight Grams	Change %	Weight Grams	Change %
Original	207.130	—	199.490	—	208.390	—
After 1 heating	207.160	+0.014	199.510	+0.010	208.400	+0.004
,, 2 heatings	207.180	+0.028	199.530	+0.020	208.420	+0.014
,, 3 ,,	207.230	+0.048	199.590	+0.050	208.470	+0.038
,, 4 ,,	207.250	+0.057	199.600	+0.055	208.490	+0.047
,, 5 ,,	207.260	+0.062	199.605	+0.057	208.500	+0.052
,, 6 ,,	207.260	+0.062	199.610	+0.060	208.500	+0.052
,, 9 ,,	207.290	+0.077	199.635	+0.072	208.520	+0.062
,, 12 ,,	207.310	+0.086	199.650	+0.080	208.550	+0.076
,, 15 ,,	207.310	+0.086	199.655	+0.082	208.550	+0.076
,, 18 ,,	207.330	+0.096	199.665	+0.087	208.570	+0.086
,, 20 ,,	207.350	+0.106	199.680	+0.095	208.590	+0.096

TABLE IX.—*Showing the Effect of Annealing at Various Temperatures:*

Temperature, deg. C.	A1.		A2.		A3.	
	Tons per sq. in.	Change %	Tons per sq. in.	Change %	Tons per sq. in.	Change %
15	10.20	—	15.00		16.60	—
100 ..	10.50	+ 2.94	15.05	+ 0.33	16.45	— 0.903
200 ..	10.45	+ 2.45	15.10	+ 0.66	16.50	— 0.603
300 ..	10.85	+ 6.37	14.84	— 1.06	16.20	— 2.400
400 ..	11.00	+ 7.84	14.40	— 4.00	16.80	+ 1.204
500 ..	10.70	+ 4.90	14.10	— 6.00	15.90	— 4.216
600 ..	9.55	— 6.37	13.20	—12.60	14.90	—10.240
700 ..	8.20	—19.61	11.84	—21.06	13.40	—19.270

Heating A5 at 450 deg. C. at first causes an increase of volume reaching its maximum at the 2nd treatment, but between 3rd and 15th a steady diminution of volume results, when at the latter constancy is obtained. Heating this material at 550 deg. C. causes a contraction to take place, which diminishes to the 9th, then increases slightly to 15th, after which no further change takes place. Heating this material to 550 deg. C., after previously being submitted to 20 treatments at 450 deg. C., causes a steady increase in volume for the first 12 heatings and shows no further change after a slight decrease at 15th.

Heating A6 at 450 deg. C. causes it to behave in a very similar manner to A5, although contraction of volume begins a little later, and the ultimate reduction of size is slightly greater than that of either A4 or A5. Heating to 550 deg. C. causes a contraction in volume after the first four heatings, but no further change occurs as a result of subsequent treatment. Heating to 550 deg. C. after previous treatment at 450 deg. C. produces a growth which reaches its maximum at the 4th; between the 5th and 6th heatings there occurs a considerable reduction in volume, but further heatings produce no change. It is to be noted that this iron retains its strength after repeated heating and cooling better than any other which the authors have mentioned in this Paper; in fact, the strength is actually greater to the extent of 3.21 per cent. after the

TABLE X.—*Strength at Elevated Temperatures in Cast and Annealed Condition.*

	A1.		A2.		A3.	
	Tons per sq. in.		Tons per sq. in.		Tons per sq. in.	
Temperature	As cast.	Annealed.	As cast.	Annealed.	As cast.	Annealed.
15	10.15	11.00	15.00	15.00	16.60	16.80
100	9.90	11.00	14.92	15.17	16.40	16.80
200	9.70	11.50	14.40	14.80	16.05	16.90
250	9.70	11.40	13.90	14.70	15.65	16.70
300	10.15	11.25	13.30	14.90	15.90	16.90
350	10.30	11.20	14.00	14.90	16.30	16.90
400	10.20	11.30	14.80	15.08	16.95	16.90
500	10.05	11.00	13.95	14.40	15.90	15.84
600	7.30	8.10	12.80	—	—	—
700	3.35	4.00	6.40	—	—	—
800	—	—	2.70	—	—	—

TABLE XI.—*Change of Strength After Repeated Heating and Cooling.*

Condition.	450°C.						550°C.					
	A4.		A5.		A6.		A4.		A5.		A6.	
	Tons per sq. in.	Change per cent.	Tons per sq. in.	Change per cent.	Tons per sq. in.	Change per cent.	Tons per sq. in.	Change per cent.	Tons per sq. in.	Change per cent.	Tons per sq. in.	Change per cent.
Original	12.96	—	13.36	—	14.73	—	12.96	—	13.36	—	14.73	—
After 1 heatings ..	12.96	—	13.87	+ 3.817	14.31	— 2.851	12.49	— 3.626	13.33	— 0.224	14.09	— 4.344
,, 2 ,, ..	12.34	— 4.780	13.58	+ 1.646	14.72	— 0.067	12.74	— 1.690	13.38	— 0.149	14.11	— 4.209
,, 3 ,, ..	12.83	— 1.003	13.51	+ 1.122	14.46	— 1.833	12.59	— 2.855	13.41	+ 0.374	14.49	— 1.629
,, 4 ,, ..	12.82	— 1.080	13.52	+ 1.197	14.32	— 2.873	12.45	— 3.935	13.65	+ 2.170	14.48	— 1.697
,, 5 ,, ..	12.25	— 5.470	13.55	+ 1.422	14.84	+ 0.746	12.65	— 2.392	13.67	+ 2.320	14.64	— 0.611
,, 6 ,, ..	12.69	— 2.083	13.31	— 0.374	14.91	+ 1.222	12.04	— 7.098	13.48	+ 0.898	14.63	— 0.678
,, 9 ,, ..	11.90	— 8.178	13.15	— 1.571	14.98	+ 1.697	10.83	—16.430	13.41	+ 0.374	14.80	+ 0.475
,, 15 ,, ..	10.72	—17.280	13.12	— 1.795	15.03	+ 2.036	9.32	—28.081	13.36	—	14.93	+ 1.357
,, 20 ,, ..	10.52	—18.820	13.22	— 1.020	15.20	+ 3.210	7.25	—44.060	13.41	— 1.690	15.24	+ 3.449

450 deg. C. treatment than the original, while the 550 deg. treatment has resulted in an increase of 3.44 per cent. on the strength of the original iron.

The satisfactory behaviour of this iron the authors consider to be mainly due to the high manganese and moderate phosphorus content. It is of interest to note that irons A4, A5, A6 are very much alike in composition except for the manganese, and that the loss of strength is less as the manganese increases.

Changes of Weight Consequent upon Repeated Heating and Cooling.

The determinations were made only on the last three irons whose analyses are given in Table I., and the results, which call for little comment, are given in Tables VII. and VIII. It will be observed that in all cases there is a steady and fairly regular increase after each heating. At 450 deg. C. A6 shows a rather smaller total increase than A4 or A5, whilst at 550 deg. C. A4 gains rather more than A5 and A6.

Table XII.—*Change of Strength After Repeated Heating and Cooling*

Condition	A1.		A2.		A3.	
	Tons per sq. in.	Change %	Tons per sq. in.	Change %	Tons per sq. in.	Change %
Original ..	10.20	—	15,00	—	16.60	—
After 25 heatings at 450 deg. C.	9.72	— 4.70	13.50	—10.00	14.85	– 10,54
After 25 heatings at 550 deg. C.	—	—	13.00	—13.30	13.99	– 15.70
After 55 heatings at 550 deg. C.	7.50	—26.47	—	—	—	—

Annealing.—The results of these experiments are shown in Table IX. The principal features are the very pronounced weakening which results from annealing at temperatures above 400 deg. C. It has previously been shown by Longmuir and Hatfield that annealing grey cast irons at high temperature destroys the strength. The other feature is the maximum strength which the materials attain at a temperature between 200 deg. C. and 400 deg. C., and which varies with different irons. The loss of strength at 700 deg. C., the highest temperature employed in these experiments, is practically of the same order for all materials.

A1 increases up to 400 deg. C., when it is 7.84 per cent. stronger than the untreated material, at 500 deg. C. a reduction occurs and continues to 700 deg. C., when the strength is reduced by 19.6 per cent.

A2 increases slightly when treated at temperatures up to 200 to 250 deg. C., after which there is a steady fall to 21.06 per cent. below the original at 700 deg. C.

A3 shows a loss of strength at all temperatures up to 300 deg. C., then it increases to 1.204 per cent. above the untreated at 400 deg. C., afterwards decreasing until at 700 deg. C. the strength is 19.27 per cent. less than the original material.

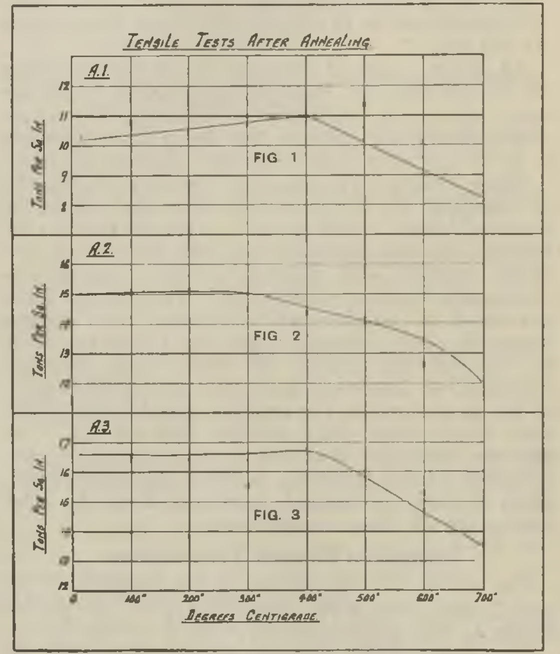
These results are somewhat difficult to explain at present. It is conceivable that the release of internal stress might cause a certain amount of increase in the strength, but the fluctuation between minima and maxima points seems to require some further explanation. The authors have examined a number of annealed irons microscopically, but it would make the paper too long to include the results of their work in this direction, so that they prefer to reserve that part of the investigation for another occasion and after they have more fully studied the subject. It appears, however, that the arrangement and distribution of the graphite, carbides and phosphides plays a very prominent part, as does also the contiguity of these constituents.

Strength at Elevated Temperatures.

The means of the results on the material "As cast," and also after annealing, are shown in Table X. and graphically in Figs. 4, 5 and 6.

Very few results of high temperature tests of cast iron have so far been published, and the majority of these are not in agreement with those obtained by the present authors, or with some unpublished results of other investigators of which they have knowledge.

Tests on Material in Natural Condition.—The most striking feature about these results is the well-defined maxima and minima points exhibited by all materials, and which occur at nearly the same temperature for each of the materials. A1 exhibits a minimum at 200 deg. C. which is, although well marked, less pronounced than in the case of A2 and A3. The maximum at 400 deg. C. is not well marked although distinct, and the strength at this point is approximately ⅛ per cent. greater than that of the original material tested at 15 deg. C. At temperatures above 500 deg. C. A1, A2 and A3 all lose strength somewhat rapidly, A1 has a strength of only 3.35 tons per sq. in. at 700 deg. C. or 67 per cent. reduction.



A2 is at minimum strength at 300 deg. C. and maximum at 400 deg. C., both points being much more pronounced than in the case of A1. The strength falls away continuously from 15 to 300 deg. C. where the reduction amounts to 11.3 per cent., rises to 400 deg., where the strength is about the same as at 15 deg., and falls away again to 500 deg. to 7.0 per cent. below the original.

A3 behaves similarly to A2, giving its highest strength at 400 deg. with an increase of 2.1 per cent. The minimum, which is 5.95 per cent. below the 15 deg. result, occurs at 250 deg. C., after which it increases to 400 deg. C. and then quickly falls away to 15.9 tons per sq. in., representing a reduction of 4.22 per cent. at 500 deg. C.

Tests of Material Previously Annealed.—The results generally are of the same type as obtained with the material in the untreated condition, but the variations of strength are smaller. The effect of the annealing has been to give greater regularity, and it will be noticed that the curves in Figs. 4, 5 and 6 are smoother, but the dip between 250 and 300 deg. C. is still evident in A2 and A3.

A1 gives a totally different result after annealing than the " as cast " material; the maximum strength is obtained at 200 deg. C., the point at which the minimum is given by the untreated iron, and further there appears no marked rise or fall below 500 deg. C.

The Authors are at present unable to offer an adequate explanation of these phenomena but are carrying out at present some investigations, the results of which they hope may shed some light on this intricate but exceedingly interesting and important problem. They have reason to think that the distribution of the graphite and phosphide eutectic is largely responsible, as well as the nature and amount of the gases occluded and dissolved in the iron.

Strength after Repeated Heating and Cooling.

The details of the tests of the six materials after repeated heating at 450 deg. and 550 deg. C. are shown in Tables XI. and XII. A1 and A2 both suffer a considerable reduction of strength as a result of the treatment as also does A4. It is somewhat curious that after 25 heatings at 450 deg. C., A2 shows a percentage loss of strength of about double that lost by A1 under similar treatment, but when the temperature of heating is 550 deg. C. the position is reversed.

A4 shows a very great loss of strength at both temperatures, especially after the sixth heating.

A5 retains its strength to a very large degree at both temperatures, the percentage reduction being only 1.02 and 1.69 after 20 heatings at 450 deg. and 550 deg. respectively.

A6 behaves differently from any of the others, inasmuch as it actually appreciates in strength at both temperatures, a fact that has already been noted in an earlier section of this Paper.

The irons dealt with in this Paper all contain the normal proportion of total carbon as they were not made from any specially selected brand of iron, the object being to obtain information as to the behaviour of castings made from ordinary everyday material, with or without special additions or treatment. Total carbon is a most important factor in determining the behaviour of iron under repeated heating and cooling however the heating may be applied, and from infor-

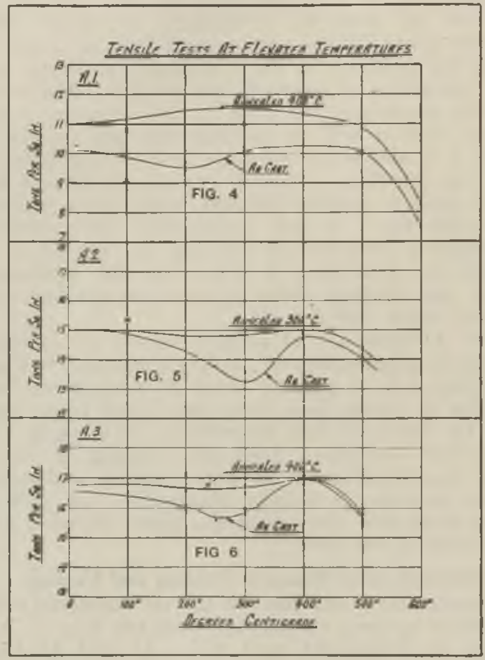


FIG. 4

FIG. 5

FIG 6

mation in their possession the Authors are confident that had the total carbon in A6 been under 3.00 per cent. it would have given still better results as regards growth and strength after repeated heating and at elevated temperatures. They are aware that in some quarters the use of manganiferous cast iron is objected to for reasons which it is difficult to understand, but it is their experience that such material gives results, in practice, much superior to that which contains low manganese. A6 is an iron which can be quite easily machined at a good speed and gives good surfaces both as regards appearance and wearing properties.

The investigations are being continued, and it is hoped to publish very shortly further results upon other materials of the cast-iron type. Semi-steel appears to offer at least a partial solution to the problem of providing a material capable of being easily cast, which will retain a greater proportion of its strength at atmospheric temperature when submitted to the action of more elevated temperatures. The authors are experimenting with such material not only in its ordinary form, but also containing certain proportions of special constituents, and prepared under different conditions. The question of heat treatment of cast iron and semi-steel is also receiving their attention.

In the present Paper the authors have purposely given only the results of tests as they have been obtained and refrained from propounding any theory to explain the various phenomena, firstly because their main object was to show how irons of widely different qualities were affected by various heat influences and secondly because the theoretical aspect of the question is of so much importance that they deemed it better to reserve it for another occasion when it could receive more detailed attention.

The authors desire to acknowledge their indebtedness to all those who have assisted them by providing material and in other ways. To Mr. J. Cameron, of Kirkintilloch, for providing the semi-steel and for the great interest he has shown in the experiments.

They also desire to thank the directors of

Messrs. Scotts' Shipbuilding & Engineering Company, Limited, Greenock, in whose works and laboratories a considerable part of the experimental work was carried out, for permission to make use of the data so obtained.

DISCUSSION.

Mr. Young remarked that if the figures adduced did not agree with their theories it did not so much matter, as the authors had given them these figures showing the result of their work without drawing their conclusions, and left it to them to use what they had discovered. This Paper was just the type the Institution wanted. The greatest compliment he could pay the authors was that he hoped they would go on with it.

Prof. Turner agreed that the Paper contained so much detail that they could scarcely criticise it in a few minutes. It opened up a new field of work, although they had been told others had been working recently in the same direction. They might regard this Paper as filling in a space in the work of Dr. Carpenter in connection with the effect of what he called high temperatures. They had not hitherto had information on cast-iron at those temperatures at which it was used in connection with superheated steam. They did know about the behaviour of cast iron where they had red heat and beyond, for such things as`fire bars, etc. But the information contained in this Paper filled in the space and supplied what was required. It would be a matter for thought and consideration as to the explanation of the effect of annealing upon cast iron. They might suppose that castings which had been allowed to remain in sand and to cool in a normal way would have annealed themselves, and that the annealing at so low a temperature as 300 to 400 deg. C. would not make any appreciable difference. Apparently that was not the case, and there was an appreciable difference due to this annealing. All kinds of suggestions might be made as to the reasons for the effect of 300 deg., and so on, because they obtained a somewhat similar effect in connection with some of the carbon steels. There was an absence of theory from the authors, and he thought further consideration would tell them the right theory. But for the time being, as Mr. Young suggested, it was well to accumulate more facts of the kind which the authors had been good enough to place before them.

Shrink Due to Low Temperatures.

Prof. Touceda mentioned that he had conducted a great many experiments to remove shrink, their idea being to make a study of the amount of shrinkage caused by low temperatures.

Dr. Johnson expressed towards the authors of the Paper his great admiration for the careful and scientific manner in which they had carried out their experiments, and he would like to ask whether they intended, in their continuation of the work, to include microscopic work and other kinds of mechanical and physical tests, such as hardness impact tests. The Institute was fortunate in having such a Paper presented to its members, containing an account of careful scientific research of such high character.

Dr. P. Longmuir, in congratulating the authors upon the excellence of their work, said they were favoured the previous night by a very good description of the original research. That morning they had an example that fitted in with that description given by the Principal of Birmingham University.

Mr. Matt. Riddell, invited to wind up the discussion, said he had seen some of the details and the material worked out, and considered the authors had done something really splendid for the information of that meeting. It was something they had been looking forward to for a long time—a piece of real original research. Prof. Campion was a man trained to do research work, and knew more on the subject of cast iron than almost anyone else. He had special facilities for carrying on his work, and also had the necessary practical experience; and if he could be persuaded to continue in this research work he was confident that Prof. Campion would furnish them with valuable information at present unknown. Alluding to the diagrams showing some change at 400 to 500 deg. C., Mr. Riddell said there must be some important factor in operation in the iron at that particular temperature which required investigation.

The Author Replies.

Prof. Campion, in reply, thanked the Conference for the kind way in which they had received the Paper, and also acknowledged the contributions made to the discussion. He quite realised that in a few minutes it was practically impossible to discuss such a Paper, because it was very difficult to digest. He trusted that those who had not been able to speak would send written contributions to the General Secretary, and assured the meeting that he and his colleague would be glad to consider them, and also to reply to Dr. Longmuir, if he would do likewise. Mr. Young had referred to other results which confirmed more or less several results they obtained. Prof. Turner raised the question about possible theories. They had given none in the Paper, because they felt they had not done sufficient work to put forward any theory. It was a very complex problem, and showed distinctly different phenomena from that which occurred at high temperature work, such as Dr. Carpenter carried out. It therefore wanted very careful consideration and far more tests and experiments than they had been able to carry out or analyse. In that respect he might also answer Dr. Johnson, for they had already done a very large amount of micro examination, thermo and other mechanical tests. But the Paper was already loaded, and he thought it was unwise to give too much at once. However, another Paper was in course of preparation for another Institution, which would be presented shortly, and he would be glad to forward to Dr. Johnson, or any gentleman present who desired it, a copy of that Paper when it was presented, and have their criticisms on it. Prof. Turner's remarks were interesting, because he did think that the question of recording casting temperatures had a direct bearing on the behaviour of these metals when heated and cooled at these low temperatures. Some preliminary experiments pointed emphatically to the fact that the amount and nature of the gases included in the iron largely affected the results; and this was largely the explanation of some of these metals beginning to contract instead of expanding when heated.

Mr. Donaldson also replied briefly, saying that they had carried out a considerable amount of work in addition to what was published, particularly in relation to the change of strength after heating and cooling, as dealt with on page 225. But they did not want to publish it, because they had not got to the end of their tests on annealing. He might also say, as to continuing on the lines of work undertaken, that they intended to go on testing those irons with the addition of special elements, to see what effect those special elements had on cast iron, chromium, and so forth.

THE DEVELOPMENT AND MANUFACTURE OF HIGH-TENACITY BRASS AND BRONZE.

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It is intended in this Paper to treat synthetically the development of complex high-strength brasses and to consider the principal problems of manufacture. In the past these alloys were termed "manganese bronzes," and in specific cases prefixed by either the inventor's or a trade name. This no doubt arose from their complex nature and costly practical evolution. At the same time it is a misnomer and surrounds them with an air of mystery which retards rather than advances their progress.

The base of practically all the so-called "manganese bronzes" is brass, and they do not derive their special virtues from manganese. The Institute of Metals has suggested the name "brass," preceded by the name of the special elements introduced, *e.g.*, the presence of aluminium would identify it as "aluminium brass," manganese as "manganese brass," if both these elements are present as "aluminium-manganese brass," and so on. This is a step in the right direction, and the recommended appellation will be adopted throughout this Paper.

To understand the function of the numerous special elements commonly introduced, viz., aluminium, manganese, iron, nickel, etc., a working knowledge of the constitutional diagram of the copper-zinc series of alloys is essential.

This diagram is generally avoided by the foundryman and engineer on account of its formidable appearance and the adoption of Greek terms.

Yet it presents a fund of information which may be readily interpreted by anyone interested.

Fig. 1 shows both the constitutional diagram and the physical properties of the pure copper-zinc series of alloys in the "cast" state.

Considering the interpretation of the constitutional diagram only, *i.e.*, the thin black lines, from lines ABCDE the melting point of any brass may be obtained; increase the temperature by 10 to 12 per cent. and a good idea of the correct casting temperature is obtained. From line AFMNOQ the temperature of complete solidification. The difference of temperature between these two lines is a measure of the range of temperature through which any brass cools during solidification. Area enclosed by AFHG, including all brasses to 37.2 per cent. zinc, shows that those containing up to 30 per cent. zinc will proceed, uninterrupted by any subsequent physical changes after solidification, *i.e.*, they will consist of a single homogeneous solid solution of copper and zinc at all temperatures. This solid solution is termed "alpha" brass, and for all practical purposes is unaffected by the rate of cooling.

Exceeding 30 per cent. zinc, another constituent appears alongside with the "alpha," and for want of a better name is termed the "beta" constituent. As the zinc content increases, the greater the quantity of the "beta" and the less the quantity of "alpha," and between 46.7 per cent. and 49.7 per cent. zinc none of the "alpha" constituent exists, but only the "beta." This is clearly shown by Figs. 3 to 6, representing 65/35, 60/40, 55/45, and 53.3/46.7 brasses respectively cut from 2½ in. sq. ingots.

In the 30 to 37.2 per cent. zinc series of brasses the line FHG marks where they pass from a region in which both the "alpha" and "beta" phases can exist side by side into the main "alpha" zone, where this constituent alone is stable. The "beta" constituent must then exist in a beta-stable state, and, if normally cooled, changes into the "alpha" phase on the alloy passing through the temperature represented by that point on line FHG.

If, now, a brass of this series is quenched in the "alpha beta" area, FHIM, and the rate of cooling is such as not to permit the natural change from the " alpha beta " to " alpha," then a duplex structure will be formed, and the brass

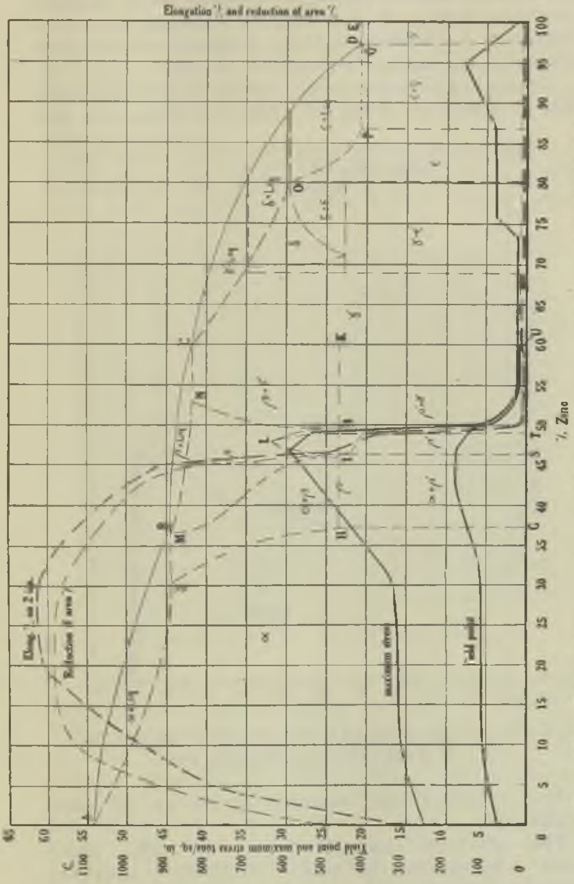

FIG. 1.—CONSTITUTIONAL DIAGRAM OF PHYSICAL PROPERTIES OF CU-ZN ALLOYS " AS CAST."

will be hardened to an amount determined by the percentage of the " beta " constituent present.

This point has been somewhat elaborated to demonstrate that brasses containing between 30 to 37.2 per cent. zinc are affected by heat treatment, and though not of practical importance, so far as improved mechanical properties are concerned, an understanding of these physical changes explains many of the defects common to these brasses. A further feature of this series is that they can be worked either hot or cold.

Exceeding 37.2 per cent. and up to 49.7 per cent. Zn a complex state of affairs exists, and the "beta" constituent remains stable at all temperatures.

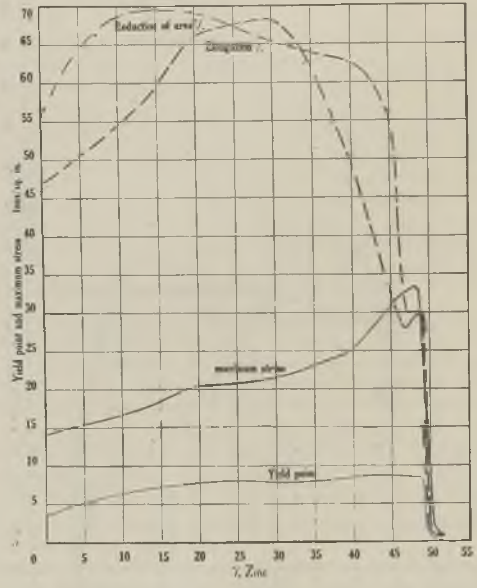

FIG. 2.—MECHANICAL PROPERTIES OF CU-ZN ALLOYS AFTER TREATMENT.

The physical changes shown to take place after solidification by region FMNCUG are not strictly correct, and are subject to alteration of academic rather than practical importance. Brasses containing 37.2 to 46.7 per cent. Zn being possibly the most important series of the Cu-Zn alloys form the basis of all high-tenacity brasses, and consist of both the " alpha " and " beta " constituents. If quenched from high temperatures—*i.e.*, temperatures above the line IM—the change from " beta " to the " alpha beta " is suppressed. Such brasses, then, may have an all " beta " structure—*i.e.*, their physical properties may conform in many respects to brasses containing between 46.7 and 49.7 per cent. Zn. It is also evident that the nearer the zinc content to the limit 46.7 per cent. the lower the temperature necessary to effect this physical change.

The next group of alloys to be considered are those containing 46.7 to 49.7 per cent. Zn. These have little commercial value. Their constitution is ambiguous. According to the accompanying diagram, the region of true stability of " beta " brasses is confined to temperatures above 470 deg. C., and whilst it must be admitted, by the inclusion of line HI IK, that some critical change does occur at these temperatures, which the author has never been able to demonstrate by heat treatment alone, that they mark the transition of the " beta " constituent into its component parts, " alpha " and " gamma," as is commonly alleged. That some critical change does occur at or about 620 deg. C. is supported by :—(1) It marks the true limiting forging temperature of practically all

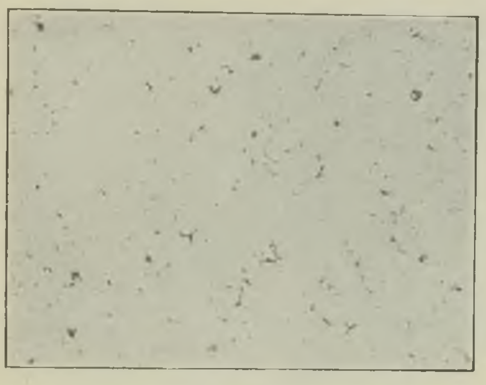

FIG. 3.—65/35, BRASS AS CAST.

the "beta" brasses; (2) it indicates the temperature of incipient heat fragility; (3) it is the correct annealing temperature for practically all pure brasses.

It is of interest to note at this stage that it is brasses which enter into region MIJN—*i.e.*, the "beta" brasses, which specially lend themselves to working hot, whilst those consisting of only the "alpha" constituent are peculiarly suitable for working cold.

Exceeding 49.7 per cent. Zn, a new constituent, gamma, makes its appearance. This is a hard, brittle alloy, and its inception in the most minute traces renders brass extremely brittle and useless as a material of construction. So brittle is the "gamma" phase that an alloy containing 60 per cent. Zn—*i.e.*, all "gamma"—may be crumbled between the fingers.

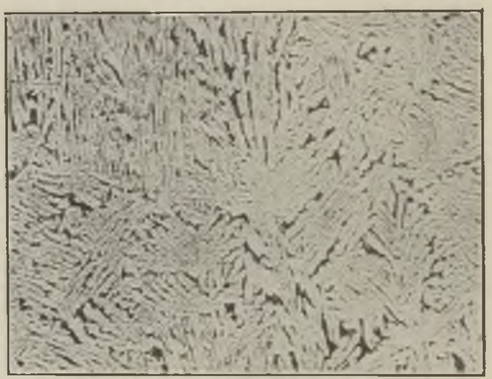

FIG. 4.—60/40, BRASS AS CAST.

The thick black lines, Fig. 1, show the physical properties of pure brass, correctly cast in chill moulds; and in Fig. 2, the physical properties after mechanical and thermal treatment, such as to remove completely casting structure, internal strain and heterogeneity. In short, No. 1 may be used as a standard of the physical properties of brass castings. No. 2 to rolled, extruded and forged brass when correctly annealed.

Development of High-Tenacity Brass.

In this research constant conditions were maintained throughout, eliminating all variables except the one desired, viz., chemical composition. For this reason virgin metals and specially prepared stock alloys were used, the chemical compositions of which are given in Table 1. Two grades of zinc were adopted, owing to the uncertain test-figures previously obtained from castings and forgings made with the lower grades of spelter.

Owing to the difficulties of obtaining standard conditions with a sand mould, each casting was made in a 2½ in. sq. chill mould, pouring with exactly 10 per cent. superheat and controlling the temperature of the mould at exactly 130 deg. F. (55 deg. C.).

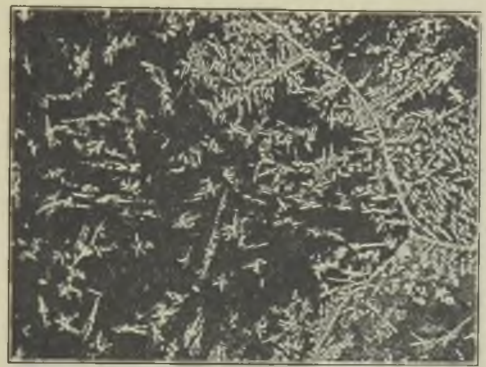

FIG. 5.—55/45, BRASS AS CAST.

Physical Tests.—Tensile tests were prepared in accordance with the specification of the Engineering Standards Committee, the area being 0.25 sq. in. and the gauge length 2 in. A permanent set of 0.01 in. is recorded as the yield point.

Hardness.—The Brinell ball-test and the Shore scleroscope were used for this purpose. The former being made with a 10 m/m ball under a pressure of 1,000 kgs., maintained for exactly 30 sec., whilst the latter were made with a soft hammer.

In order that complete data should be obtained both regarding the peculiarities of manufacture and mechanical properties, each alloy was made under works conditions. Melting was performed in a 50 or 100 lbs. crucible, according to the size of casting, in a natural-draught coke furnace.

The method of introducing the various special metals investigated, and the precautions necessary, will be detailed under each distinctive heading. These, by no means arbitrary or exhaustive, represent a practice that has withstood the test of time and can be commended.

Mechanical Treatment.—Where it was desired to investigate in the forged or heat-treated condition, the lower half of the ingot was forged into 1 in. sq. bars. In the case of cold-working alloys, a 100-lb. ingot was cast 1.05 in. by 4 in. wide. The lower half was cold rolled in three passes to 0.55 in., annealed at the correct temperature, reduced to 0.45 in., and re-annealed so as to restore to its original "cast" Brinell hardness number before testing.

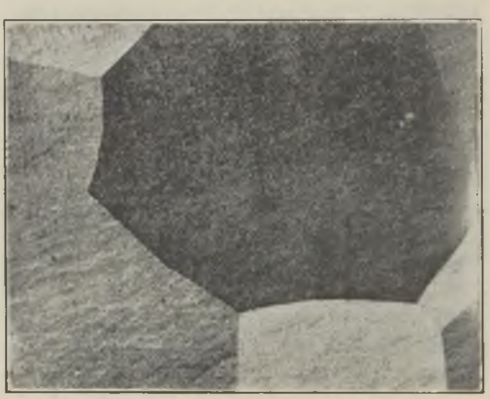

Fig. 6.—53/47, Brass as Cast.

Dynamic Stress Tests.—Both alternating and single-blow impact tests were made where possible. In the former the test-piece used was 4 in. × ½ in. × ½ in. with a 1/16 in. radius groove milled in the centre of one face, at right angles

TABLE I.—*Analyses of Materials Used.*

Material.	Zn.	Cu.	Pb.	Fe.	Si.	Al.	Sn.	Cd.	O.	P.	Co.	Ni.	As.	Mn.
Zinc (Crescent Brand) ..	99.99	Nil.	Tr.	Tr.	Tr.	—	—	Tr.	—	—	—	—	—	—
Zinc (Crown Brand) ..	98.58	0.03	1.13	0.14	Tr.	—	—	0.12	—	—	—	—	—	—
Copper (Wallaroo Brand)	—	99.81	Tr.	Tr.	—	—	—	—	0.19	—	—	Nil.	—	—
Aluminium	—	Tr.	—	0.40	0.09	99.51	—	—	—	—	—	—	—	—
Tin	Nil.	Nil.	0.20	Nil.	—	Nil.	99.7	—	—	—	—	—	0.10	—
Ferro-zinc	94.10	0.29	1.16	4.45	—	—	—	—	—	—	—	—	—	—
Ferro-copper	—	90.00	—	10.00	—	—	—	—	—	—	—	—	—	—
Copper-manganese ..	—	72.73	0.09	2.36	0.30	—	—	—	—	0.03	—	—	—	24.35
Cupro-nickel	—	92.58	—	Tr.	—	—	—	—	—	—	—	7.42	—	—
Cupro-cobalt	—	90.00	—	0.20	—	—	—	—	—	—	9.76	0.04	—	—

TABLE I.A.—*Physical Properties of Pure Brass.*

Composition.		Condition.	Y. P. Tons per sq. in.	M.S. Tons per sq. in.	E. Per cent. on 2 in.	R. A. Per cent.	Alternating Impact No.	Brinell hardness No.	Scleroscope hardness No.
Cu.	Zn.								
70	30	As cast	6.50	16.70	58.00	57.00	79	55	15
		As forged and annealed	8.00	21.50	68.00	65.00	85	57	15
59	41	As cast	8.80	24.90	45.00	49.70	79	90	14
		As forged	9.00	26.00	47.00	62.00	87	90	14
		Forged and annealed, 650° C. for 1 hr. ..	7.00	24.00	49.00	55.00	—	79	12
53.3	46.7	As cast	9.00	29.70	24.00	21.50	34	108	18
		As forged	9.70	32.80	28.00	30.60	49	114	18
		Forged and annealed, 650° C. for 1 hr. ..	7.50	29.10	22.50	31.60	—	108	18
51.2	48.8	As cast	7.20	26.90	19.00	21.50	27	108	18
		As forged	9.20	33.40	37.00	33.50	36	114	18
		Forged and annealed, 650° C. for 1 hr. ..	5.30	29.00	25.00	27.00	—	108	18
50.19	49.81	As cast	6.00	8.80	1.00	1.50	1	108	18
		As forged	2.30	15.80	5.00	5.50	9	117	19

to the principal axis. A steel tup having a total weight of 10 lbs. was allowed to fall from a height of 18½ in. on to the test-piece, the first blow being given on the face opposite to the groove, and, for every succeeding blow, the test-piece rotated through an angle of 180 deg. The blows were delivered at a regular rate of 25 per min., and that number taken to break completely the test-piece, was recorded as the alternating impact number. The single-blow impact test was made in the Izod machine, using the standard 10 m/m square test-piece, notched 2 m/m deep at an angle of 45 deg. and the striking hammer contacting the test-piece at a distance of 22 m/m above the bottom of the notch.

Aluminium Brasses.

Manufacture.—The copper was first melted under charcoal, the necessary additions of aluminimum made with stick aluminium and the zinc worked in last. The whole was well stirred, introducing a little salt from the bottom of the pot, and allowing to remain in the furnace until the desired temperature had been reached, this usually taking from 5 to 8 mins. The pot was withdrawn, the temperature measured with a Pt.—Pt.—Rh. thermocouple and cast at the predetermined temperature.

From the point of view of practical utility 1.0, 1.5, 2.0, 3.0, 4.0, 4.5, and 5.8 per cent. of aluminium were chosen as the most suitable quantities. These were decided upon from a series of exploratory casts, when it was found that 1 per cent. Al. equalled approximately 5.6 per cent. Zn. in its effect on the general physical properties. For example, a 70 per cent. Cu.-26.5 per cent. Zn.-3.5 per cent. Al. brass possesses the principal features of ordinary Muntz metal; a 70 per cent. Cu.-24.2 per cent. Zn.-5.8 per cent. Al. brass somewhat similar features to a 53/47 *id est*, all "beta" brass. Likewise a 59 per cent. Cu.-39.67 per cent. Zn.-1.33 per cent. Al. brass appears to be equivalent to 70 per cent. Cu.-24.4 per cent. Zn.-5.8 per cent. Al. brass or to a 53/47 brass and so on. These equivalents have also been worked out by Guillet from their structure, and his figure of 6 is in fairly close agreement with the above.

The physical test results obtained from the large scale alloys are embodied in Table II.

Chill Cast.—Prominence is given to the remarkable effect of small quantities of aluminium in increasing the yield point and the strength of both 70/30 and 59/41 brass, which is accompanied by a

TABLE II.

No.	Actual composition.					Physical condition.	Y. P.	M. S.	E.	R. A.
	Cu.	Zn.	Al.	Mn.	Fe.		Tons per sq. in.	Tons per sq. in.	Per cent. on 2 in.	Per cent.
9	69.79	26.67	3.54	Nil.	Nil.	As cast	13.60	29.30	26.00	27.60
						As forged	23.40	37.10	34.00	41.90
10	69.13	26.32	4.55	—	Trace.	As cast	17.6	31.9	8.0	11.7
						As forged	20.3	38.6	17.00	20.00
11	69.42	24.68	5.90	—	—	As cast	28.10	38.00	3.00	1.50
						As forged	32.50	42.30	6.00	8.40
A.1	59.48	39.52	1.00	—	—	As cast	14.80	32.00	30.00	33.50
						As forged	11.10	31.30	41.00	44.60
A.2	58.35	40.11	1.54	—	—	As cast	16.4	35.20	17.00	18.50
A.3	58.26	38.56	2.18	—	—	As cast	16.00	36.40	16.00	21.50
						As forged	11.70	37.40	27.00	33.50
A.4	59.85	37.13	3.02	—	—	As cast	22.30	42.00	18.50	21.50
						As forged	19.00	40.3	24.50	30.60

No. 11 showed 133 crystals per sq. cm. as cast and 2,430 when forged.

TABLE II.—continued.

No.	Tensile Fracture.	Impact No.	Fracture.	Izod impact No.	Brinell hardness No.	Scleroscope hardness. No.
9	Oblique silky. Elongation uniform over the 2 in. parallel. Trace of inter-crystallinity.	101	Fine, stony, semi-vitreous, silky edges.	—	104	—
	Fine, silky oblique, necked	91	Ditto. ditto.	—	143	—
10	Coarse crystalline, stony, defective (sand contamination).	33	Mixed crystalline and granular, free from lustre.		134	32
	Uneven, coarse crystalline, stony, sound	51	Ditto. ditto.		143	34
11	Coarse crystals. Free from lustre. Trace of inter-crystallinity along the 2 in. parallel.	13	Very coarse, crystalline, crystal grains free from lustre.	—	185	—
	Coarse, stony, crystalline. Inter-crystalline along the 2 in. parallel.	25	Coarse, crystalline, inclined to be lustrous.	—	193	—
A.1	Coarse, stony, and acicular. Trace of inter-crystallinity along the 2 in. parallel.	46	Fine, stony, vitreous	40	114	21
	Fine, stony. Free from inter-crystallinity	67	Fine, stony, semi-amorphous	41	104	18
A.2	Coarse crystalline	23	Coarse, crystal, stony	—	129	21
A.3	Coarse crystalline, high lustre	25	Coarse crystalline, stony	—	138	22
	Coarse crystalline, lustre	30	Coarsely crystalline, strongly laminated.	—	143	23
A.4	Coarse crystalline, high red lustre	27	.. ..	—	159	25
	Highly crystalline. Brilliant red lustre. Presence of slight inter-crystallinity along the 2 in. parallel.	41	Fine, stony, inclined to exhibit inter-crystallinity.	—	154	23

No. 11 showed 133 crystals per sq. cm. as cast and 2,430 when forged.

corresponding fall in ductility and shock-resisting properties. Thus alloy No. 9 which is structurally equivalent to a 59/41 brass possesses the strength of mild steel and a remarkable resistance to dynamic stress. Above 3.5 per cent Al. the ductility of a 70 per cent. Cu-base alloy rapidly falls, and at 5.9 per cent. Al. when only the "beta" constituent exists, a high strength is obtained but little ductility.

FIG. 7.—FRACTURE OF A HIGH TENACITY "BETA" BRASS VALVE ON A HYDRAULIC PRESS.

In the 59/41 series, 1.35 per cent. seems to be the rapid strengthening limit of aluminium, although the maximum strength is not reached until 3.0 per cent. has been added. Exceeding this amount the strength steadily falls away, and on the inception of the "gamma" constituent the alloy loses its commercial value.

After forging, alloys 9, 10, and A1, which are essentially "alpha-beta" brasses show an all-round improvement in ductility and shock-resisting properties, and possess a wide range of combined strength and ductility.

In the ordinary way "alpha-beta" Al. brasses do not present any difficulties in working, and may be forged, rolled or extruded as readily as Muntz metal. Their increased hardness, however, demands a relatively greater blow or pressure in working, and readily hardening up cannot be worked down to small sections with the ease of Muntz metal.

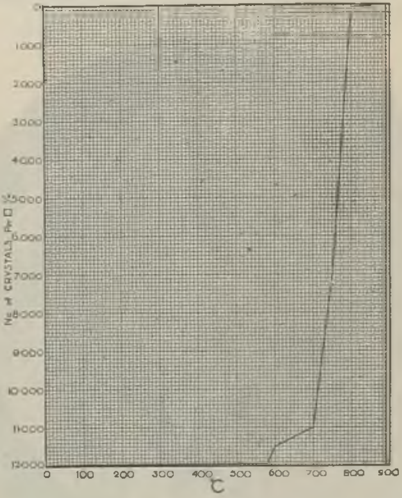

FIG. 8.—SHOWING THE RAPIDITY OF CRYSTAL GROWTH OF ALUMINIUM BRASSES.

All "beta" aluminium brasses suffer from a long period of heat fragility regardless of their chemical composition. There is, however, no difficulty in working them hot, although the range of temperature permissible is limited. Ordinary "beta" brasses of the Cu.-Zn. series have a period of heat fragility extending from 315 deg.-455 deg. C.; "beta" brasses of the Cu.-Zn.-Al. series approximately from 226 deg. to 558 deg. C.

In the "beta" alloys under consideration, forging was performed between 700 deg. and 620 deg.C.

They may be worked safely at temperatures above 700 deg. C., but there is great danger in doing so owing to the abnormally rapid crystal-growth at such temperatures, which is not readily eliminated by a continuance of the work at lower temperatures. At the best, high tenacity "beta" brasses are brittle alloys, and slight overheating renders them unsafe in use. An instance of this may be cited in the form of a stop-valve for a hydraulic compressor, which gave serious trouble in service. These valves were made to the following chemical composition:—Cu., 59.0; Zn., 36.5; Al., 3.0; Mn., 1.5; and Fe. and Pb., less than 0.2. A tensile test showed that it had a strength of 39 tons per sq. in., and an elongation of 15 per cent. on 2 in.

Fig. 9.—Effect of Substituting 1 Per Cent. Al. for same Amount of Zn. in a 59 Per Cent. Copper-brass.

Fig. 7 illustrates the fracture of one of these valves, and is typical of many which collapsed in service, although each passed the specified physical tests. Alternating impact tests taken from some of the defective valves ranged between 7 to 10 blows, and the Izod 6 to 10-ft. lbs., figures which are more or less expected from the appearance of the fractures.

An inquiry into the method of manufacture showed forging to have been performed between 800 deg. C. and 720 deg. C., allowing to cool off on the floor. Forging the ingot at 700 deg. C., overcame this difficulty, and the following is the average physical tests obtained from some of the valves subsequently made:—

Yield point, 21 tons per sq. in.; maximum stress, 43 tons per sq. in.; elongation on 2 in., 26 per cent.; reduction of area, 34 per cent.; alternating impact number, 48; and Izod, 27-ft. lbs.

Fig. 8 gives some idea of the effect of temperature on the rapidity of crystal growth of aluminium brasses.

Microstructure.—Figs. 9 and 10 depict the effect of substituting 1.0 per cent. and 1.5 per cent. Al. for the same amount of Zn. in a 59 per cent. copper-brass. They amply demonstrate the co-efficient of equivalence previously referred to, and explain hardening propensities of Al.

Manganese Brass.

Manganese may be introduced by means of an 80 per cent. Mn., ferro-manganese, or 30 per cent. Mn., cupro-manganese. The common objection to the former is its high melting temperature and its association with 5 per cent. to 6 per cent. carbon which renders alloying difficult. The principal trouble arising from the use of Fe.—Mn., apart from these difficulties, is the inability to control the chemical composition of the finished alloy and the formation of intensely hard metallic pellets, which pellets not only create serious trouble in machining but adversely affect the mechanical properties. This latter defect has been encountered in castings made by various foundries, and in every instance a chemical and physical examination proved the trouble to be unalloyed Ferro-Mn. The use of Cupro-Mn. by no means ensures freedom from this defect; it is no uncommon thing to find lumps of undissolved Ferro-Mn. in Cupro-Mn. alloys, unless skilfully prepared.

Commercial Cupro-Mn. is best made by first melting the Cu. under a slag consisting of 1 part broken glass, 1 part fine silica sand, and 1 part borax, stirring in molten Ferro-Mn. a little at a time. The whole should then be brought to a good temperature, a little phosphor-copper added (0.03 per cent. P. calculated), again well stirred, skimmed and cast. Obviously special care is needed in the preparation of this alloy. If the Cu. and Ferro-Mn. are melted together there is always the danger of some few specks of undissolved Ferro-Mn. remaining, which are quite sufficient to cause trouble. The use of a protecting flux is necessary, or the melting losses are high, a hard, rich Mn. crust forming on top of the melt. Cupro-Mn. may be prepared also from pure Mn. and Cu. or by the aluminium thermit process. The former is costly, the latter unreliable, and there is no advantage from these expensive methods, if due precautions are taken in the alloying of Ferro-Mn. and Cu.

FIG. 10.—EFFECT OF SUBSTITUTING 1.5 PER CENT. AL. FOR SAME AMOUNT OF ZN. IN A 59 PER CENT. COPPER-BRASS.

In the following examples the Cupro-Mn. of the composition shown in Table I. was used throughout.

TABLE III.

Series No.	Composition.					Physical condition.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E. Per cent. in 2 in.	R. A. Per cent.
	Cu.	Zn.	Mn.	Fe.	Si.					
M.1	58.95	39.72	1.01	0.24	0.08	As cast	10.1	25.1	51.0	49.7
						As forged	10.1	26.1	47.0	57.0
M.2	58.42	39.80	1.48	0.25	0.05	As cast	8.9	26.0	49.0	61.5
M.3	58.42	39.25	2.00	0.28	0.05	As cast	9.1	26.9	45.0	52.7

TABLE III.—continued.

Series No.	Tensile Fracture.	Alternating impact No.	Fracture.	Brinell hardness No.	Scleroscope hardness No.
M.1	Fine, stony, semi-cup and cone	59	Fine, silky, slightly vitreous in appearance in the lower half.	80	13
	Fine, stony, silky edges, semi-cup and cone	—	..	—	—
M.2	..	74	Fine, stony, slightly crystalline	90	14
M.3	Fine, stony, semi-cup and cone, silky edges	63	As M.2, but more crystalline	90	14

The Cu. and Cupro-Mn. were melted together under charcoal; Zn. was then worked in, introducing a little common-salt when the desired melting temperature had been reached in the furnace. The casting temperature was controlled pyrometrically.

Considered as a Zn.-replacing element, 1.0 per cent. Mn. is equivalent to about 0.8 per cent. Zn. Such a comparison, however, is of little value, the function of Mn. lying in other directions.

Details of compositions and physical test obtained are embodied in Table III., showing 1.0, 1.5, and 2.0 per cent. to exert, very little influence on the tensile test, although both strength and ductility are slightly improved.

Owing to the similarity of these three alloys, and showing no marked variations from the ordinary standard 59/41 brass, forging tests were conducted on alloy M.1 only. This does not call for special comment, and Mn. does not appear to affect the hot working properties.

The value of Mn. as a deoxidant lies in its ready affinity for oxygen. When introduced in quantities in excess of that necessary to de-oxidise, its ready oxidation is responsible for considerable trouble in casting, and special precautions are necessary in temperature control and method of pouring, or exfoliation of oxide will be encountered, and cause much defective work.

Microstructure.—Under the microscope both M.1 and M.3 appear to possess the structure of ordinary 59/41 brass, although a notable reduction in the size of primary crystal grains is evident, and also indications of a better cohesion between adjacent grains, which suggests Mn. to be of value as a toughener. This assumption appears to be substantiated by the impact test figures obtained from alloys M.1, M.2 and M.3.

Tin Brass.

The chief function of tin in brass is to improve the corrosion-resisting properties. In complex brasses of high ductility 0.7 per cent., is the maximum amount that should be used. In naval brass the limit is 1 per cent.

In a series of exploratory casts it was found that the amount of tin that brass will take into solution in the solid state is determined by the Zn. content. In the "alpha" series, the lower the Zn. content the greater the quantity of Sn. which it can dissolve, *e.g.*, an 80/20 brass will dissolve 5.0 per cent., whilst a 70/30 will scarcely dissolve 1.0 per cent. Of the "alpha-beta" series, the standard 59/41 brass dissolves approximately 1.0 per cent. when sand-cast and 1.2 per cent. chill cast, whilst as the Zn. content increases up to 47 per cent. the solubility rises to a maximum of 1.80 per cent. From these results 0.5, 1.0, 2.0 and 3.0 per cent. tin brasses were made of a 59 per cent. copper base. Conditions of manufacture were those outlined for the aluminium brasses, introducing the Zn. and the Sn. as such, last.

Physical Test Results.—These are detailed in Table IV.

As Cast.—0.50 per cent. Sn. increases the yield point and maximum stress 2.25 tons and 1.3 tons respectively without affecting the elongation, reduction of area, and alternating impact strength. Increasing to 1.0 per cent. hardens, without strengthening, and impairs both the ductility and impact strength. This embrittlement is naturally accentuated by further quantities of Sn., as in alloys S3 and S4, the latter having little strength and being void of ductility.

Forging.—No difficulties were encountered in the forging of alloys S1 and S2, and worked with the ease of ordinary Muntz metal. The test results of alloys S3 and S4 in the "cast" condition were such that they did not justify consideration in the forged or heat treated condition.

After forging, the yield point of S1 is raised 6.6 tons per sq. in., and the maximum stress 2.8 tons per sq. in., but the elongation is slightly reduced. The drop in ductility, however, is not of material importance, the alternating impact figure being raised no less than 15 per cent. Whilst the physical properties of the 1 per cent. Sn.-brass in the "cast" state are inferior to those of 59/41, they are superior after forging, but it is clearly demonstrated that 1 per cent. is the limit of practical utility.

Structure.—There is little perceptible difference in the structure of an "alpha-beta" brass containing 0.5 per cent. Sn. and that containing 1 per cent. Exceeding 1 per cent. a brittle Cu.-Sn. compound,

TABLE IV.—*Showing the Effect of Tin on the Physical Properties of Brass*

Series No.	Composition. Cu.	Zn.	Sn.	Fe.	Physical condition.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E per cent. on 2 in.	R. A. per cent.
S.1	59.95	39.38	0.47	0.20	As cast	11.0	26.2	44.0	42.0
					As forged	15.6	28.8	38.0	60.0
S.2	58.90	40.10	1.00	Trace.	As cast	9.6	26.7	32.0	33.5
					As forged	13.6	28.6	38.0	44.6
S.3	58.82	38.76	2.11	0.31	As cast	11.8	26.1	13.0	15.0
S.4	59.17	37.62	2.98	0.22	As cast	16.4	21.25	1.5	3.2

TABLE IV.—continued.

Series No.	Tensile Fracture	Alternating impact No	Fracture.	Brinell hardness No.	Scleroscope hardness No.
S.1	Fine, stony, silky edges. More or less hackly ..	77	Fine, silky, semi-vitreous	87	13
	Fine, granular, silky edges. Cup and cone ..	113	Fine, granular, semi-vitreous in upper half.	107	15
S.2	Fine, stony, silky edges. Trace of crystallinity existing as exhibited by S.3	47	Fine, crystalline, with a slight appearance of the laminated crystals exhibited by S.3.	98	15
	Fine, granular, silky edges. Semi-cup and cone ..	107	Fine, granular, semi-vitreous in upper half.	107	16
S.3	Short, coarsely crystalline, consisting of greyish and stony crystals existing alternately	5	Short, grossly coarse laminated crystals.	114	20
S.4	Coarse, alternating grey and stony coloured crystals.	1	Short, coarse, laminated crystals ..	136	23

resembling the Cu.-Sn. compound, found in ordinary Sn. bronzes, makes its appearance. The effect of this constituent is shown to be similar to the " gamma " compound in ordinary brass.

From these results one cannot regard Sn. in the same light as any of the elements previously considered, it being neither a Cu.- nor a Zn.-replacing element; although, structurally, attempts have been made to consider it as a Zn.-replacing element, giving to it a co-efficient of equivalence of 2.

Iron Brass.

Copper and iron form a heterogeneous series of alloys except at the terminals of the curves. Between these proportions the alloys consist of two constituents, the one rich in iron the other rich in copper. Carbon and copper do not associate in any form, and the presence of C. in Fe. reduces the solubility to any extent that neither steel nor cast iron can be satisfactorily alloyed with copper, but merely exist side by side as a mechanical mixture of one with the other. Zinc readily unites with iron.

Iron may be introduced into brass by means of a Cu.-Fe. or Zn.-Fe. stock alloy. The preparation of either stock alloys is a comparatively simple operation, if certain elementary chemical laws are observed and manufacture carefully conducted. The first essential in the preparation of a Cu.-Fe. stock alloy is the use of pure iron, not steel, cast iron or ferro-manganese. The iron may be purchased in sheet form as scrap clippings from horse-shoe nails or as Swedish bar-iron. The Cu. should be melted to a good temperature under a suitable slag, and the iron introduced in small quantities at a time up to about 10 per cent. and well stirred. When thoroughly alloyed, the pot should be withdrawn from the furnace, again stirred and quickly poured out into a thin flat mould. Unless this latter precaution is taken, there is a danger of the iron-rich material formed segregating in the upper regions of the cast.

Correctly made, a 10 per cent. Fe., Cu.-Fe. stock-alloy is soft, and has a Brinell hardness of 62 against 55 for pure copper and 92 for pure iron.

Johnson recommends the use of a Zn.-Fe. stock-alloy, prepared by immersing strips of clean sheet-iron in a crucible of molten Zn., the temperature of which is maintained for several hours at 800 deg. C., in a muffle furnace. Luting on the crucible lid is suggested for preventing volatilisation.

This method is costly on account of the difficulties of manufacture; moreover, one cannot dissolve, commercially, more than 6 per cent. Fe.; consequently its use cannot be adopted for high-Fe. iron brass of low-Zn. content. Commercial Zn.-Fe. stock-alloys are generally prepared by liquidating the hard Zn. from galvanising works to remove part of the Zn., and then heating the Fe.-rich residue to a high temperature until the desired Fe. content is obtained. The objection to this by-product is its irregular composition and the impurities it carries.

Effect of Iron on 70/30 Brass.

To ascertain the effect of iron on 70/30 brass ("alpha") three alloys were made and designated F, F1, and F2. The first contained 70 per cent. Cu. and 30 per cent. Zn.; the second 69.75 per cent. Cu., 29.75 per cent. Zn. and 0.5 per cent. Fe.; and the last 69.50 per cent. Cu., 29.50 per cent. Zn. and 1 per cent. iron.

The iron was introduced by the 10 per cent. Fe., Cu.-Fe. stock-alloy. No peculiarities or difficulties were encountered either in melting or pouring. The tensile, impact and hardness tests are tabulated in Table V.

In the cast condition 1 per cent. Fe. is shown to raise the yield point from 6.5 to 10.7 tons per sq. in., the tenacity from 16.7 to 24.5 tons sq. in., and the Brinell hardness from 55 to 76 without materially affecting the ductility as measured by both the static and dynamic stress tests. After cold-rolling and annealing, the yield point is raised from 8 to 11 tons per sq. in. and the tenacity from 21.5 to 26.5 tons per sq. in., also without affecting the ductility. The most interesting feature is the beneficial effect of iron on the physical properties in the cast state, whilst the range of physical properties possible from 70/30 brass containing 1 per cent. Fe. is noteworthy, as they give a yield point of 10.7 to 18.5 tons per sq. in., a maximum stress of 24.5 to 41 tons per sq. in., an elongation of 14 to 54 per

TABLE V.—*Showing the Effect of Iron on the Physical Properties of 70/30 Brass.*

Mk.	Composition. Cu.	Zn.	Fe.	Treatment.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E. Per cent. on 2 in.	R. A. Per cent.	Alternating impact No.	Izod impact No.	Brinell hardness No.	Scleroscope hardness No.
F.	69.80	30.20	Trace.	As cast	6.50	16.70	58.00	46.20	79	41	55	15
				Cold rolled and annealed, 650° C. ..	8.00	21.50	68.00	65.00	—	61	57	15
F.1	69.67	29.82	0.50	As cast	8.70	19.40	58.00	47.20	61	49	64	12
				Cold rolled and annealed, 775° C. ..	9.50	22.80	65.00	67.00	—	—	54	10
F.2	69.42	29.57	1.00	As cast	10.70	24.50	50.00	59.30	80	45	76	12
				Cold rolled and annealed, 700° C. ..	14.00	27.00	47.00	62.00	—	63	92	12
				Cold rolled and annealed, 825° C. ..	11.00	26.50	54.00	67.00	—	—	76	12

cent., a reduction of area of 44 to 67 per cent., and a Brinell hardness of 76 to 185.

A series of experiments on the effects of Fe. on malleability—which property was determined by cold-rolling to destruction, cupping and drawing tests—proved that Fe. up to 1 per cent. is not detrimental if correctly alloyed, the intervening annealings correctly performed and the changed physical properties taken to account. Fuller details of these tests are published in the "Metal Industry," Vol. 17, No. 22, page 424.

Microstructure.—The beneficial influence of Fe. in the manufacture of brass castings is readily explained by means of the microscope.

The outstanding feature is the refining effect of small quantities of iron on the texture and the improved homogeneity. The explanation of the mechanism of its action is not far to seek. Iron exists in brass as an insoluble constituent rich in Fe. in the form of finely-divided particles, each of which acts or tends to act as a nucleus for the germination of a primary crystal-grain. The true solubility of Fe. in 70/30 brass is unknown. By ordinary microscopical examination the Fe.-rich particles are just discernible between 0.35 and 0.45 per cent. That the actual solubility is less than this figure is shown by tho grain-refining of less quantities than 0.35 per cent. For ordinary workshop practice, however, 0.35 per cent. may be taken as the solubility limit, this being the safe-working limit of iron for articles which are to be spun, cupped or drawn.

Effect of Iron on 59/41 Brass (" Alpha Beta.")

The composition of the materials used were similar to those adopted for the 70/30 series, except that the iron was introduced into alloy 1.F.2. by means of a Zn.-Fe. stock-alloy and that 2½-in. sq. ingots were cast instead of 1-in. slabs. The tests results are shown in Table VI.

In ingot form 1.0 per cent. Fe. improves both the tenacity and shock-resisting properties. No further improvement is to be gained by exceeding this quantity whilst the shock-resisting properties tend to fall; particularly is this so in the case of alloy 1.F.2. The low ductility of this alloy, however, is accounted for to some extent by the crystalline form of the impurities introduced by the

TABLE VI.—*Showing the Effect of Iron on Alpha-Beta Brass.*

Series No.	Composition.				Physical condition.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E. Per cent. on 2 in.	R. A. Per cent.	Fracture.	Alternating Impact No.	Fracture.	Brinell hardness No.	Scleroscope hardness No.
	Cu.	Zn.	Fe.	Pb.										
1.F.	58.96	41.04	—	—	As cast ..	8.80	24.90	45.00	49.70	Fine, stony, semi-cup and cone.	79	Fine, granular, silky edges.	90	14
					As forged ..	9.00	26.00	47.50	62.00	Fine, stony, silky edges.	87	Fine, granular, silky edges.	90	14
1.F1.	59.37	39.68	0.95	Nil.	As cast ..	9.40	26.80	44.00	44.60	Fine, silky, semi-cup and cone.	95	Fine, silky, semi-vitreous.	90	13
					As forged ..	13.90	28.80	44.00	63.70	Fine, granular, cup and cone, silky edges.	81	Fine, stony, semi-vitreous.	107	14
1.F.2	59.04	38.95	1.56	0.45	As cast ..	11.00	26.80	33.00	30.60	Fine, stony, granular, semi-cup and conc.	31	Fine, stony ..	85	13
					As forged ..	13.60	27.60	43.00	59.30	Fine, granular, cup and cone, silky edges.	49	Fine, stony, inclined to be vitreous.	98	15
1.F.3	59.12	38.36	2.52	Nil.	As cast ..	10.00	26.50	46.00	49.70	Fine, silky, semi-cup and cone.	71	Fine, slightly more silky in aprearance than 1.F1.	92	14
					As forged ..	15.80	28.30	39.00	54.60	Stony, granular, uneven.	79	Fine, stony, semi-vitreous.	110	16

Zn.-Fe. alloy, and is typical of the troubles encountered when this impure material is used for the purpose of introducing iron.

Hot-working results in an all-round improvement of the tenacity of each alloy, having little influence on the ductility, except in the case of alloy 1.F.2, which improvement is as expected.

Microstructure. — The Fe.-rich constituent appears to be similar in form to that found in the 70/30 brasses, although the limit of solubility seems to be increased. It exerts a similar action on the crystal growth.

Effect of Iron on 53.3/46.7 Brass (" Beta").

In view of the fact that the hardness of pure iron is similar to that of 59/41 brass, its limitations as a hardener or strengthener will be in brasses containing up to 41 per cent. Zn., and that it will neither affect the tenacity nor hardness of " beta " brasses. Its common use in high-tenacity brasses, therefore, must be a question of the manner in which it affects the crystal growth. To investigate this, three alloys were made, and designated 2F, 2F1, and 2F2. The first contained 53.3 per cent. Cu. and 46.7 per cent. Zn., the second 51.5 per cent. Cu., 47.5 per cent. Zn., and 1 per cent. Fe., whilst the last one was made up of 51 per cent. Cu., 47 per cent. Zn., and 2 per cent. Fe.

The copper and zinc were adjusted so as to bring each to a similar position in the " beta " phase area of the copper zinc constitutional diagram.

Materials used, conditions of manufacture, and method of casting were identical to those adopted in the 59/41 series, excepting that only the Cu.-Fe. stock-alloy was used for the purpose of introducing the iron.

Mechanical Properties.—Chemical composition and physical test results obtained are embodied in Table No. VII. These indicate Fe. to be detrimental to the ductility in the " cast " state, but beneficial when forged. It will be observed also that forging lowers the yield point but raises maximum stress, increases both the yield point and the maximum stress of alloy No. 2F1 and lowers both the yield point and maximum stress of alloy 2F2 though each was treated similarly and

TABLE VII.—*Showing the Effect of Iron on the Physical Properties of "Beta" Brass.*

Mark.	Composition. Cu.	Composition. Zn.	Composition. Fe.	Pb.	Physical condition.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E. Per cent. on 2 in.	R. A. Per cent.	Fracture.	Alternating impact No	Brinell hardness No.	Scleroscope hardness No.	No. of crystal grains per sq. cm.
2.F.	53.41	46.59	Nil.	Nil.	As cast ..	9.00	29.70	24.00	21.50	Coarse, crystalline, exhibiting brilliant lustre.	34	114	15	39
					As forged ..	8.70	32.80	28.00	30.60	Coarse, flaky, exhibiting brilliant yellow crystalline facets, extension uniform over the 2 in. parallel.	49	114	15	488
2.F1.	51.73	47.23	1.05	Nil.	As cast ..	8.00	30.00	16.00	15.00	Fine, crystalline, exhibiting brilliant crystal facets.	9	114	15	1,765
					As forged ..	9.60	33.00	38.00	33.50	Flaky, uneven ..	39	114	15	2,336
2.F2.	50.77	47.03	2.20	Nil.	As cast ..	11.10	33.00	17.00	15.00	Fine, crystalline, exhibiting brilliant crystal facets.	9	114	17	2,314
					As forged ..	8.60	30.60	43.00	44.60	Fine, yellow, almost granular.	85	114	17	2,200

has the same Brinell hardness in both the "cast" and the "forged" condition.

Microstructure.—The mechanical properties of "β" brasses being unaffected by normal heat treatment—both tenacity and ductility being similar, no matter the rate of cooling—the changes responsible for the peculiar test results, which are typical of those obtained from complex "β" brasses, must be attributed to one or all of the following causes:—(1) Internal molecular changes or structural conversion of the "β" constituent; (2) geometrical outline of the crystal grains; (3) the mode of distribution of the free Fe.-rich constituent.

Actual examination proved that iron renders both the internal and external form of the crystal grains more regular, and that this is the principal cause of its embrittling properties in cast brass. Forging, refining and effecting an interpenetration of adjacent crystal grains explains the improved ductility wrought by mechanical work. The effect of the iron-rich particles is unimportant, providing they are uniformly distributed and in a fine state of division.

Having established the functions of the third element in the development of high-tenacity brass, the effect of two or more elements in combination will now be considered.

Aluminium Manganese Brasses.

For the purpose of this investigation the ternary alloys A1, A2, A3 and A4 were taken as basis, the Mn. additions replacing the Zn.

Manufacture.—Constant conditions were maintained throughout, and were those adopted in the ternary series. Mn. does not improve the casting qualities, and unless great care is taken, overlaps and surface unevennesses are formed owing to the ready oxidation in the molten state. No difficulties were encountered in forging, rolling, extruding or cold drawing. Owing to the polymorphic nature of the "Alpha-Beta" series, higher temperatures than 750 deg. C. and rapid cooling after working should be avoided, otherwise they will possess the properties of an all "Beta" brass. When hardened or embrittled by such treatment annealing at 650 to 700 deg. C. is recommended, and cooling to 500 deg. C. during a period of at least one hour.

TABLE VIII.—*Showing the effect of 3.5 per cent. Mn. on alloy A1.*

Mark.	Composition.						Physical Condition.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E. Per cent. on 2 in.	R. A. Per cent.
	Cu.	Zn	Al	Mn.	P.	Fe.					
A.1.	59.48	39.55	1.00	Nil	Nil	Nil.	As cast ..	14.80	32.00	30.00	33.50
							As forged ..	11.10	31.30	41.00	44.60
AM.5.	59.45	35.85	0.98	3.49	0.01	0.22	As cast ..	13.40	31.80	25.00	24.60
							As forged ..	20.70	35.10	36.00	47.20
A.2.	58.35	40.11	1.54	Nil.	Nil.	Nil.	As cast ..	16.40	35.20	17.00	18.50
							As forged ..	11.60	36.40	28.00	34.00
AM.2.	59.45	36.60	1.56	1.97	0.02	0.40	As cast ..	17.00	35.90	22.00	20.00
							As forged ..	17.20	37.00	28.00	30.60

TABLE VIII.—continued.

Mark.	Tensile Fracture.	Alternating impact No.	Fracture.	Brinell hardness No.	Scleroscope hardness No.	Crystal grains per sq. cm
A.1.	Coarse, stony, accicular. Trace of inter-crystallinity along the 2 in. parallel.	46	Fine, stony	114	21	αβ
	Fine, stony, free from inter-crystallinity	67	Fine, stony, semi-vitreous ..	104	18	αβ
AM.5.	Fine, granular, short. Extension uniform over the 2 in. parallel.	18	Fine, stony, crystalline ..	114	21	αβ
	Stony, granular, cup and cone, silky edges	75	Fine, stony, silky	134	23	αβ
A.2	Between A.1 and No. 6, in appearance	23	Coarse, crystalline, stony ..	129	21	αβ
	Crystalline	41	Coarse, crystalline, stony ..	138	22	αβ
AM.2.	Highly crystalline, very pale yellow, free from lustre. Trace of inter-crystallinity along 2 in. parallel.	27	Short, fine, crystalline, with a slight lustre.	138	26	143
	.. ..	41	Fine, stony, granular. Trace of inter-crystallinity.	148	33	170

Effect of Manganese on 1 per cent. Aluminium Brasses

Alloy AM5, Table VIII., shows the effect of 3.5 per cent. Mn. on alloy A1, retaining the Cu. content constant at 59 per cent. In the cast condition the yield point, maximum stress and hardness are practically unchanged, but the ductility as measured by both static and dynamic stress tests is lowered. Forging reverses this state of affairs, the manganese alloy being superior in both tenacity and ductility, although each offers a good range of mechanical properties.

Fig. 11 illustrates the micro-structure of AM5 in the " cast " condition, and shows Mn. to reduce the size of the crystal grains, to break down the junctions of adjacent grains, and to increase the quantity of the " Alpha " constituent. This latter feature corroborates the author's previous finding that Mn. is a Cu.- rather than a Zn.-replacing element. In view of the observed structural change, the natural corollary is that Mn. is beneficial to the ductility and toughness of Al. brass castings, yet actually, the reverse proved to be the case.

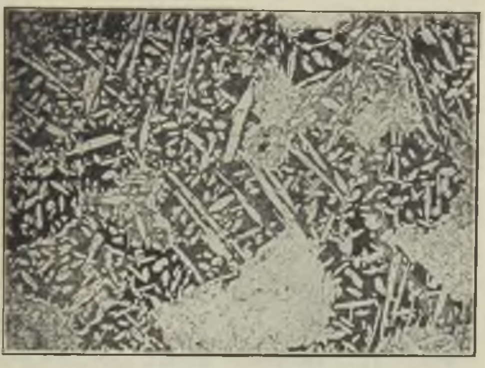

FIG. 11, SHOWING MICROSTRUCTURE OF ALLOY AM5 " AS CAST."

The explanation of this is clear from Fig. 12, which shows films of a brittle Mn.-rich constituent to have formed at the junctions of the adjacent crystal grains. The advantage, therefore, of the refined texture does not appreciate until this undesirable structural weakness has been eliminated. Fig. 13 shows the effect of forging in this direction, and to have conferred to the forging a grain which strengthens against stress applied at right angles to the grain, but weakens it against stress applied parallel with it.

Effect of Manganese on 1½ per cent. Aluminium Brasses.

The test results in the "As Cast" and in the "Forged" conditions are included in Table VIII., alloy AM2. The Mn. additions are limited to 2 per cent., no object being served by exceeding this amount. The tensile and impact tests suggest Mn. slightly to improve the ductility. Apart from this, its influence is apparently negligible in either the cast or forged state.

Fig. 12, showing Films of Mn-rich Constituent at Junctions of Crystal Grains.

Micro-structure.—Manganese shifting the position of the "Beta" phase field-boundary to the right, the micro-structure is changed from an all "Beta" brass to an "Alpha-Beta" brass. This does not imply the mechanical properties of alloy A1 or allow AM5—both of which contain 40 to 50 per cent. of the "Alpha" phase—as the predominating micro-constituent determines the final physical properties.

The structural change wrought by the addition of 2 per cent. manganese on alloy A2 is shown in Fig. 14, although this alloy contains 1 per cent. of Fe. in addition to 2 per cent. Mn.

Effect of Mn. on 2, 2.5 and 3 per cent. Al. Brasses.

By a further addition of 1.0 per cent. Al. to the 1 per cent. Al.-4 per cent. Mn., alloy (AM5), the yield point and maximum stress are appreciably increased, but at the expense of the ductility as in alloy AM4 in Table IX. By raising the Al. to 2.5 per cent., reducing the Mn. to 2.0 per cent. and the Cu. to 57 per cent. (alloy AM 2B, Table IX.), the test results are very similar to those obtained from alloy AM4, excepting that the yield point is lower.

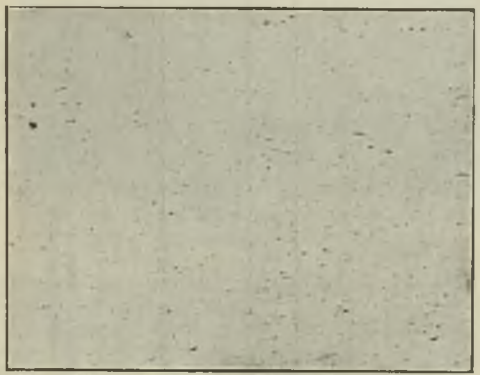

Fig. 13, showing the Effect of Forging.

In view of the interesting test results obtained from the 3 per cent. Al. bross (alloy A4, Table II.) a series of alloys of this type was prepared, and a new standard marked No. 6—Table X. To the first, 1 per cent. Mn. was added, to the second 2 per cent. Mn., to the third 4 per cent. Mn., retaining the Cu. and Al. constant at 59 per cent. and 3 per cent. respectively.

Complete data regarding composition and test results are given in Table X. Here 1.0 per cent. Mn. appears to reduce the shock-resisting properties in the " cast " state, and 2 per cent. Mn. to

TABLE IX.—*Showing the Effect of Manganese on Aluminium Brass.*

Mark.	Composition.						Physical condition.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E. Per cent. on 2 in.	R. A. per cent.
	Cu.	Zn.	Al.	Mn.	Pb.	Fe.					
A.3.	58.26	38.50	2.18	Nil.	Nil.	Nil	As cast ..	16.00	36.40	16.00	21.50
							As forged ..	13.00	38.90	22.00	30.00
AM.4.	58.15	35.18	2.24	4.10	0.08	0.25	As cast ..	23.90	40.50	14.00	15.00
							As forged ..	24.80	43.40	18.50	21.50
AM.2B	57.23	37.90	2.59	2.08	Nil.	0.20	As cast ..	19.40	41.40	18.00	20.00
							As forged ..	20.50	42.60	24.00	24.50

TABLE IX.—continued.

Mark.	Fracture.	Alternating impact No.	Fracture.	Brinell hardness No.	Scleroscope hardness No.	Crystal grains per sq. cm
A.3.	Coarse, crystalline	25	Coarse, crystaline, stony ..	138	22	202β
	Crystaline	39	Coarse, crystaline, stony ..	143	23	149β
	Whitish yellow colour. Coarsely crystalline. Free from lustre. Inter-crystalline along the 2 in. parallel.	15	Whitish grey. Coarsely crystalline.	165	—	192 β
A.M.4.	Whitish yellow colour. Oblique, hackly. Marked crystalline. Free from inter-crystallinity along the 2 in. parallel.	39	Whitish grey. Fine crystalline.	159	—	3,700 β
A.M.2B	Fine, crystalline	20	Stony, strongly crystalline at outer edges.	165	25	387
	Oblique, even, crystalline, high lustre	29	Fine crystalline, stony. Presence of trace of a larger crystalline structure due to incipient overheating.	159	28	467

increase the yield point, maximum stress and hardness without affecting the ductility. Reducing the Cu. content of the latter alloy to 57 per cent. and proportionately increasing the Zn. content (alloy AM3D), apparently lowers the yield point without affecting the tenacity and hardness, but improves the ductility as measured by both the tensile and impact tests.

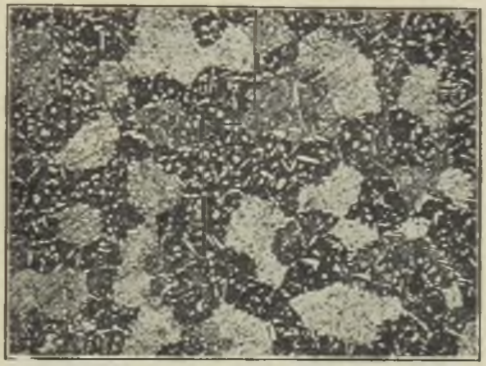

FIG. 14; SHOWING THE INFLUENCE OF 2 PER CENT. MANGANESE ON ALLOY A2.

Reverting to the 3 per cent. Al.-59 per cent. Cu. basis brass, 4 per cent. Mn. (alloy AM13) raises the yield point maximum stress and hardness, but adversely influences the ductility. The improvement made by forging, demonstrates the value of Mn. in these alloys in the forged, stamped, rolled or extruded conditions.

Micro-structure.—Each alloy was found to possess in all " Beta " structure. The Mn.-rich constituent formed in alloys AM4, AM2B, AM3C, AM3D and AM13, is responsible for the embrittlement in the " cast " state and a reduction in the size of the crystal grains. A notable structural feature of Mn.-Al. " Beta " brasses is the interpenetration of the adjacent grains, and the evidence of a more mixed orientation. This is particularly well-displayed by the fracture. Generaly speaking Cu.-Zn. " Beta " brasses and Al. " Beta " brasses present a coarse crystalline frac-

TABLE X.

Mark.	Actual composition.						Physical condition.	YP. Tons per sq. in.	MS. Tons per sq. in.	E. Per cent. on 2 in.	RA. Per cent.
	Cu.	Zn.	Al.	Mn.	P.	Fe.					
6	58.85	38.05	2.10	Nil.	Nil.	Nil.	As cast .	20.50	38.60	19.00	21.50
							As forged ..	18.90	43.00	29.00	33.50
AM.12	58.87	37.13	2.94	0.96	Nil.	0.10	As cast ..	20.80	38.70	11.00	11.80
							As forged ..	20.50	40.80	22.00	24.50
AM.3C	59.34	35.34	3.10	2.02	Nil.	0.20	As cast ..	23.70	43.00	15.00	15.00
							As forged ..	23.60	43.40	19.00	24.50
AM.3D	57.07	37.68	3.12	1.81	Nil.	0.32	As cast ..	19.80	43.90	20.00	21.50
							As forged ..	20.70	44.90	33.00	44.00
AM.13.	58.32	34.54	3.12	3.02	Nil.	0.10	As cast ..	22.80	45.30	13.00	20.00
							As forged ..	24.50	43.80	22.00	27.60

TABLE X.—continued.

Mark	Tensile Fracture.	Alternating impact No.	Fracture.	Brinell hardness. No.	Scleroscope hardness. No.	Crystal grains per sq. cm.
6	Coarse, crystalline, deep reddish colour	30	Coarse crystalline, reddish colour	148	—	152
	Flaky, coarse, crystalline, deep reddish colour ..	49	Fine, crystalline, reddish colour.	159	—	2,555
AM12	Coarse, crystalline as No. 6 but not quite so lustrous	9	As No. 6, but not quite so lustrous.	159	—	—
	Fine, reddish, granular, flaky	29	Fine, reddish, mixed, crystalline and granular.	159	—	—
AM3C	Coarse, crystalline, stony, with a slight lustre. Trace of inter-crystallinity.	23	Stony. crystalline at outer edges.	171	27	125
	Between AM.1 "Forged" and AM2B. "Forged" in appearance, and is free from inter-crystallinity along the 2 in. parallel.	39	As AM.2B " Forged " ..	165	30	62
AM3D	Coarse, crystalline and much inter-crystallinity ..	23	Fine, crystalline, exhibiting inter-crystallinity.	154	—	760
	Fine, red fracture, free from inter-crystallinity ..	93	Fine, amorphous, indicating " Forging " too cold.	165	—	3200
AM13	Mixed fracture, mainly earthy, what crystallinity is present is free from lustre.	14	Fine, whitish, earthy, with a tinge of crystallinity.	171	—	—
	Fine, earthy, granular, laminated, rough ..	70	Fine, whitish, earthy, granular	171	—	—

ture with bright crystal facets, whilst Al. Mn. "Beta" brasses invariably exhibit a mixed granular and crystalline fracture, and the crystal facets lack lustre and have a stony appearance.

Aluminium-Manganese-Iron Brasses.

The principal high-tenacity brasses of to-day contain Al., Mn., and Fe. They vary widely in composition, but generally fall within the following limits:—Cu., 57 to 64; Zn., 31 to 40; Al., 0.20 to 4.0; Mn., 1.0 to 4.0; Fe, 0.10 to 2.0; and Sn., nil to 1.0. Although alloys are made which do not come within this range, some of which contain as many as 15 elements.

That Fe. cannot be regarded in the light of a hardener or strengthener in this class of alloy has been established by the iron-brass series. Acting as a Cu.- rather than a Zn.-replacing element, and refining the texture, its value, if any, must be that of a toughener.

Alloy AM6, in Table XI., shows the effect of 1.0 per cent. Fe. on alloy AM2—the Fe. meant to replace 1.0 per cent. Zn. In the chill cast condition, the tensile and hardness figures remain unchanged, although the toughness is somewhat improved. The change in this direction is by no means proportional to the corresponding reduction in the size of the grain, the full advantage of which does not appear to materialise until the cast structure has been broken down by mechanical work.

Fig. 14 shows the micro-structure of alloy AM6 and illustrates the structural changes wrought in alloy A2 by the substitution of 3.0 per cent. of Zn. by 2.0 per cent. Mn. and 1 per cent. Fe.

Alloy AM14 serves to demonstrate the effect of 1½ per cent. Fe. on alloy AM11. Here, again, the grain refining effect of Fe. does not improve the mechanical properties until after forging. Alloy AM3B exhibits identical features and special comment is not necessary, the test results and details of the fractures being self-explanatory.

Before concluding this section, attention should be drawn to the yield point figures given in this Paper, which appear in some instances to be both erratic and contradictory. In considering the elastic properties of brass, however, it must be remembered that there is no uniform relation between the proportional limit and the yield point, and that from the ordinary extensometer diagram it is difficult to locate where the elastic state ends and the plastic state begins, or even make a satisfactory comparison of the form of the curves of one alloy with that of another. The yield point figures given indicate the stress to produce a permanent set of 0.01 in. on a 2-in. gauge length, and nothing more. They are included in this Paper because of their common insertion by the engineer in his specification, although some form of dynamic stress test would better serve his purpose.

Heat Treatment.

From the comments made on the microstructure of these brasses, it is evident that high strength brasses may be divided into three categories, "alpha," "alpha beta," and "beta," according to the predominating micro-constituent.

"Alpha" and "beta" brasses being unaffected by the rate of cooling, only the "alpha beta" brasses are amenable to heat treatment.

59/41 *Brass*.—Reverting to the aforementioned equilibrium diagram, it will be seen that at 730 deg. C. the "alpha" constituent is gradually absorbed by the "beta." By rapidly quenching from this temperature the structure is fixed and the tenacity and hardness are increased at the expense of the ductility and impact strength. By tempering, *i.e.*, letting down the hardness by heat, this "beta" constituent is decomposed, the "alpha" again falling out of solution, and at 600 deg. C. the normal structure is again restored.

The value of this to high-strength brasses coming within the "alpha beta" area is apparent to all and presents real possibilities, as demonstrated by a casting of which the composition was:—Cu., 60.5; Zn., 33.65; Al., 2.80; Ni., 2.96; and Fe., 0.08 per cent., which gave, as cast, 16.0 tons per sq. in. yield point, 36.7 tons maximum stress, 19.0 per cent. elongation on 2 in., and 21.5 per cent. reduction of area, associated with Brinell and scleroscope hardness numbers of 125 and 18 respectively. After being heated to 789 deg. C., water quenched, and re-heated to 450 deg. C. for 30 mins. and cooled in the furnace, the alloy gave 28.0 tons yield point, 46.2 tons maxi-

TABLE XI.—*Showing the effect of* 1 *per cent. Fe. on alloy AM2.*

Mark.	Actual composition. Cu.	Zn.	Al.	Mn.	P.	Fe.	Physical condition.	Y. P. Tons per sq. in.	M. S. Tons per sq. in.	E. Per Cent. on 2 in.	R. A. Per Cent
AM 2	59.45	36.60	1.56	1.97	0.02	0.40	As cast ..	17.00	35.90	22.00	20.00
							As forged ..	17.20	37.00	28.00	30.60
AM 6	58.74	36.61	1.60	1.83	Nil.	1.22	As cast ..	17.90	36.50	19.00	21.50
							As forged ..	17.80	36.90	34.00	46.00
AM. 11	58.76	35.16	1.95	3.43	Nil.	0.20	As cast ..	22.00	39.60	13.00	18.30
							As forged ..	21.00	40.70	17.00	21.50
AM. 14	58.11	34.31	1.95	3.98	Nil.	1.65	As cast ..	21.10	42.30	14.00	18.30
							As forged ..	19.90	39.50	28.00	33.50
AM.3C	59.34	35.34	3.10	2.02	Nil.	0.20	As cast ..	23.70	43.00	15.00	15.00
							As forged ..	23.60	43.40	19.00	21.50
AM 3B	59.67	32.73	3.30	2.05	0.27 (Silicon)	2.25	As cast ..	25.00	43.70	13.50	18.30
							As forged ..	24.70	44.00	27.00	33.50

TABLE XI.—continued.

Mark.	Tensile Fracture.	Alternating impact No.	Tensile Fracture.	Brinell hardness No.	Scleroscope hardness No.	Crystal grains per sq. cm.
AM.2	Highly crystalline, very pale yellow, free from lustre. Trace of inter-crystallinity along 2 in. parallel.	27	Short, fine, crystalline, with a slight lustre.	138	26	143
	.. ..	41	Fine, stony, granular. Trace of inter-crystallinity.	148	33	170
AM.6	Fine, earthy, semi-cup and cone	33	Fine, crystalline	129	21	3,937
	Fine, earthy, semi-cup and cone	46	Fine, crystalline	138	22	4,500
AM.11	Coarsely crystalline. Whitish grey. Free from lustre.	20	Fine, stony, almost free from crystallinity.	159	—	239
	Oblique, shear-like appearance	44	Fine, stony, free from crystallinity.	159	—	187
AM.14	Fine, crystalline, whitish grey, almost earthy ..	17	Short, fine, earthy	165	—	6,365
	Fine, yellow, earthy, granular, silky edges ..	41	Fine, earthy	159	—	14,215
AM 30	Coarse, crystalline, stony, with a slight lustre. Trace of inter-crystallinity.	23	Stony, crystalline at outer edges.	171	27	125
	Between AM.1 forged and AM.2 B forged in appearance, and is free from inter-crystallinity along the 2 in. parallel.	39	As AM.2 B forged	165	30	62
AM.3B	Dull yellow, spongy appearance, shallow semi-cup and cone, silky edges.	17	Fine, crystalline, dull ..	171	31	5,824
	Granular, semi-cup and cone. Trace of silky edges.	43	Fine, crystalline, pale brown, free from lustre.	178	31	11,020

mum stress, 18.0 per cent. elongation, and 21.5 per cent. reduction of area. The Brinell and scleroscope numbers were 272 and 32 respectively, the test results of which after treatment compare favourably with some of the best-made forged and heat-treated carbon steels. Whilst the heat treatment of "alpha beta" brasses may be exploited advantageously, more harm than good will result if not scientifically performed, for unless the "alpha" constituent is completely absorbed on heating and quenching sufficiently drastic, both the strength and ductility are impaired rather than improved.

Impurities.

The question of impurities in brass of any kind is problematic. The difficulty is to differentiate between impurities that are harmful and those that are not. Lead, whilst commonly responsible for low-test results, local weaknesses in castings, forgings and stampings due to segregation, patchy appearance of castings and the like, is actually an asset in quantities up to 0.70 per cent., if homogeneously distributed, both cheapening cost and facilitating machining without affecting the physical properties. On the other hand, Sn., Al., Fe., Ni., V. and such special elements of proved value may come under the heading of "harmful impurities," if present unintentionally or incorrectly alloyed. As., Cd., Sb., and Bi. are amongst the most dangerous impurities in brass, but whilst small quantities of these might be harmful singly, they may not be objectionable if in combination with each other or with some other particular element.

Possibly the most objectionable impurity in high-strength brass and one that does not receive the attention it deserves, is Si. In no instance has the author found its presence advantageous—small quantities being conducive to brittleness without conferring any other useful property to compensate for the loss in ductility. It is one of the principal hardeners, and is twice as effective as Al. and ten times that of Zn., weight for weight.

The real value of Si. to the brass founder is as a deoxidant, and should be used in the same way as Mg. and P., which are amongst the best scavengers, but harmful if any remains in the finished alloy. Mg. exerts a similar effect to Si. P., if present in quantities of over 0.15 per cent., causes both blistering and honeycombing.

CO., SO_2, N., H., and various hydrocarbon gases. are present in all brass, sound and unsound. If during melting the charge is overheated or directly contaminated with obnoxious fumes, they are absorbed in excessive quantities, and their evolution on cooling is the principal cause of blowholes in castings.

Problems of Manufacture.

On discussing the manufacture of manganese bronze with the owner of a large brass foundry, he expressed the opinion that the difficulties were such that he did not consider them commercial alloys. This appears to be common experience, yet they are not impossible alloys if the precautions outlined in the first section of this Paper are followed. Certainly Al., Fe., Mn., Ni. and such metals are amongst the most dangerous materials in the brass foundry, and require both a metallurgical knowledge and consummate care in handling, but, apart from these, the actual difficulties of manufacture are no greater than those of ordinary brass.

Melting.—Briefly stated, the principal features to be observed in melting are:—(1) Preparation of suitable stock alloys for the introduction of the more refractory metals. (2) Correct selection of materials; calculating the mixtures from their actual chemical composition, and allowing for melting losses. (3) Carefully weighing out the necessary additions and charging in their correct order. (4) Avoid the use of scrap of doubtful chemical composition, particularly with regard to Fe., Al., Sn., Si. and dross contamination. (5) Melt as rapidly as possible in a neutral or slightly reducing atmosphere, but never superheat more than 20 per cent. of the actual melting temperature and control pyrometrically. (6) Avoid retention in the furnace for long periods after correctly melting. Where this is impossible, carefully control the temperature, cover with a protecting slag, and adjust for Zn. losses. (7) Mix well, but do not oxidise in so doing. (8) Deoxidise with a little phosphor-copper or phosphor-tin just before casting if the alloy contains Mn.; if Mn. is absent, as in the Ni.-Al.-Fe.-brasses, a little copper-manganese is beneficial both as a deoxidant and desulphuriser. (9) Avoid as far as possible contamination with slag in the ladle.

Crucible Melting.—If melted in the crucible, no difficulties present themselves other than those mentioned in the preparation of the development alloys. Despite the high cost in fuel and crucibles, this is still the most commonly used method, and is favoured because of the flexibility of temperature control, the ease of mixing, low melting losses and protection from dirt and obnoxious gases during melting.

At the same time, the open-hearth furnace is of particular value for the manufacture of large castings. Where first cost permits, the gas producer regenerator or recuperator type is recommended. It is flexible, economical and efficient. The coal-fired open-hearth furnace is commonly installed, but it is costly to run, and both the temperature and composition of the metal are difficult of control.

The thermal efficiency of the oil-fired open-hearth furnace works out roughly at about twice that of the ordinary coal-fired air-furnace. Lighters-up, furnacemen, and ash-removers are dispensed with, and flexibility of control of the furnace is a decided advantage. The fierceness of the oil flame is a disadvantage to this furnace, although by the aid of a burner, permitting of accurate regulation of both oil and air and by the used of a good fuel-oil, no trouble should be encountered in this direction.

The common objection to all open-hearth furnaces for the melting of special brasses is the large surface of metal exposed to the furnace gases, which, if oxidising or sulphurous in nature, are injurious. A few logs of hardwood charged during the melting-down period, an occasional shovelful of hardwood charcoal or anthracite coal, and a suitable protecting flux remedy this. The choice of the flux is extensive, but either of the following may be recommended:—(1) Equal parts by weight of plaster of Paris and fluor-spar; (2) soda ash, 30; fine silica sand, 20; fluor-spar, 33; and borax, 17 per cent. by weight. These should be ground down, 2 to 3 per cent. by weight of the charge being sufficient. Melting should not be forced.

Electric Furnace.—This is the ideal melting furnace so far as quality of metal is concerned. With either the direct or indirect resistance or induction furnace melting is almost automatic, Zn. losses and impurity contamination are reduced to a minimum, and melting temperature under perfect control. Unfortunately, electricity is not a commercial fuel in this country, and the crucible resistance furnace—an ideal brass melting furnace —on trial under actual foundry conditions, proved to be costly in both current and crucibles. The induction furnace is flexible, but costly in fuel consumption. The indirect-arc, rocking-furnace appears to be a promising development, but having no working experience, the author can express no opinion.

Scrap.—For high-grade castings only approved scrap should be used. Where the chemical composition is uncertain, and when the metal is either of undesirable form or dirty, it should be run down into pigs. In the recovery of brass swarf, all scrap contaminated with white metal and excessive oxide should be thrown on one side, and the remainder passed through a magnetic separator. If briquetting is possible, 2 to 3 per cent. of borax or plaster of Paris should be mixed in and sprinkled with water immediately before pressing. If this procedure is not possible, the swarf should be mixed with 3 to 5 per cent. plaster of Paris or 5 per cent. of the No. 2 flux mixture given above, together with a little coal dust, and melting with a reducing flame.

The objection to the use of fluxes in the open-hearth furnace lined with ganister is the accumulation of slag which banks up the hearth and puts the furnace out of commission. To avoid this, the bottom should be flowed with a suitable flux such as plaster of Paris or this material in conjunction with soda ash and fluor-spar, according to the nature of the slag.

Removal of Iron.—Iron, existing as an Fe.-rich constituent of lower density than brass, rises to the surface on melting. By using a siliceous slag and an oxidising atmosphere, much of the iron may be oxidised out into the slag as a ferrous silicate.

Removal of Sulphur.—Some protection against this obnoxious impurity is afforded by the introduction of a little NaCl, into the melt. This should be worked in from the bottom, followed by a little Cu.-Mn., which procedure is a safeguard against gas-holes and porosity, common defects of castings made from scrap. With correctly refined scrap of desired composition up to 60 per cent. may be used with safety. Of the ordinary domestic scrap, such as gits, risers and clean overflow metal, no more than 30 per cent. is recommended. All scrap should be tested carefully for Si., As., Sn., and Sb.

Casting.

Ingots and Chill Castings.—Ingot moulds should be short and squat rather than long and thin, and slightly wider at the top than at the bottom. Both ingot moulds and chill moulds should be preheated to a temperature of 37 to 93 deg. C., cleaned with a steel brush and dressed with an organic material. When a clean, smooth skin is desired, a simple tallow or heavy mineral oil dressing is recommended. For general work, a facing of tar followed by a second one consisting of a mixture of dark cylinder-oil of over 205 deg. C. flash point, mixed with powdered charcoal and followed by a dusting of fine charcoal. Polishing-in of black-lead or smoking with burning resin or creosote oil is quite satisfactory for ingots, and does not belch forth the obnoxious fumes and flames common to oil and tar-dressings.

Speaking generally, 10 per cent. superheat is a satisfactory casting temperature, although for heavy ingots it may be reduced to 7 per cent. Top-pouring through a specially prepared runner basin is recommended. A refractory head is an advantage, but not essential, if the caster understands his job. For the manufacture of high-class stampings or sheet, machining the skin of the ingot or slab may be found advantageous.

Green Sand, Dry Sand, and Loam Castings.—The success in the manufacture of any brass casting mainly depends upon the selection of the correct moulding materials and the individual skill of the moulder. There is not time here to detail the preparation of moulding sands and loam, so the problems dealing with such must be reserved for a later date. Briefly stated, the technical properties to be controlled in a moulding sand are:—(1) Bond, *i.e.*, strength; (2) grain size or texture: (3) heat conductivity; (4) refractoriness; (5) permeability and longevity.

Having once established a means to control and standardise the mixtures for the various classes of work, many of the moulder's problems automatically disappear, and the economies effected soon compensate for the initial expenditure necessary. In green sand moulding alone the preparation of synthetic-moulding sand has effected a saving in moulding costs of not less than 20 per cent.

Conditions governing the choice of mould-green, dry sand or loam, and the general principles of moulding, are very similar to those of ordinary brass-castings, and call for no special comment.

Gating and Feeding.—Without doubt this is the cardinal problem of the moulder. Wrong gating and feeding are responsible for more defective work than any other operation in the foundry. They call for an elementary knowledge of both physics and mechanics, together with practical experience—without which it is impossible to make a commercial casting, *i.e.*, a good quality casting for the minimum expenditure of time, labour and materials. It is folly to attempt to lay down hard and fast rules, as almost every class of casting presents its own difficulties. The principal points to be observed in gating and the fixing of risers are:—

Gits.—(1) *To fill the mould so that the stream of metal is continuous and not broken up on entering the mould.* Wherever possible, run from the bottom or on the level with a good head. This is particularly important in brasses containing aluminium and manganese, which must be cast under the exclusion of air as far as possible. (2) To prevent dross from entering the mould. For flat, circular castings a whirl gate is preferable; for cylinders and the like run from the bottom by means of a series of tangentially cut "V" shaped jets, and for general castings, an ordinary skim gate. (3) To arrange for a straight run of the metal and to avoid direct contacting on delicate cores or projections in the mould. Avoid sharp angles at turning points.

Feeding.—(1) Mould in such a way that the heavy sections are placed in the upper part of the mould. (2) Connect the heavy sections, which are shut off from the lighter sections, to a good feeding riser, by a section of increasing dimensions. (3) Use chills on the thicker sections to equalise the rate of cooling. (4) Use risers or flows of conical form appreciably larger at the top than the thickest section of the job. (5) Place risers at the highest point of the castings and directly above the thickest sections. (6) It is false economy to cut down the number or size of the risers and small dummy risers should be placed where dirt is likely to be trapped. (7) Risers should be filled preferably with hot metal from another ladle or crucible. (8) Where rod feeding is necessary, choose the right section of rod and pre-heat before immersing.

Pouring Dishes.—These should be designed so that bottom pouring is always obtained, so preventing the entrance of scum into the mould. To this end, deep pouring dishes and cast-iron plugs are an advantage. For large important castings, the pouring dishes should hold at least $\frac{1}{3}$ the weight of the casting.

Pouring.—In the final operation of pouring, the first and foremost factor controlling the production of sound castings is the selection of the correct casting temperature from the dimensions and requirements of the job. Never cast with under 6 per cent. superheat nor over 15 per cent.

The casting temperature of these alloys usually range between 930 deg. C. to 1,030 deg. C., according to the chemical composition, etc. The actual casting temperature, however, is best found from Fig. 1, adding the desired percentage of superheat to the melting-point figure. For actual foundry use, small quantities of special metals (under 0.5 per cent.) need not be taken into account. Exceeding this amount, they should be calculated back into either their Cu or Zn equivalents. When the alloy is complex an actual freezing temperature determination is the only satisfactory method. If cast with metal on the cold side, short runs, low strength, brittleness, drawing, blowholes, cracks and mechanically contaminated oxide are the principal defects encountered. If too hot, honeycombing, wrong composition, poor physical tests, weak crystal zones and segregation. Whilst absolute control of casting temperature is appreciated by all founders, there are few who actually measure it from day to day. This may be attributed to the want of a reliable instrument. To anyone interested in foundry pyrometers, the author would refer them to a Paper given by J. Arnott (Proceedings B.F.A., August, 1920), and a Paper read to the Newcastle Branch of the Institution, March, 1922.

In concluding, the author desires to express his thanks to the directors of Sir W. G. Armstrong, Whitworth & Company, Limited, for their permission to publish this Paper, particularly to Sir G. Hadcock, F.R.S.; also to recognise the invaluable assistance and advice rendered by Mr. Homfrey, chief of the Brass Department, and to thank Mr. Adam for his kind indulgence, encouragement and keen interest evinced throughout.

Discussion.

Introducing the Paper, MR. SMALLEY said his object in choosing the subject was to present to them the possibilities and to discuss and deal with the pitfalls encountered in the manufacture of high tenacity brass, or, as it was commonly termed, manganese bronze. The Paper then treated of the manufacture of pure brass, its physical properties and constitution, and then dealt with a third element, aluminium, going on to tin and manganese, and so forth. The effect of a fourth element was then considered, and had been thoroughly investigated, and then they went on to a fifth element. They would realise that to explore these fields exhaustively one would require a good many papers, and he merely presented to them a general outline of the procedure adopted by their foundries in overcoming the problem of high tenacity brasses, in order to put the manufacturer on a sounder basis and to understand the true functions of the elements introduced. He thought most of them would agree that in high tenacity brasses the number of constituents introduced was so high that they were almost bewildered by the complexity, and hence manganese bronze had got a bad name. This, he was afraid, was largely due to many inventors having appeared to gather as many elements as possible in an alloy. This, then, was really the object of bringing before them this partly synthetic examination of high tenacity brass and bronze. In the second portion he dealt with practical problems of manufacture. Some objection might be put forward that he had only dealt with chilled castings for tests, and they might say that these did not represent sand castings or casting tests. While that was practically true, they must at the same time bear in mind that his investigations in the first place were to find out the effect of the elements introduced, and that could only be done by having a constant area of solidification and knowing the casting temperature. Had he adopted a sand casting, it would have been impossible to do that.

Lead Content of Brass.

Mr. V. C. Faulkner mentioned that he had recently met a very important representative of an American firm which manufactured a certain amount of non-ferrous material in this country, and he was told that they were buying brass from the States and France, especially light material, because it had a higher lead content than English material, and the latter did not machine up so easily. It seemed almost necessary that lead would have to be introduced in larger quantities for small repetition jobs. Mr. Smalley had said that manganese bronze had a very bad name, but he thought that statement needed some qualification. He believed that it had already established itself as a very excellent material within limits for propellers.

Casting Temperature.

Dr. P. Longmuir said the Paper was one of keen interest to the brassfounder, and he would especially emphasise the author's remarks in presenting the diagram of the constitution of Cu-Zn. alloys (Fig. 1). All high tenacity brasses or bronzes were based on round about 60 copper and 40 zinc, extra strength being secured by small additions to something within that composition. He did not know whether the author had experimented at all on a varying zinc content. Experience had shown that approximately 60/40 was the best; but in practice, especially with air furnace melting, zinc losses did occur. Many years ago they were up against this problem of always having in manganese bronze a constant zinc, and they took lessons from Siemens steel furnaces by sampling their air furnace charges, and, according to the result of the sample, making up any deficiency in zinc. If the zinc kept constant, then constant tensiles ensued, provided the casting temperature was watched. He could hardly agree in fixing a definite 10 per cent. ; super-heated casting temperature must vary with the section of the casting. He congratulated Mr. Smalley on his Paper.

Importance of Manganese Bronze.

Mr. G. C. Pierce (London) said he merely wanted to substantiate what Mr. Faulkner had said about the utility of manganese bronze. He was reminded that something like 200 tons per week were put into castings in London alone, and he mentioned this to show that there was a big field for its use.

Mr. Sperring corroborated this statement so far as the dockyards were concerned. All the propellers and 50 per cent. of the metal melted in the dockyards was manganese bronze.

Important Points Indicated.

The President (Mr. H. L. Reason) thought it would be generally agreed that in the short time they had had to consider this Paper, containing as it did such an abundance of information in connection with high tenacity brass, there was a lot that would require a good deal of further study. Mr. Smalley had made it quite clear, and it was corroborated by Dr. Longmuir, that if they were out to make high tenacity brass it could not be done by the ordinary rule-of-thumb methods of the brassfounder. In making ordinary brass alloy or bronze alloy they had carefully to watch their constituents and their losses, and also watch very closely their pouring temperatures. If one was inclined to think that these alloys could be taken up haphazard and get good results, disappointment was bound to follow. But Mr. Smalley had pointed out quite clearly that if they watched the point he had referred to they ought not to have a great deal of difficulty in obtaining good and regular results. Looking through the totals and the results obtained by different alloys, they would notice that the increased yield point and tensile had invariably been obtained by a loss on the elongation. The increased yield point and tensile, or the figures that Mr. Smalley gave, were of course high, due to the fact that they were chill-cast. They must not expect to get these results in an ordinary sand cast, for, as Mr. Smalley pointed out, in making research of this description and giving reliable results, he was bound to have a fixed rate of cooling, and he must compliment him on the step he was taking in that direction. By having a fixed rate on permanent moulds Mr. Smalley had been able to place before them most reliable data. As an example of what took place by raising the yield point and elongation, if they examined Table 2 (page 241), and compared No. 9 with No. 11—he thought it was No. 9, without referring to the Paper—that No. 11 gave the highest tensile of the 42 alloys that had been dealt with. It would be surprising to those who had not studied the Paper to know that the author had given the result in his Paper of no fewer than 42 distinct alloys. In the one which gave the highest tenacity they found the lowest elongation, 3 per cent.; but in No. 9 there was a considerable drop in the yield point and tensile. But they would notice that for that corresponding drop there was a considerable increase in the elongation, and he thought Mr. Smalley would agree that, generally speaking, for copper alloys, an alloy that would not give them 15 to 25 per cent. elongation was really too hard and brittle for commercial use. The alloys that appealed to him, and should be considered in conjunction with the results in Table 1A, were 70/30, 59/41; for standard commercial alloys he should pass to Table 2 and mark Nos. 11, 9, A2, and A4; and then to Table 5 he should number F2, Table 9 AM4, and Table 10 AM3C and AM3D. Mr. Smalley had confined his attention to what he (the speaker) should term brass. Although he headed his Paper " High Tenacity Brass and Bronze," he hoped they would pardon him for saying that he thought it was distinctly high tenacity brass. He hoped that at some future date the author would have the opportunity of conducting a similar investigation in connection with brasses with a copper content from 85 to 88, and show the effect of tin, zinc, lead, nickel, manganese, aluminium and iron. He could strongly support what Dr. Longmuir had said, that this was one of the best Papers given on high tenacity brass, and, as an Institution, they were very much indebted to Mr. Smalley for his investigation, and for giving them the results.

The Author's Reply.

Mr. Smalley, in reply, agreed with Mr. Faulkner that lead was very necessary in these alloys; but he had not considered lead, because he thought he had gone far enough. However, as far as its effect on the physical properties went, he thought he could say that on ordinary manganese bronze, lead had no appreciable effect up to 0.75 per cent., and they would be safe in using that quantity. If they went beyond that. they would be limited by the test results as to what they required. Mr. Faulkner had perhaps misunderstood him in regard to the usefulness of manganese bronze. He did not wish to imply that it was an unreliable material; what he meant was that he had seen so many papers on manganese bronze with a condemnation of it by various engineers in the past, and it was to this he referred rather than to the position of manganese bronze to-day. Thanking Dr. Longmuir for his kind remarks, Mr. Smalley said, as the Doctor pointed out, absolute precision and control of composition was a first essential in the manufacture of these alloys. He would not do it by the zinc content; he did it preferably by structure, because in having control of the structure they controlled their properties to a more reliable degree. For if they introduced various elements which had high zinc equivalents, then they exercised a much more important effect than zinc. For example, aluminium was six times as efficacious as zinc, silicon ten times, magnesium 2½ to three times, and so forth; and so in a complex alloy they must have precise control of the composition. Mr. Pierce had referred to the important use of manganese bronze, and he (the speaker) confirmed that, and quite agreed it was a very successful material.

Contribution to the Discussion.

Dr. F. Johnson wrote that he wished to congratulate the author on the presentation of a Paper of great interest, and one of far-reaching importance. It represented a combination of high technical skill, scientific knowledge and works experience, backed up by the resources of a big industrial organisation.

Much of the work described in the Paper bore upon problems with which the writer was familiar. and to a great extent some of his own work had been carried out in the same domain.

There was one charge which he would level at the author, which, however, sprang from no lack of appreciation of the splendid services rendered to foundrymen by the author's work, and that was that the Paper almost completely ignored the work which had been done by other investigators. There were, for instance, the researches of Charpy, Lohr, Guillet, Hudson, Professor Turner and his collaborators, and so on, which should, at least, have merited reference. The writer was particularly gratified to observe that Mr. Smalley accepted the constitutional diagram of the copper-zinc series so far as it related to the beta phase as based on the dimorphism of that phase. With this acceptance he (Dr. Johnson) wholly concurred.

With regard to the curves representing the relationships of mechanical properties to compositions, the writer felt that an insufficient number of points had been taken, apart from the fact that the constitutional diagram represented conditions much nearer to equilibrium than the author's alloys could be. But for practical purposes the author's results were invaluable. The writer was particularly interested to note that Mr. Smalley placed the alloy of maximum strength as existing in the all-beta field.

This confirmed the result which the writer had previously obtained, upon which considerable doubt had been cast, but which the author's results now entirely vindicated.

The results obtained by Mr. Smalley and by the writer are given herewith for comparison: —

There were many points of detail in the Paper which presented themselves for discussion. On page 239 the composition of the fourth alloy was given as 46.7/53.3. This reversed the order in which the components of the other three alloys were given. On page 238 the author stated that he re-annealed his rolled ingots so as to restore them to their original "cast" Brinell hardness number. From experiments on the annealing of chill castings the writer had found that marked differences of hardness were obtained as between small ingots "as cast" and after cold-working and annealing.

No. and Composition.	Treatment.	Y.P. Tons per sq. in.	M.S. Tons per sq. in.	E. Per cent
No. 12 from the writer's Inst. of Metals paper. Cu. 53.11 % Zn. 46.8 %	Cast bar annealed at 650° C. for 2 hrs.	10.53	30.4	37.5
From the author's present paper. Cu. 53.3 % Zn. 46.7 %	Cast bar as forged	9.0 9.7	29.7 32.8	24 28
	Forged and annealed at 650° C. for 1 hr.	7.5	29.10	22.5

Had the author experienced the same thing, and did he endeavour to adjust the annealing conditions so as to obtain no further softening than represented by the hardness as cast?

On page 240 the author stated "1 per cent. of aluminium equalled approximately 5.6 per cent. of zinc in its effect on the general physical properties."

The writer would suggest that Mr. Smalley should make it quite clear that his figure 5.6 was really the co-efficient of equivalence, and that when substituted for 1 in the composition, made the total over 100, so that when the new percentage came to be worked out, it would be less than 5.6

for the apparent composition; it would, in fact, be nearer to the figure 4.

On page 249 the author stated that "exfoliation" of oxide would be encountered, if special precautions were not taken in the case of brass containing high manganese. Assuming the author's term "exfoliation" to mean the interpenetration of a tenacious oxidised skin with layers of the metal, a fault to which the writer had drawn attention in the Institute of Metals Paper already mentioned, he would draw attention to the ease with which this fault could be obviated by the addition of a very small quantity of aluminium—less than 0.25 per cent.

The author's claim for the grain-size reduction effected by iron fully confirmed the writer's own experience, but he was not prepared to accept the explanation offered by the author, that it was due to the nuclear action of insoluble particles of an iron-rich compound. Manganese was readily soluble in brass, but it effected a reduction of grain-size also, and the same explanation would not hold good for a metal which went entirely into solid solution. On page 265 the author referred to a manganese-rich constituent as being responsible for embrittlement and grain-size reduction.

The writer would be glad if evidence of the existence of this constituent could be provided, and also of the alleged desulphurising influence (p. 276).

The paragraphs on heat-treatment were extremely interesting. Could the author give the size of the test-pieces heat-treated, as he would be the first to recognise the profound influence of mass on the properties of heat-treated alloys?

Further evidence in favour of the solubility of N in brass would be welcomed, as, if this were established, it would be of profound scientific and industrial importance.

In conclusion, the writer desired to express his appreciation of the Paper and his hope that the value of it would become more widely known.

American Exchange Paper.

AMERICAN *v.* BRITISH GREY CAST-IRON.*

By F. J. Cook.

Rightly or wrongly, the average British engineer and foundryman considers that American grey irons of their respective class are inferior in physical properties to those of Great Britain. He bases this opinion, first of all, upon the undoubtedly poor wearing qualities of the cast iron which some years ago formed the material of the large quantities of machine tools sent to England. It was commonly said that the cast iron was so soft as to be easily cut with a pocket knife, a statement often enough literally correct.

Some Poor American Irons.

Recently, some improvement has been noticed, attributed partly to wider bearing surfaces and the application of chills on wearing parts, combined with the use of semi-steel. Nevertheless experiences are still related, in connection with the war, showing that American material frequently left a good deal to be desired. The author was familiar with an American machine supplied by a well-known maker which was commandeered by the Government for a special operation in connection with parts for large guns.

Owing to the poor quality of the cast iron the machine was constantly breaking down. No fault could be found with the design, which was excellent for its specific requirement; yet owing to the long periods when it was out of commission through breakdowns the output was less than that obtained from an improvised old machine. It was necessary to replace the broken parts with castings produced from local irons utilising the broken portions for patterns. These substituted parts proved quite satisfactory, and there was some foundation for the statement, although not strictly and liter-

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* The Institution of British Foundrymen's Exchange Paper read at the Rochester Conference of the American Foundrymen's Association.

ally true, that the only part remaining of the original cast iron in the machine at the end of the war was the name plate on the bed.

American Failures.

Writers of scientific papers in America frequently refer to the failure under superheated steam of cast-iron parts. This is a state of affairs unusual in England, grey iron castings being made without difficulty sufficiently strong to withstand working temperatures and pressures quite equal to those under which American castings have broken down—the composition of this more durable material being not widely different from the American irons which have proved unsuitable.

Some years ago an American technical journal with which the author was familiar regularly gave reports of burst flywheels, until at last it became quite natural to look for them with much the same amused interest as the readers of *Punch* anticipated the historical cartoon. English engineers regularly engaged in designing cast-iron flywheels up to a weight of 25 tons, having periphery speeds of not less than 100 feet per second, sometimes wondered as to the character of the remarkable material of which the American wheels were made.

Travel naturally widens one's views and extends one's knowledge, and conversely, there is a tendency on the part of the stay-at-home to become parochial and narrow. One of the results of the war has been a more frequent interchange of visits, and we on this side from a period shortly before the end of the war consider ourselves specially favoured in the visits we have received from many leading American foundrymen, whose eminence consists not only in foundry knowledge but in general accomplishments.

We hope they will pardon the amusement we have derived from the very candid opinions they have expressed in regard to us and our Institution in the old days before, like the Queen of Sheba, they came to see for themselves. One American, for example, expressing the belief that British foundries were generally so badly lighted that an electric torch was necessary to find one's way about in them, and the moulding shops were so low that one had to be careful not to knock his head against the roof girders, was candid enough to say that the first British moulding shop he entered fairly took away his breath. After spending the whole afternoon in it, he regretted his inability to stay longer and see more. He discovered that he had only seen a small part of the whole, and was a little surprised at the offer of his guide that "any time he had a week to spare they would be pleased to show him the remainder." As a matter of fact, he was in the largest foundry in the world, and had no idea that so fine a concern could be found on the European side of the Atlantic.

The author has to admit that up to the present he has been among the stay-at-homes, and is quite prepared to find that his references to American practice will furnish foundrymen on the other side of the Atlantic with at least as much amusement as Britishers have derived from Americans and their opinions of Great Britain. The great purpose of the paper, however, is to furnish a basis for a good discussion, and it may be hoped that this object will be realised.

As the subject of grey cast-iron obviously is too wide to be dealt with in a single paper, it is proposed to limit its scope to the consideration of grey cast-iron made from commercial pig-irons, and cast-iron scrap melted in a cupola by means of coke, and without the addition of steel or any ferrous or non-ferrous materials introduced either into the cupola or the ladle of molten metal.

Conditions of Test Vary.

When one comes to deal specifically with mechanical tests the fact has to be faced that the conditions relating to mechanical tests for cast iron vary considerably in the two countries. Little importance appears to be attached in America to tensile testing, while the size of the transverse bars tested, differs widely from British practice. The ruling tests for cast iron may be said to comprise in Great Britain: For pipes, constructional and general engineering work for more or less rough and large character, transverse bars, 2 inches deep 1 inch thick and tested deep-part-down on centres 3 feet apart; for engine details other than cylinders, transverse bars 1 inch square tested on centres 12 inches apart. It is also becoming more general in the finer classes of engine work to cast the transverse bars 1¼ inches square, machining down to 1 inch square to insure accuracy. For cylinders of all descriptions, tensile bars exactly of the same material as the castings they are to represent are demanded. Practically every tensile bar has to be tested in the presence of an inspector, and the casting of the bars on the job therefore generally gives more satisfaction and prevents the suspicion which might possibly arise if the bar was separately cast without the presence of the inspector. There is a great deal also to be said in favour of the tensile test for cylinders, since the castings themselves are necessarily subjected to tension. Moreover, a tensile test gives a better indication of the wearing properties of this class of iron than any other test known to the author.

It may possibly be that the apathy with which the tensile test in America is regarded may to some extent be due to certain conditions named by Dr. Moldenke, though of that, of course, the author is not in a position to judge. Dr. Moldenke says* :

"In this country (America) you will find about 99 out of 100 testing machines that are not in proper condition for the tensile test. On the other side they calibrate the machines often, and they have their Governments to test them."

There can be no gainsaying his further statement on the same page that "for scientific investigation the tensile bar is preferable."

The reading of American scientific papers and of the technical Press conveys the impression that a tensile test going a little beyond 14.0 tons is considered worthy of special notice; certainly in Great Britain anything like this would be considered quite mediocre. Mr. Ernest Wheeler,† representing Messrs. Crossley Brothers, Limited, Manchester, states that he has found it "quite possible, without the aid of steel to prepare and obtain mixtures of cast iron having a tensile strength of over 18 tons per square inch," and this is confirmed by other workers in the same field. The same gentleman has prepared for the author a bar cast in accordance with the specification for the "Arbitration bar," which has given a result of 17.5 tons.

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* American Foundrymen's Association, "Proceedings," vol. 22. p. 368.

† Manchester Association of Engineers, "Proceedings," 1921

Tensile Tests.

A short time ago the author tabulated his average tensile test results over a working period of 500 consecutive days. The average figure was just over 16 tons per sq. in.; no test was as low as 13.5 tons, while the highest figure reached was 19.2 tons. All the bars were 1¼ inches diameter and were cast on the castings they were to represent—not separate—and were turned down in the middle to ½-square inch area before testing. A typical range of tensile test results with this class of iron with the accompanying analysis is given in Table 1.

TABLE I.—*Results of Tensile Tests.*

Analysis.						Tensile test result, tons per sq. in.	Transverse test equivalent lbs. per sq. inch on Arbitration Bar.
C.C.	G. C.	P.	Si.	S.	Mn.		
0.98	2.074	0.974	1.213	0.146	0.324	14.6	5146
0.84	2.214	1.046	1.166	0.136	0.432	14.6	5146
0.89	2.410	1.140	1.40	0.134	0.453	16.1	5146
0.66	2.498	1.186	1.40	0.136	0.465	17.5	5373
0.84	2.432	0.981	1.143	0.137	0.288	18.4	5562
0.72	2.49	1.2	1.49	0.126	0.420	19.9	5600

For mechanical tests to be strictly comparable it is essential that the bars should be of the same dimensions and similarly moulded, gated, cast and tested. It may be argued, therefore, that the tensile test results given in Table I. are not comparable to those obtained by the American arbitration bar. But the author suggests that in this respect the advantage has not been with those cited. The bars were of the same dimensions as the arbitration bar, and they certainly had the advantage of static pressure due to casting head, as they were placed on the middle joint of short-stroke cylinders. They have one disadvantage, however, in that they were cast with cooler metal than if they had been cast from a small ladle direct from a cupola, while the rate of cooling is slower, owing to their having been cooled down in close proximity to a larger body of metal. The disadvantages of all these conditions were well set out in the admirable exchange paper presented by George K. Elliott to the Institution of British Foundrymen last September.

Comparisons between the transverse tests made in the two countries are necessarily hampered by serious difficulties, chiefly on account of the difference in shape and dimensions of the bars used. The arbitration bar has a diameter of 1¼ inches and is tested as cast, on centres 12 inches apart. The bars with which the author is familiar and of which particulars are given later are cast 1¼ inch square, machined down to 1-inch square, tested on 12-inch centres, and cast on to castings as previously defined in connection with the tensile test.

Constant Necessary.

In the absence of an available machine suitable for taking a bar of 1¼ inches, it has been necessary to evolve a constant which will reconcile the differences of dimensions in the two bars.

The results of the arbitration bar can be converted into those comparable for a 1-inch square bar tested on the same centre by multiplying the breaking load obtained by 0.74: conversely the result obtained on the 1-inch square bar divided by 0.74 will give the equivalent load in the arbitration bar. The formula used for obtaining this factor is given in the appendix to the paper.

In the discussion on Elliott's paper already referred to, the author gave some details of 25 transverse tests of bars giving an equivalent average breaking load on an arbitration bar of 5,300 pounds; the lowest bar gave an equivalent load of 5,146 pounds, and the highest 5,600. The minimum load is a higher figure than that obtained by Mr. Elliott with American metal having a similar silicon content, but with lower phosphorus and sulphur after undergoing the refining action of an electric furnace.

Table I. gives particulars of the transverse results brought up to an equivalent on the arbitration bar relative to bars cast on the same cylinders as those selected for the tensile example.

Keep's Tests Compared.

Although the two previous tests are not in the strictest sense comparable, there is a mechanical test common to both countries, namely, Keep's shrinkage and transverse test. The author was probably the first in Great Britain to have at his disposal a complete set of Keep's machines, and the present opportunity is gladly taken to acknowledge the great value of the shrinkage and transverse test in connection with this class of cast iron.

A rather lengthy correspondence took place with Mr. Keep relative to the working of the transverse machine with the ½-inch shrinkage bars. Mr. Keep expressed the opinion that the alignment of the machine had become affected during its transit. He arrived at his conclusion from the high results shown in the diagrams forwarded to him. In regard to these he said : " Probably we should not have a ½-inch square bar to break at over 425 pounds." Nothing could be found wrong with the machine, and as the result appeared to be borne out by other mechanical tests taken on bars of varying sizes from the same metal a few ½-inch bars were sent to Mr. Keep with a diagram of the corresponding bar in each set. The breaking loads varied from 590 to over 700 pounds. Mr. Keep replied as follows: " I did consider the high results obtained as due to your machine being out of order, but I was mistaken, as my machine gives the same results. The iron is remarkably strong; I don't know of anything as good."

In Great Britain we consider Mr. Keep knew all about the mechanical tests that American irons will stand. The results shown in Table II. of tests made with the same class of iron as those dealt with in Table I. are not only typical of results obtained by the author but of those secured by other workers.

TABLE II.—*Keep's Tests on Cast Iron.*

Shrinkage inches.	Transverse Breaking Load in pounds.	Deflection inches.
0.146	550	0.14
0.161	600	0.15
0.157	650	0.18
0.158	675	0.19
0.159	700	0.21
0.161	800	0.23

Thirty tests on this same size bar gave an average breaking load of 622 pounds.

The general practice differs somewhat between the two countries in regard to the allowable percentage of the chemical elements in different classes of grey cast-iron. This is undoubtedly due to prevailing differences in the irons, and not to a lack of metallurgical knowledge.

Briefly stated, some of the principal differences are as follows :

With one or two notable exceptions, practical foundrymen in America appear to pay little attention to total carbon. While carbon receives special attention and is frequently mentioned, it is only lately that total carbon has had due consideration. The quantity of combined carbon is important, but it is obvious that with varying amounts of total carbon the same percentage of combined carbon will have a different effect. Dr. Stead* has shown examples in which increases of 0.1 per cent. of graphite have reduced transverse strength by 224 pounds and tensile strength by 8 tons per square inch.

Silicon receives a great amount of attention in American foundry practice, and in conjunction with sulphur appears to be regarded as the Alpha and Omega by the purchasers of pig irons. One hears a great deal of "silicon control." In Great Britain silicon is merely considered with all the other elements entering into a commercial analysis. It must not be supposed that there is any lack of appreciation of the value of silicon, since in Birmingham—the home of Professor Turner—it is probable that more research work has been done with regard to the influence of silicon than in any other centre. A formula which the author has used for many years with marked success in connection with the ratio of silicon to carbon in grey cast-iron mixtures is as follows:

$$X = \frac{C}{4.26 - \frac{Si}{3.6}}$$

where X = the ratio of silicon in total carbon.

C = total carbon present.

Si = Silicon present.

$X = 0.9$ to 1 for such work as pipes, grates, easily machined castings and general work.

$X = 0.83$ for locomotive cylinders and castings requiring *maximum transverse strength.*

$X = 0.76$ to 0.82 for steam, gas, oil and Diesel-engine cylinders, and castings requiring *maximum tensile strength.*

$X = 0.75$ to 0.8 for chilled castings.

$X = 0.85$ for acid-resisting castings.

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* British Foundrymen's Association, "Proceedings," 1915.

Effect of Sulphur and Phosphorus.

At one time in this country sulphur was considered the arch enemy of the ironfounder, although probably it is not taken quite so seriously as it is in America. In his exchange paper George K. Elliott considers that sulphur above 0.07 per cent. is dangerous. This does not agree with the results of Coe's* research on British irons. Coe found that sulphur within the limits of his work did not increase the brittleness of cast iron but appears to increase resistance to fracture.

In Table I. the sulphur appears in a proportion twice the amount which Mr. Elliott considered dangerous, yet it does not appear to have prevented a high degree of strength being obtained. A liberal proportion, up to 0.12 per cent., has, in the author's experience, been found to have a beneficial effect upon the wearing properties of cylinders and liners subjected to heat conditions, while no difficulty has been met with in the way of blow holes provided the metal has been melted and cast hot.

To an appreciable extent phosphorus is considered in America to be detrimental to the strength of grey cast-iron. George K. Elliott, in his paper, states "Irons of greatest strength contain only a small amount of phosphorus." Dr. Moldenke, in "Principles of Iron Founding," appears to put the limit for strong castings free from strains at 0.4 per cent. The author's experience points to the conclusion that with the strongest British iron the *distribution* of the phosphorus, provided the amount does not exceed 1 per cent. is more important than the actual quantity present. Phosphorus in a segregated form, the usual form in all weak irons, is dangerous where strengths are required, but provided it appears in the network or cellular form no detriment to strength is experienced with phosphorus up to 1 per cent. This form is assisted so long as the silicon and total carbon are restricted in the ratio appearing in the formulæ for strong irons.

Manganese Held to be Detrimental.

Agreement appears to be more general in regard

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* British Foundrymen's Association, "Proceedings," 1911-12.

to the benefit to be derived from the poling action of manganese, but the author believes that manganese to the extent of 1 per cent. or over is detrimental to good wearing properties under heat conditions. This element has a way of developing spikey crystals which break off under rubbing and prevent the formation of that highly polished surface generally regarded as the distinguishing characteristic of all good-wearing cast iron. Apparently there is much to be gained by keeping this element restricted to the proper proportion called for by the amount of sulphur present, and for this purpose manganese should not exceed five times the amount of sulphur; beyond this proportion there is a danger of the formation of manganese carbide.

FIG. 1.—MATRICE CONSISTING OF WELL-DEFINED LUMINATED PEARLITE.

Although chemical analysis necessarily forms the basis of all scientific work in regard to cast iron, it does not follow that similar analyses necessarily involve similar physical properties. It is also admitted that strong grey irons are associated with the matrix consisting of fairly large areas of well-defined laminated pearlite, relatively stiff portions of cementite and small graphite, and these formations are illustrated by typical examples in Figs. 1 and 2.

While the microscope is a useful adjunct to chemical analysis, the utility of the micrograph is limited; it being impossible to determine therefrom relative physical properties of specimens with mathematical precision, or to ascertain within narrow limits the relative variations. In all probability this is due to our imperfect knowledge of both subjects, and it may be hoped that further research will clear up some of these matters.

Occasionally it is quite impossible, in dealing with this class of iron, to discover either by chemical analysis or the usual methods of microscopic examination great differences in physical properties. An interesting example of this took place some time ago. It was found that the highest tensile test obtained in sixty consecutive days' workings was lower than the lowest tensile test during the next sixty days. The metal was of similar chemical analysis, but the mixture had been varied by introducing a different pig-iron brand as one of the three constituting the charge.

Fig. 2. Note Cementite and Small Flakes of Graphite.

A research was carried on by the late George Hailstone and the author* in connection with this class of investigation. All the methods usually employed for detecting the cause of difference in physical properties, such as chemical analysis, high and low power microscopic analysis, and the employment of various etching agents, failed to show any reasonable cause for the great difference which existed.

As a further test, specimens were deeply etched with 20 per cent. nitric acid in water as suggested by Stead, and afterwards re-examined under low magnification. It was then found that the strength of the material was directly related to the particular formation of the cementite and phosphide eutectic. The stronger the iron, the clearer were these two microscopic elements in the network formation, as will be seen from Figs. 3, 4, and 5.

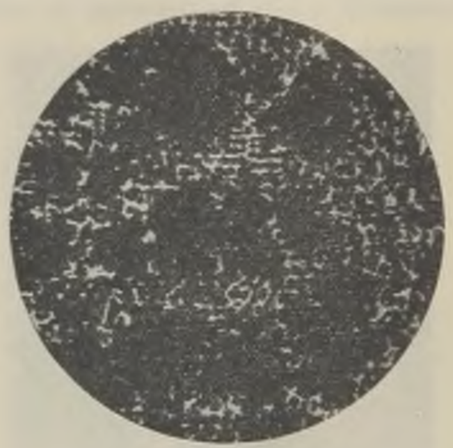

FIG. 3.

The author has made many hundreds of examinations in order to test this, and has never found a single example to the contrary. The network formation is apparent at about 12 tons tensile strength, and becomes more pronounced as the strength increases. In the author's view, this method gives a surer approximation of the physi-

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* British Foundrymen's Association, "Proceedings," 1908-09.

cal properties of the metal than any other form of metallography, and is often superior to chemical analysis. It must be remembered, however, that the field under observation must be typical of the whole. The accompanying illustrations are from micrographs taken from the centre of the bar.

In connection with the research already referred to, the authors, as one of their conclusions, decided that the temperature at which the pig iron is made in the blast furnace has a direct effect upon the formation of this network structure. At the time this statement aroused a great amount of criticism, one professor stating that, after remelting, the iron had forgotten all about the hole from which it had been dug. Time has since proved the inaccuracy of this view, and it is now clear that the temperature of the blast furnace has a marked effect upon the physical properties of the metal, and that these are maintained after remelting.

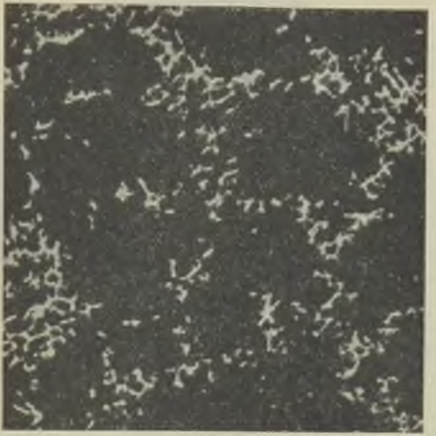

Fig. 4.

One progressive blast-furnace manager has found that pig-iron having this network structure, after going through the puddling furnace, yields wrought iron with higher physical properties than is to be obtained from a pig-iron of similar analysis without this structure. He discovered further that with similar working and furnace burden the network structure was controlled by the blast temperature. When using a blast temperature of 900 deg. F. (480 deg. C.) he is always able to get the network structure; whereas, if the temperature is increased, the network diminishes until at 1,100 deg. F. (590 deg. C.) it disappears entirely, with a corresponding lowering of physical properties of the wrought iron, the general chemical composition of the metal being the same. As the result of these discoveries, the blast-furnace manager has now fitted his furnace with pyrometers for recording the temperature of the blast, and is able thereby to obtain more regularly consistent results.

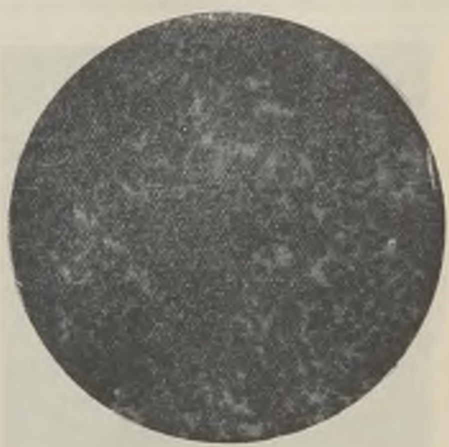

FIG. 5.

Figs. 3, 4 and 5.—Micrographs showing network of cementite and phosphide eutectics—deeply etched with 20 per cent. nitric acid solution.

Network Structure Increases Strength.

Another criticism by a well-known metallurgist was that, although greater tensile strengths were associated with a network formation of the cementite and phosphide eutectic, he thought the metal would give less resistance to shock or fatigue.

Rotary fatigue tests were taken by the Wohler method by the Sheffield testing works on the bars whose structure is shown in Figs. 3 and 4, and these are given in Table III. Fig 6 gives details of the method of applying the test and the dimensions of the test bar. The comparative results are even wider apart than appears from the tensile results.

TABLE III.—*Results of Chemical and Physical Tests.*

		Rotary fatigue test results.			
Chemical analysis	Tensile strength, tons per sq. in	Revolutions per minute	Fibre stress tons per sq. in.	Total number revolutions to produce fracture.	Appearance of fracture
	9.1	980	11	100,800	Fracture sound.
T.C. 3.25% G.C. 2.397 C.C. 0.853		980	5	10,000	Fracture sound
Si. 1.328	9.1	980	6	9,200	Slightly open.
S. 0.95 P. 0.923 Mn. 0.290				19,200	Grained
T.C. 3.192	18.3	980	5	10,000	Major Portion Fine Grain but trace unsound near periphery
G.C. 2.289		980	6	10,000	
C.C. 0.903		980	7	10,000	
Si. 1.314		980	8	10,000	
S. 0.101		980	9	10,000	
P. 0.909		980	10	10,000	
Mn. 0.335		980	11	10,000	
		980	12	10,000	
		980	13	10,000	
		980	14	10,000	
		980	15	800	
				100,800	

The fundamental law governing the phenomena of the formation of the network structure has not so far been definitely and satisfactorily proved. J. E. Fletcher, however, has furnished an explanation which has the greatest degree of probability. Mr. Fletcher is advising director to the British Cast Iron and Wrought Iron associations and has devoted much thought and research to the elucidation of this problem in connection both with the blast furnace and the cupola. His explanation is as follows :

He believes that this structure follows the original boundaries between the crystals of the metal which is first fused during the descent of the iron to the fusion zone in the blast furnace. The carbonisation of the crystals follows their boundaries as decarbonisation follows them in the mechanism of the malleablising process.

If the blast penetration effect while passing the tuyere zones is drastically oxidising, following rapid carbonisation in hot-blast furnaces, then the strong boundary intercohesion is more or less destroyed, with possible gas and oxide inclusions along the boundary films.

With the soft blast of cool or cold-blast furnaces this action is absent, and the intercohesional strength of the crystalline structure, due to the presence of combined carbon and air—unimpaired by gaseous and iron oxides and minute slag inclusions—is maintained.

Shock Test Advocated.

Points which the author has found helpful in producing regular results with this class of iron have been close attention to chemical analysis and regular testing for general hardness by the drill method. But it should be remembered that with these strong irons a much stiffer machine is required than that known as the Keep's machine. Owing to its lack of rigidity the author's experience with this machine has been disappointing.

Regularity of hardness, which is a governing factor of high physical properties, is only attainable by strict attention to blast pressure, and in this connection a recording blast pressure gauge attached to the cupola is most desirable.

A test becoming general in Europe for cast irons of the highest physical properties, more particularly in connection with casting for Diesel and large gas engine piston and cylinder liners, is the shock test. This is carried out by testing a bar cast 40 millimetres square supported on knife edges 160 millimetres apart by dropping on to it a weight of 12 kilograms from varying heights. Attached to the weight in such a way as to strike the bar in the centre parallel to the supporting knife edges is fixed another knife edge. The face of all the knife edges are rounded to a 1/16-inch radius. So far as the author is aware this test is not in use

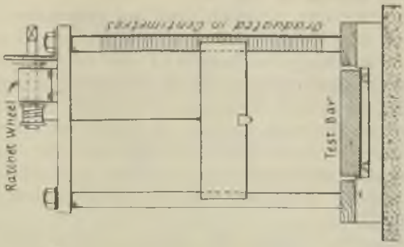
Ratchet Wheel
Graduated in Centimetres
Test Bar

FIG. 7

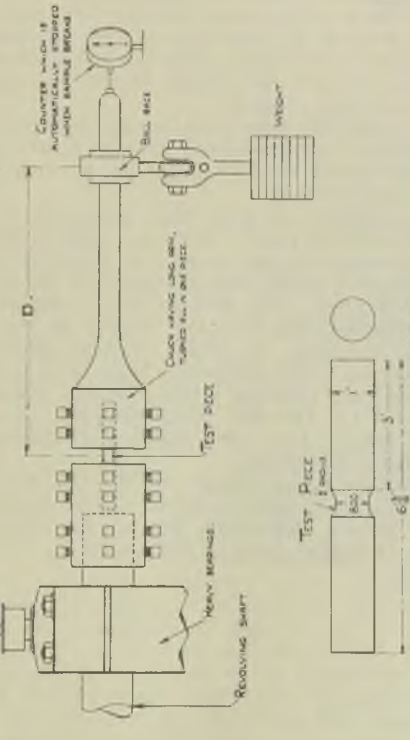
Counter which is automatically stopped when sample breaks
Ball race
Weight
D.
Chuck having long arm, turned all in one piece
Test piece
Heavy bearings
Revolving shaft
Test Piece
.800
5"
6⅛"

FIG. 8

in America. A general arrangement of such a machine is shown in Fig. 7.

In carrying out a shock test we commence with a drop of the weight from a height of 30 centimetres, increasing the height of the drop by increments of 5 centimetres until the sample breaks, the height at which the bar eventually breaks being taken as the test figure. A result of 55 centimetres is considered none too high for the class of work named, although it is quite a severe test. The maximum attained by the author has been 88 centimetres.

Mr. Wheeler uses the same sized bar and machine as a fatigue test, but for this commences with a drop of 28 centimetres and increases by heights of 1 centimetre. The number of blows required to fracture the sample should be taken as the fatigue-test numeral.

A bar from the same metal as the tensile bar of Mr. Wheeler's referred to in the early part of the paper withstood 30 blows, having a range from 28 to 57 centimetres.

In conclusion, as has been suggested in the first part of this paper, there is a wide difference in the strength of the respective grey cast-irons, of which some particulars in regard to the British have been given, the author would suggest the query whether this may not be due to the slow running furnaces in Great Britain producing metal having better properties than that made by the large fast running furnaces which appear to be general in America. Unfortunately, even in Great Britain the slow running furnaces are diminishing in number.

The author's best thanks are due to Professor Turner for help with some of the micrographs, and to Messrs. Bellis and Morcom for their permission to publish some of the results.

Coventry Branch.

SOME DETAILS OF FOUNDRY PRACTICE.*

By E. Carey Hill.

It will be generally agreed that the one common objective underlying all systems of foundry management, whether ferrous or non-ferrous, is the maximum output of good castings of consistently high standard, fully conforming to their various specifications as regards analyses and physical qualities. But, this maximum output must not be attained at the expense of a serious increase in the percentage of scrap, which would, of course, neutralise the advantages gained by increased production. The percentage of rejected castings or "wasters" from all causes must be as small as possible, and the number to be rejected by a customer after delivery should be negligible, or, preferably, none at all.

This desirable state of affairs can only be attained by a continuous anti-waste campaign, conducted according to pre-arranged plan, and forming part of the regular foundry routine. It is intended to deal only with certain details of works organisation and the methods which the writer has developed to secure the desired result in an aluminium foundry.

In aluminium founding the production of successful castings hangs on threads so slender and numerous that the greatest attention to detail is imperative. It is of primary importance that the aluminium casting starts its career in the right direction, as an error at this stage may cause its ultimate rejection, whatever good qualities it may otherwise possess, and however unblemished its individual appearance may be. If it is constitutionally out of order the only remedy lies in avoiding similar symptoms in its successors, which leads to the important question of the preparation of furnace charges, as controlling the properties

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* This Paper was given as the Presidential Address before the Coventry Branch on September 1, 1921.

of the materials of which the casting is to be composed.

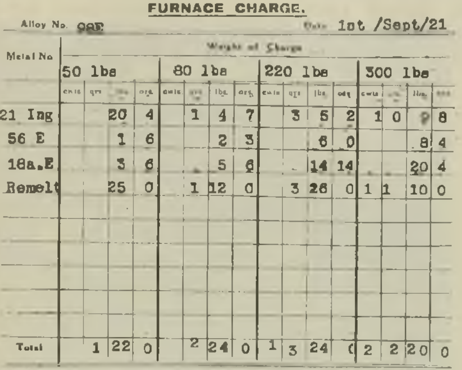
Furnace Charges.

It is in the nature of things for furnace charges to vary considerably in their composition, owing to the multiplicity of alloys which are in regular use in the foundry. In our case, we have, first of all, our standard alloy, containing a small amount of copper, and a much larger quantity of zinc. This alloy is used for the general run of castings and is admirably suited for the purpose. Then there are various other alloys, more or less standard, which are particularly adapted for special work, such as the manufacture of pistons and motor radiator tanks. These alloys contain aluminium and copper only, a harder and more closely-grained metal being required. Again, orders are frequently received—especially for castings destined for aircraft work—which specify certain stringent Government, Admiralty or other specifications that must be rigidly observed. Frequent examples are the Air Board Specifications L5, L8, and 2L11.

Finally, alloys containing the rarer constituents, such as nickel, magnesium and manganese are sometimes called for—magnesium especially being in increasing demand as an important constituent, not only in Mg-Al alloys, but also in a recently-tried new piston alloy containing also copper and nickel.

It will, therefore, be readily seen, that alloys varying so much in their composition, necessitate certain precautions to avoid incorrect mixtures and the intermixing of "remelts." It is desirable at this juncture that our meaning of the term "remelt" should be interpreted. Remelt consists essentially of runners and risers, which are cut off by the fettlers. Aluminium is a metal that contracts appreciably during solidification, and this contraction calls for liberal runners and feeders if a sound casting is to be produced. A small feeder is generally of very little use; in fact it may be acutely detrimental to the casting, inasmuch as the desired result may be reversed, the casting feeding the riser instead of the riser feeding the casting. Consequently, it often happens that the weight of the gates and feeders often equals or exceeds the weight of the casting itself. When the castings are fettled, it naturally follows that the gates and feeders cut off accumulate very rapidly, and have to be again remelted. Obviously, the risers and runners consist of exactly the same alloy as the castings, and from which they have been detached, and can, therefore, be used as portions of successive charges of alloys of the same composition.

Remelt also consists, in a much lesser degree, of castings which are cut up and remelted, because, for some reason or other, they have failed to pass the inspector. As the composition of the remelt obviously is identical with the castings of which it originally formed a part, it is of great importance to keep the remelt of each particular alloy separate.



FURNACE CHARGE.

Alloy No. 92E Date 1st /Sept/21

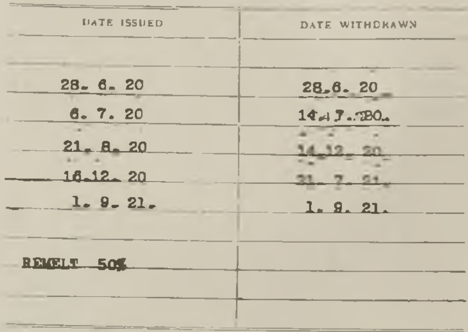
Metal No	Weight of Charge															
	50 lbs				80 lbs				220 lbs				300 lbs			
	cwts	qrs	lbs	ozs	cwts	qrs	lbs	ozs	cwts	qrs	lbs	ozs	cwts	qrs	lbs	ozs
21 Ing			20	4		1	4	7		3	5	2	1	0	9	8
56 E			1	6			2	3			6	0			8	4
18a.E			3	6			5	6			14	14			20	4
Remelt			25	0		1	12	0		3	26	0	1	1	10	0
Total		1	22	0		2	24	0	1	3	24	0	2	2	20	0

FIG. 1.—THE FRONT OF A FILLED-IN FURNACE CHARGE SHEET.

Each alloy is allotted a number, by which it is generally known throughout the works. For example, our standard alloy is No. 97; the alloy commonly used for radiators is No. 55, and one of our standard piston alloys is No. 92. Further, every constituent of each alloy has its own number, *e.g.*, Cu is added in the form of a 50/50 Cu.-Al alloy, known as No. 56. Pure aluminium ingots are No. 21 and zinc is No. 18.

Each charge is carefully worked out, and is typed on a furnace charge sheet, as shown Fig. 1 Only one alloy, of course, is represented by each card, which is made out in duplicate, one copy being issued to the man responsible for weighing out the charges, and the other copy being retained in the office as a record. Four different weights of charges are made out on the card, viz., 50, 80, 220 and 300 lbs. The normal charge is 300 lbs., but the smaller charges are issued when required and melted in furnaces of approximately corresponding capacities.

It should further be explained that for each alloy three separate cards are made out in duplicate, the final composition of the alloy being the same in each case. The variable factor is the percentage of remelt, and it is always our object to keep the stock of "remelt" for each alloy at a more or less constant level in order to prevent it accumulating too much or vanishing altogether. The quantity of "remelt" which enters the metal mixing room—that is, where the charges are prepared—from the fettling shop and foundry varies considerably, owing principally to the variation in the size and number of gates and feeders on different types of work in progress at various times, and due also to a less extent to the variation in the quantity of defective castings which must be melted down. The weight of gates and



DATE ISSUED	DATE WITHDRAWN
28. 6. 20	28.6. 20
6. 7. 20	14. 7. 20.
21. 8. 20	14.12. 20
16.12. 20	21. 7. 21.
1. 9. 21.	1. 9. 21.
REMELT 50%	

FIG. 2.—THE BACK OF A FILLED-IN FURNACE CHARGE SHEET.

feeders depends chiefly on the size of the castings being made in the shops. Heavy castings require substantial feeding; smaller castings have smaller feeders and castings with pronounced variations in thickness usually require more feeding than castings of uniform thickness; hence the variation in the bulk weight of "remelt" available. To counteract this variation, when it occurs, the percentage of remelt in the charges is altered as required, and furnace charge cards are already made out containing three different proportions of remelt, so that no time is lost in making out a new card, when more or less remelt is required, as the case may be. The remelt is kept in the metal mixing room, and each day a requisition is made out by the metal mixer to the metal stores for the estimated amount of virgin metals or special alloys required for the day's output.

FIG. 3.—A 300-LB. CHARGE, SHOWING VIRGIN METALS AND "REMELT," TOGETHER WITH ITS CONTAINING BOX.

Thus, the furnace charge sheets serve a double purpose: They provide the metal mixer with the exact weights of the various metals in each alloy, and they also, almost automatically, regulate the stocks of remelt.

But the correct weighing out of the consituents in accordance with the figures on the charge cards does not necessarily, of itself, ensure that the foundry manager's desideratum—that is, the uniform analytical composition of alloys, is always being realised. It is highly important that the remelt does not get mixed up, as might quite easily happen, with the remelt of another alloy, which might be of totally different analysis.

It would be a serious matter if an aero-engine piston was found upon analysis, after it had failed in service, to have contained 5 per cent. too little copper, and 5 per cent. more zinc than it ought to have—which, as far as the zinc is concerned, is probably nil. This would result if the remelt of standard alloy No. 97, for example, had been confused with the piston alloy remelt No. 92.

There, however, the problem is not quite so difficult in practice as it might appear to be. The sawyer, who cuts off the runners and risers, has his boxes for the various alloys plainly marked with their respective numbers, and he gets to know through experience from what alloy the castings he handles are made. Generally speaking, the great majority of gates travel the way they should go, and find themselves ultimately in the right box. If the sawyer is uncertain of the alloy, the information is easily obtained on the lines just detailed.

With respect to remelt from the foundry, that is, runners of feeders broken off hot, in extracting the castings, or spilt metal, this is collected by the moulder and put in bins provided for the purpose, each bin being plainly marked with its alloy number; and, of course, each moulder knows from his instruction card the number of the alloy with which he is working.

Adequate attention to the weighing out and distribution of the constituent alloys and remelts which make the charge, should ensure that each alloy is maintained well within the limits of its specification. In foundries, where a quantity of scrap metal of unknown and probably varied analysis is bought from outside sources, it is practically impossible to maintain any uniform specification, and obviously, no guarantee of analysis or physical qualities could be given.

If any alloys must be purchased from extraneous sources for any reason, they must be of stable composition, and the guarantee of the suppliers should be consistently checked by the taking of independent analyses. Scrap metal bought indiscriminately is really within the province of the metal refiner and not of the aluminium founder; for the latter, generally, has not the necessary facilities for melting down large quantities of scrap in bulk—a process that is imperative, in order that an alloy of uniform composition may be obtained. It is true that an analysis of the metal made from melting scrap only, in bulk, if well mixed during melting, would give the founder something more definite, at least, to work from, in making up his furnace charges, but the probable presence of excessive impurities would greatly detract from the physical qualities of the final alloy in the casting. We now may justifiably assume that the charge weighed out in the metal mixing room is correct, and it is conveyed in boxes, shown in Fig. 3, of adequate size corresponding to the charge, to the furnace man, who assumes responsibility for it.

Test Bars.

Between the filling with molten metal of the carrying ladle or crucible, and its subsequent pouring into the mould test pieces have to be cast. This may have a vital effect on the history of the casting into which that metal will shortly be transformed. These bars, when pulled, show the tensile strength and elongation of the alloy, and the figures thus attained are generally of great interest to the designer of the engines or structures in which the castings represented by the bar are ultimately intended to play their part. During the war, especially, great stress was laid on the physical qualities of all alloys, especially those used in aeroplane work, where weight was cut down to a minimum and factors of safety reduced to fine limits.

Progress in the direction of commercial aviation will, inevitably, be accompanied by a demand for materials of the very highest efficiency, and there is no doubt that metallurgists and founders between them will have to produce alloys of very high and uniform qualities. It is admittedly difficult to reproduce all the complex stresses, that aluminium castings have to undergo during service, in a simple test that has to be carried out in a few hours, or, at most, in a few days. The time factor has to be eliminated practically altogether, and, consequently, some stress has to be enormously increased in order to produce a sign of strain in a reasonable time. The repeated impact test is an example of this. Test bars will be demanded both now and in the future, so that it may be to our advantage to consider in greater detail the question of making test bars in the foundry.

The first question to be decided is, when and when not to take test bars? This depends almost entirely on the terms on which orders are accepted, and several alternative courses may be adopted :—

1. It was during the war, as we all have either the fortune or misfortune to know, the general rule with Government contracts, as regards aeroplane castings particularly, to insist on all castings being inspected and passed before they left the works by an A.I.D. Inspector. This official not only examined the castings, but selected representative test-bars, and held the castings in quarantine till the physical reports were received. If the result was satisfactory the castings were released, if not, a duplicate bar had to be tested. It may be stated here that two bars were always cast against this contingency. If the second bar went down, all the castings represented were rejected.

2. A second method is to send a bar to the customer with each agreed number of castings. The castings are stamped with the number of the bar, and a duplicate bar is kept by us in reserve.

3. A third method is to make the tests in our own laboratory, and send a certified report to the customer.

4. The last method is that our general guarantee of the alloy be accepted, neither test bars nor copies of physical results being sent to the customer. In this case it is decided by us whether tests are taken or not, and our procedure, in order to safeguard our customers and ourselves, is to take bars and test them at frequent and irregular intervals.

That there is more in so outwardly simple a process as the casting of test-bars than meets the eye is undoubtedly true, for the foundry manager sometimes finds himself confronted with the most curious anomalies. It has been found that two test-bars, cast one immediately after the other from the same pot of metal, behave in a most inconsistent manner when tested. One may give a tensile strength of 13 tons per sq. in., while the other gives a paltry 7. The alloy in each is undoubtedly the same, the pouring temperature must be substantially the same, both are machined to within identical limits, and are pulled in the same testing machine. The only possible explanation, provided that the metal is clean and free from blowholes, is that one bar is correctly poured whilst the other is not.

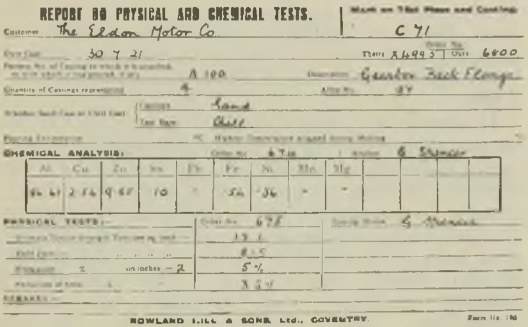
FIG. 4.—POURING A TEST-BAR IN A CHILL-MOULD.

The test-piece is a rod, 1 in. in diameter, cast in an iron or bronze chill, from 7 in. to 9 in. long, which is either sand-plugged in the bottom or has a metal end. A test-bar cast independently in a chill is accepted as a criterion of the physical qualities of a casting, because the strength of the latter depends on the rate of cooling, and therefore one test-piece cannot possibly represent all parts of the casting. The faster the metal cools in the mould the stronger it becomes, so that chill castings are considerably stronger than sand castings, and thin parts stronger per unit section than thick parts. In sand a $\frac{1}{4}$-in. plate is 3 or 4 tons per sq. in. stronger than a 2-in. plate. For this reason it was decided by the Air Board originally, during the war, to cast samples to represent the alloy rather than the casting, and this is the function of the test-bar. The previous practice of casting test bars as an integral part of the casting has been discontinued for reasons which we can, in view of the foregoing, easily understand. Not only is the cooling slow and uncontrollable, so as to make it difficult to procure good uniform and comparative results, but in many cases difficulty is experienced in adequately feeding the test-bar, and in deciding which is the least inconvenient, and also the most satisfactory place to attach it to the casting, as it may sometimes be found that the test bar has unintentionally fulfilled the function of a feeder to the part of the casting to which it is attached, and has thereby been deprived of the feed necessary to compensate for its own contraction during solidification.

The chill is well warmed before the metal is poured into it, and it is held at about 45 deg. while being filled, and tipped upright when full. The secret of the successful pouring of a bar is to pour the metal into the chill as slowly as practicable. This operation is illustrated in Fig. 4.

A few simple experiments were recently carried out in our works, illustrating the importance of the rate of pouring. Four bars were cast quickly, and when the moulds were full they were instantaneously turned upside down, which process had, of course, the effect of bleeding the bar. Similarly, four other bars were cast slowly and inverted, and a comparison of the results were made. The quickly poured bars were hollow to within $2\frac{1}{2}$ to 3 in. of the bottom of the mould, though in most cases the shell was correctly formed practically to the top of the bar.

The slowly-poured test-pieces were hollow to within about 2 in. of the top, while their shells were perfect throughout their length. Obviously, the slowly cooled bars had had more time to cool than those poured quickly, but the value of the experiment lies in the fact that it does prove that the quickly poured bar solidifies from the outside inwards and simultaneously throughout its length, while the slowly poured bar solidifies gradually from the bottom upwards. When a bar solidifies throughout its length at practically the same moment, the metal on the top cannot adequately, if at all, feed the lower parts when contraction takes place, with the result that the bar is inclined to be piped, or porous, down the centre. On the other hand, in the slowly poured bar the bottom layer is fed by the layer of molten metal immediately above it. When this layer solidifies, it is in turn fed by the next successive layer, which is formed as the metal is slowly poured into the mould. This process continues till the bar is cast and a sound test-piece results. Incidentally, the slowly cooled bar has also a better exterior finish.



REPORT ON PHYSICAL AND CHEMICAL TESTS.

Customer The Eldon Motor Co. | C 71

30 7 21 | Their X4993 | Ours 6600

A 100

Quantity of Castings represented 4

Sand

Chill

CHEMICAL ANALYSIS:

Al	Cu	Zn	Sn	Pb	Fe	Si	Mn	Mg				
86·61	2·74	9·67	·10	·	·54	·36	-	-				

PHYSICAL TESTS:—

on inches — 2 | 5 %

ROWLAND HILL & SONS Ltd., COVENTRY.

FIG. 5.—PHYSICAL TEST AND ANALYTICAL REPORT FORM.

This theory, in our opinion, is the only feasible manner of accounting for the variations in the physical qualities of duplicate bars. If, therefore, so slight an error can cause the ultimate rejection of many valuable castings, for both the duplicate bars might, through carelessness, have been poured too quickly, it follows that careful supervision of the apparently trivial detail will amply justify the trouble taken.

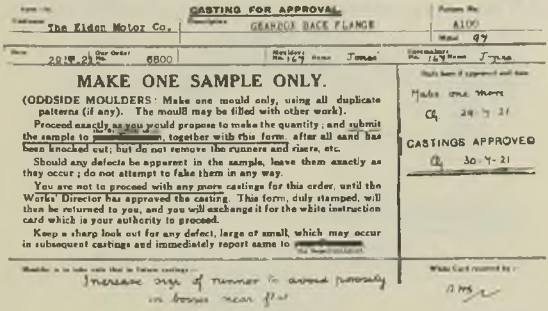
Regarding the internal organisation relative to the recording of physical test results and the retention of duplicate bars, the test-bar record gives the following particulars:—Test-bar and alloy number, description, pattern number, and quantity of castings represented, date and time of day cast, name of moulder and furnaceman, type and number of furnace in which metal was melted, and, finally, the temperature of the metal when cast, if taken. This record is shown in Fig. 5.

When physical test reports and analyses are received from the laboratory, the details of each report are also copied on to the form. Thus there is always available, in a compact and convenient form, a complete history of each test-bar pulled and of each sample analysed. If the sample is of the same cast as the test-bar, and bears, therefore, the same number, then the analysis and physical test results are given on one and the same form, enabling an instant comparison to be made.

If aluminium alloys are cast at an unduly high temperature the rate of solidification is necessarily reduced. Consequently, the crystals formed increase in size, and this is a symptom which is always accompanied by a decrease in strength. If test-pieces are taken as an example, the surplus heat of the metal increases the temperature of the already warm chill. thus reducing its chilling qualities, and affecting the physical properties. The moral, therefore, is that aluminium test-bars should not be poured at a temperature exceeding about 710 to 720 deg. Cent.

The superheating of the metal in the furnace, even though it be allowed to cool before the test-piece is actually cast, is also detrimental to the production of the best results. There may be some inclined to combat this statement, holding the view that, provided the metal is not actually burnt, no real harm ensues. It must be remembered, however, that all metals absorb and dissolve impurities, both gaseous and solid, with greater avidity the higher their temperatures are above their melting points. For example, aluminium will absorb, at a very high temperature, quite an appreciable amount of iron from the ladle used for stirring, also the silicon content will be increased by absorption from the wall of the crucible or furnace lining; and these occurrences militate seriously against the maintenance of the alloy at any given standard of composition or of physical properties.

Also, it is probably true that superheated aluminium combines more readily with oxygen forming Al_2O_3 (aluminium oxide), and unless this oxide is reduced by the addition of a flux such as 1½ to 2 per cent. of Mg. the excess oxide remains in solution, being expelled during freezing, to the crystal boundaries, thus forming an amorphous substance separating the crystals from each other. Naturally this would be a source of weakness, and would probably account for the frequently observed inter-crystalline cracks which sometimes characterise castings poured at too high a temperature.



CASTING FOR APPROVAL

The Elden Motor Co. | GEARBOX BACK FLANGE | A100 | 97

29.4.21 | Our Order No. 6800 | Moulder's No. 167 | Name Jones | Coremaker's No. 167 | Name Jones.

MAKE ONE SAMPLE ONLY.

(ODDSIDE MOULDERS: Make one mould only, using all duplicate patterns (if any). The mould may be filled with other work).

Proceed exactly as you would propose to make the quantity; and submit the sample to [redacted], together with this form, after all sand has been knocked out; but do not remove the runners and risers, etc.

Should any defects be apparent in the sample, leave them exactly as they occur; do not attempt to fake them in any way.

You are not to proceed with any more castings for this order, until the Works' Director has approved the casting. This form, duly stamped, will then be returned to you, and you will exchange it for the white instruction card which is your authority to proceed.

Keep a sharp look out for any defect, large or small, which may occur in subsequent castings and immediately report same to [redacted]

Make one more

Cq. 24-4-21

CASTINGS APPROVED

Cq. 30-4-21

Increase size of runner to avoid porosity in boss near flat

AMS

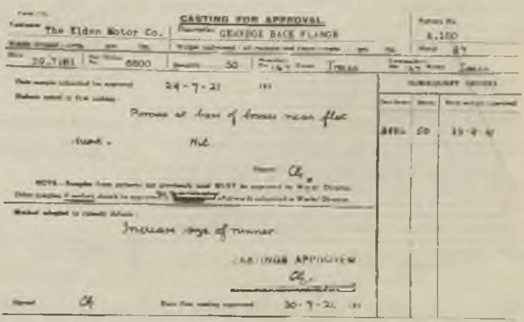
FIG. 6.—FLIMSY COPY OF SAMPLE CASTING APPROVAL FORM.

Sample Castings

The statement made at the outset that one of the essential features of foundry management is the reduction to the absolute minimum of the proportion of scrap castings to total output is equivalent to stating that foundry errors must be eliminated. The battle is half won if the first castings made off a pattern are made under adequate supervision. The battle is completely won, figuratively speaking, at any rate, if this special supervision is repeated at later dates, when further orders for castings off the same patterns are received—provided that the previous experience has been duly recorded in an available form and is subsequently utilised.

The primary function of the technical department is the supervision of sample castings. No pattern should be put into work for production without its express sanction, and this sanction should not be given until a sound casting has been made and approved. It is the business of the technical department to insist that the first casting off any pattern is properly run and sound in every way before permission is given to the production department to proceed with the order. The actual routine method devised and adapted by ourselves may be of interest.

When every order for castings is received in the general office a printed form, called "The sample approval form," or more familiarly the "Flimsy" copy, is typed out for each individual pattern. This form, shown in Fig. 6, is issued by the general office to the technical department. If the pattern is a new one, or new as far as the foundry is concerned, another similar, though not identical, form is typed out, called the stiff copy of the sample approval form, or in short the "Stiff" copy. If the pattern described on the "flimsy" has previously been in use in the foundry, no new stiff copy is made, but the original stiff copy is procured from the file.



CASTING FOR APPROVAL

The Elden Motor Co.

GEARBOX BACK FLANGE

24-7-21

Porous at base of bosses near flat

Nil

Increase size of runner

CASTINGS APPROVED

30-7-21

FIG. 7.—FRONT OF STIFF COPY OF SAMPLE CASTING APPROVAL FORM.

These two forms, the flimsy and stiff copies of the sample approval form, constitute the main-springs of the system. The flimsy copy is an authority for the moulder to proceed with one casting off the pattern whose number and description appear on the heading. The printed instructions to the moulder are shown in Fig. 6.

The flimsy is issued by the technical department to the foundry foreman, who hands it, together with the pattern, to the moulder whom he has selected for this particular job. The moulder then proceeds to make one casting as directed on the flimsy. As soon as the casting is cold enough the sand is knocked out, and the moulder sends it, together with the flimsy on which he has written his name and number, to the inspection branch in the technical department. It is immaterial whether the casting is obviously scrap or not; it has to be sent, as it came out of the mould, for inspection. The moulder has no authority to proceed with another casting off that pattern, for his flimsy is on the inspection bench with the sample. This first casting is made entirely according to the moulder's own idea of how the casting should be made. No one interferes with him, or makes any suggestion. He acts purely on his own initiative. The underlying motive is that this method encourages the moulder to originate the best method of tackling new patterns, and forms a valuable part of his experience.

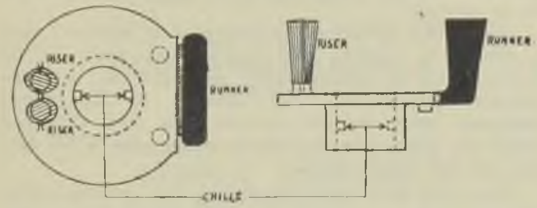


FIG. 8.—THE BACK OF FIG. 7, SHOWING A TYPICAL SKETCH RECORD.

The sample casting now on the inspection bench, with all the runners and risers on, is carefully examined by a member of the technical department staff. If, as is sometimes the case with new patterns, there are some defects, the flimsy is marked "make one more," and re-issued to the same moulder. Suggestions to overcome the difficulty are written on the bottom of the flimsy. Possibly, the gates and feeders must be placed differently, or chills should be added where a riser cannot conveniently be put, in order to overcome local porosity. If the defects, when such exist, are not easily explained in writing, the moulder is summoned, verbal suggestions are made, probably by both sides, and the moulder proceeds to make another casting on the new lines, the flimsy having been given back to him as his authority.

It but seldom happens that a second sample when it is found on the inspection bench, accompanied by the flimsy, is incorrect; but should this be the case the trouble is further investigated, and still another sample made which is practically certain to be correct.

When the technical department is assured that a sample is sound, the casting is sent to be fettled and is subsequently returned for a more minute inspection. Of course it sometimes happens that certain defects are not observed until the gates are cut off, in which case a further sample has to be made.

When the technical department are satisfied that the casting is correct, the stiff copy comes into action. This form, shown in Fig. 7, has two functions. It first of all provides a detailed description of the technical history of the casting. If the first sample is not satisfactory, the remarks on the flimsy copy are also put on the stiff copy, the defects noted and the methods adopted to overcome them being fully detailed. If the sample casting is sound, the stiff copy is marked "sample approved" and initialled by the works superintendent. The second function of the stiff copy is as follows:—Each casting off a new pattern is sketched on the back of the card. An elaborate diagram is not required, it being only necessary to indicate the position of runners, risers and chills. Any special points which can be made clearer by a diagram are also noted. A typical example is shown in Fig. 8.

Thus the stiff copy, which is made of thick cardboard, suitable for sketching, provides in an easily accessible form, for future reference, a diagrammatic illustration of the correct method, based on actual experience, of moulding a casting from a particular pattern.

Meanwhile, the sample casting has now been sketched and fettled. It is next sent to the pattern shop so that its main dimensions can be checked, if we are responsible for the making of the pattern. If the customer supplied the pattern this is not done. To all appearances, now, the casting is correct, and it is sent to the customer for his approval before the order is proceeded with.

A duplicate of this Label appears on the Casting.

SAMPLE CASTING

FOR YOUR APPROVAL.

Please check dimensions, and ascertain if this Casting will meet all your requirements to your

ORDER No.................................... then send instructions to proceed to :—

ROWLAND HILL & SONS Ltd.

COVENTRY.

A duplicate of this Label appears on the Advice

SAMPLE CASTING

FOR YOUR APPROVAL.

Please check dimensions, and ascertain if this Casting will meet all your requirements to your

ORDER No.................................... then send instructions to proceed to :—

ROWLAND HILL & SONS Ltd.

COVENTRY.

FIG. 9.—RED SAMPLE-CASTING LABELS.

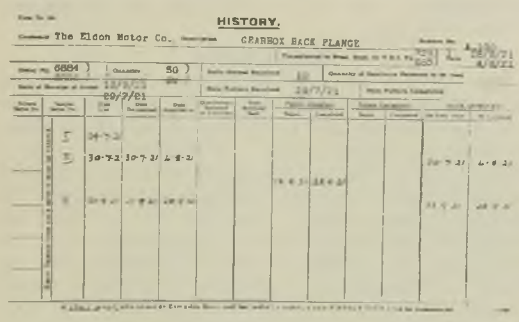
In order that a customer may readily distinguish a sample casting, a distinctive red label is gummed on to it. One of these with a black corner is attached to the casting, and the other is sent with the advice note, which is enclosed with an accompanying letter and sent by post. The sample casting itself is despatched, if too large for the post, by passenger train, in contra-distinction to the general run of castings which are sent by goods. These forms are shown in Fig. 9.

When the customer's report is received, and the casting is approved by them, a technical department instruction note, to the production department, commonly called T.D.I., is issued, denoting that the casting in question has been approved and that the pattern is released for production when required. Further, the flimsy copy of the sample approval form, which in the interim between the despatch of the casting and the receipt of the customer's report has been filed with its accompanying stiff copy, is issued to the foundry foreman, who exchanges it for a white card at the general office, where the flimsy is now filed, its work having been done. The stiff copy is filed in the office of the technical department. The white card is the foreman's authority to proceed with the order, and a receipt for its issue is obtained by the production department as the foreman is required to initial in the space provided in the bottom right-hand corner of the flimsy copy. During the continuation of the order in foundry, the technical department is not directly concerned with the castings made, though the department's inspector keeps a watchful eye on the castings as they come through. It is not, however, this inspector's duty carefully to examine each casting that is made in the foundry, for this is done by the general inspection staff attached to the production department.

Should the customer's report on the sample submitted not be satisfactory, then the necessary alterations or corrections are made, and a second sample is submitted to them if necessary.

Proceeding with the case when fresh orders arrive for castings off patterns which have been previously used in the foundry. When the "flimsy" is received from the main offices the "stiff" copy for that pattern is withdrawn from the file in the office of the technical department. This form, of course, contains on the back a sketch made when that pattern was used for the first time. The value of the sketch can now be readily appreciated, for whatever time has elapsed since the previous order was received the correct method of moulding is known and no experimental work has to be done, with its consequent risk of scrap. The advantage is particularly noticeable when the casting is either large or complicated. The new flimsy copy and the old stiff copy containing the sketch are issued by the technical department to the foundry foreman, who gives the flimsy to the selected moulder and explains how the casting should be made. If possible, the flimsy is given to the man whose name appears on the stiff and flimsy copies, and who therefore made the previous sample. This cannot always be done, for various reasons, neither can the man who made the sample always conveniently be given the pattern when released for production, though this is desirable and is always done when possible.

When one casting, and one only, has been made on the authority of the flimsy, it is placed, when cold, on the inspection bench unfettled. This is examined by the technical department, before and


HISTORY.

The Eldon Motor Co.

GEARBOX BACK FLANGE

6884

50

20/7/21

30-7-21 30-7-21

FIG. 10.—THE HISTORY CARD.

after fettling, and if it is correct the flimsy is stamped and re-issued to the foreman, who exchanges it for a white card at the main office. In this case it is obvious that unless any material alterations to the pattern have been made no sample need be sent to the customer, who has previously approved the casting. Should there be any doubt on this point, however, it is better to err on the side of excessive caution rather than otherwise, for though naturally it is not desirable unnecessarily to delay production, yet the loss of production involved by the delay incurred in sending samples for approval is small in comparison with the loss that might be sustained if large quantities of incorrect castings were made.

Should the first casting made off the flimsy be incorrect, then a second one is made, which has every chance of being in order. The flimsy is then issued to the foreman as explained.

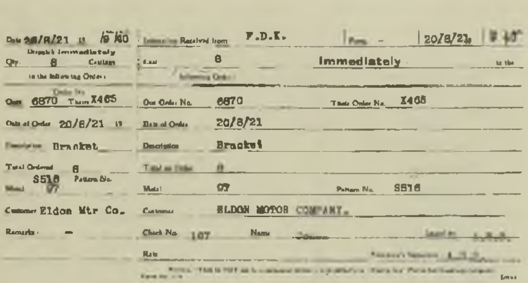
It will be noted from Fig. 7 of the " stiff " copy of the sample approval form that on the right-hand side there are three columns provided for the purpose of recording the order number and quantity of all subsequent orders, together with the date of approval by the technical department of a sample casting for each order. Thus it will be seen that the stiff copy provides (1) a record of difficulties encountered, if any, in the making of the first sample casting off that pattern and how the difficulties are overcome; (2) a sketch, on the back of the form, showing the correct method of moulding; and (3) a record of all subsequent orders received.

History Cards.

The system of making sample castings thus described is extremely efficient in practice, but it is highly important that there be no undue delay in carrying it into effect. For example, when a flimsy copy of the sample approval form is handed to the foundry foreman for a sample casting, the technical department must see to it that the sample is received within a reasonable time, or when the first sample made is defective and the flimsy is re-issued for another one, the second sample also must be received for inspection without undue delay. In order that the technical department may be kept in touch with all the castings and patterns which happen to be passing through their hands at the time, a special form called the " history card, shown in Fig. 10, is made out for each particular pattern. This form gives the complete history of the casting, and gives, when kept daily up to date, the existing position of the pattern in question at a glance. The cards are filed in a box which has three main compartments. In the first compartment all history cards are kept whose patterns for some reason or other are not available for the foundry so as to get a sample casting. For example, the pattern may be in the pattern shop undergoing alteration or corrections, or it may have been returned to the customer.

In the second compartment the cards are filed whose respective patterns are in the foundry for samples. When the alterations or corrections to the pattern are completed, or when the pattern is received back from the customer, the card is transferred from compartment 1 to compartment 2. All sample castings made off the flimsy copy are recorded on the history card whether they be defective or not, so that a record is kept of the number of castings which have had to be made before a sound one is produced.

When a sample casting is approved by the technical department and has to be sent to the customer for his approval, the card for this casting is transferred from the second compartment to the third, which contains therefore all history cards whose respective sample castings are awaiting the customer's reports.



Date 20/8/21 19
Dispatch Immediately
Qty. 8 Castings
to the following Order:
Order No.
Ours 6870 Theirs X465
Date of Order 20/6/21 19
Description Bracket
Total Ordered 8
S518 Pattern No.
Metal 97
Customer Eldon Mtr Co.
Remarks —

Received from F.D.K. | 20/8/21
Cast 8 Immediately to the
Our Order No. 6870 Their Order No. X465
Date of Order 20/8/21
Description Bracket
Total on Order 8
Metal 97 Pattern No. S516
Customer ELDON MOTOR COMPANY.
Check No. 107 Name
Rate

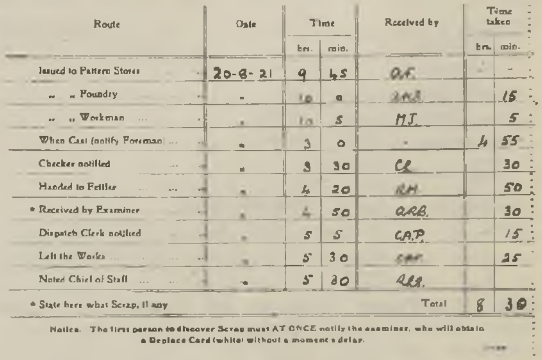
FIG. 11.—FRONT VIEW OF AN EMERGENCY ORDER FORM.

When the report is received and is satisfactory the date and number of the technical department instruction note to the production department releasing the particular pattern for production are inserted in the spaces provided in the top right-hand corner, and the card is filed in a separate box, where it remains until a further sample is required for some reason or other.

The function of the history card is that it enables the technical department to watch every stage in the production of a sample casting and readily to check the time taken either to make, alter, or correct the pattern in the pattern shop, or to cast its sample in the foundry. In this manner it is assured that the sample castings are put through in the least possible time. Moreover, the history card shows what delay, if any, is actually due to the customer, owing may be to the time that elapses before his report is received; so that if a complaint is made that deliveries are overdue, the actual time spent in the making of the sample and the time taken by the customer to check it over are immediately available at a glance.

Emergency Orders.

There remains only one item of special routine which will be mentioned. If castings off new or old patterns are very urgently required, the whole routine just described is laid aside and what is called a "Red Order" is issued. This order, shown in Figs. 11 and 12, is an authority to the foreman to make a specified number of castings without delay. No sample is submitted either to the customer or the technical department, though the progress of the castings is carefully watched by the technical department's inspector until the requisite number of castings is made.



Route	Date	Time		Received by	Time taken	
		hrs.	min.		hrs.	min.
Issued to Pattern Stores	20-8-21	9	45	O.F.	-	-
„ „ Foundry	„	10	0	[illegible]		15
„ „ Workman ...	„	10	5	M.J.		5
When Cast (notify Foreman) ...	„	3	0	-	4	55
Checker notified ...	„	3	30	C.L.		30
Handed to Fettler	„	4	20	R.H.		50
* Received by Examiner	„	4	50	Q.R.B.		30
Dispatch Clerk notified	„	5	5	C.A.P.		15
Left the Works	„	5	30	[illegible]		25
Noted Chief of Staff	„	5	30	Q.R.S.		
* State here what Scrap, if any				Total	8	30

Notice. The first person to discover Scrap must AT ONCE notify the examiner, who will obtain a Replace Card (white) without a moment's delay.

FIG. 12.—THE BACK OF THE EMERGENCY FORM.

A more or less detailed description has now been given of the routine methods adopted with the object of ensuring, first of all, that all castings are made of alloys uniformly correct as regards analyses and physical qualities, and, secondly, that the percentage of scrap is reduced to the absolute minimum.

That the systems described are efficient the experience of several years abundantly proves, and it is for this reason and with the hope that they may be of some interest and practical value to others that they have been outlined.

DISCUSSION.

The Chairman (Mr. G. E. Roberts), in congratulating the President on his address, said he envied the organisation Mr. Hill's firm must have to carry out such a system so thoroughly.

Mr. F. H. Hurren, A.I.C. (Past-President), after endorsing the previous speaker's remarks, said the system which the lecturer had explained of course required establishment before one could say much in the way of criticism or praise. But on the face of it the arrangements outlined certainly looked as if it would show up all the dangers and pitfalls into which the foundry trade occasionally fell. However, the system was, he thought, to be commended in that it showed at a glance to anyone engaged in the management of the foundry the exact position in which any particular order stood. This was a matter which was of vital importance to the management at all times.

Mr. Lane congratulated the Branch-President on his instructive address, and also on following their last President's precedent in avoiding the subject of foundry training, which appeared to be the stock subject for presidential addresses. Mr. Carey Hill seemed to have confined his forms to an absolute minimum for obtaining efficiency. One matter had been mentioned which particularly interested him. Mr. Carey Hill had referred to the well-known change which occurred in metals on constant remelting, but stated that the previous day's risers would be of the same composition as the casting, and he would like to know if this similarity was an invariable experience, because on one or two occasions risers sent for analysis were found not to be so. The foundry foreman told him that a mistake must have been made in the analysis, urging that the composition of the risers or runners must necessarily be the same as the casting, and the casting was all right. According to the analysis of the risers or runners the sample, the foundryman argued, must be all wrong, and therefore they were wrong in the laboratory. The only explanation appeared to be that there was a difference in the composition of the casting and that of the risers.

The Lecturer's Reply.

Mr. Carey Hill, replying, said that in preparing this address he had borne in mind that the aspect of the organisation of the technical details referred to, so that they could be controlled as a matter of routine, was a matter which must be regarded almost exclusively as one embodying the view point of the management in any foundry; and this being so, he had considered that the matter might be of interest to those present who were foundry managers, or who were members of the manager's staff, as it would enable them to compare the methods he had employed with their own, and to take notes of the points of dissimilarity as worthy of consideration.

On the other hand, those members present who were craftsmen in the various local foundries might be assisted to see the matter from a view point differing from their own, which, in his opinion, could not fail to have the effect of widening their knowledge and of assisting them in their work.

In reply to Mr. Lane, he said that in the case of heavy or thick castings it was quite possible that segregation might occur, the heavier constituent in the alloy sinking and causing a difference in the compositions of the casting and the risers; but that in thin light castings the composition should be the same. Of course, with proper treatment, it would be possible to get variations; if, for instance, the metal was stirred vigorously with an iron rammer for ten minutes before pouring, it would be quite likely that some iron might be introduced. On the other hand, there might be something in the foundry foreman's side of the question, for analysts sometimes made mistakes. He had on one occasion agreed to buy ingots on analysis, with a penalty for variation from specification.

Lancashire Branch.

At the opening meeting of the session, held on October 1 at the Municipal College of Technology, Manchester, the following address was read by the Chairman (Mr. J. Haigh), who presided, in the absence of the Branch-President, Mr. W. H. Meadowcroft.

PRESIDENTIAL ADDRESS.

Emerson, the great American essayist, said that in times of doubt and difficulty it is helpful to sit down and have a good think. Obviously the present time is full of doubt and difficulty, and it will certainly do us no harm to sit down and have a good think on matters that are pressing themselves on our notice.

As to the future of the foundry, undoubtedly it will be very different from most of our present-day foundries. Now, more than at any time, it is essential that we should compare our position and practice with that of our competitors. We have ample opportunity for the study of American foundry methods from the literature that reaches this country. Profiting by our mistakes and the mistakes of others, America started at the foundry end in building up their engineering works, with the result that in repetition work they are enabled to get the best results. This is achieved by organisation and detailed study of methods and materials. Great sums are sunk in equipment and the provision of various labour-saving appliances. All this, together with an unlimited supply of alien unskilled labour, which obeys instructions without question and is paid by results, enables them to get a much greater production than we. Even in the larger castings they strive to cut out as much manual labour as possible. In studying the relative merits of American and British foundry practice it is necessary to bear in mind the great difference in the aims and ideals of the engineers and designers of the two countries. The American machines are designed with a view to massed production in every stage, including the foundry, and the engineer spends money freely in convincing the buyer that his machine is what the customer needs, whereas the British engineer has, in the past, followed every whim of the customer, with the result that we have not had full opportunity to develop the various manufacturing processes to their fullest extent owing to these variations. In no department is this felt more than in the foundry, and it is a question of vital importance to-day if we are to compete in the markets of the world.

In Germany we have somewhat similar practice to the American, for reasons which are rather different. The British foundry equipment manufacturers in the early days found their chief market in Germany, with the result that German foundries are, on the whole, much better equipped than ours for massed production, and will soon be keen rivals for our trade.

On examining our own position, the outlook is not discouraging, for we find that great strides have been made in recent years in developing foundries. It is true that the modern trend of foundry practice clashes with our traditional methods, but if we are to hold our own we must unhesitatingly scrap obsolete methods and plants which have long passed their career of usefulness and now serve but to impede our progress. It would not be a wise step to cut ourselves away from the old before we have something to take its place, but with all our modern research work and experiments to guide us, we are not taking a leap in the dark when we decide to do away with out-of-date methods.

In the haste to develop industry in the past we have to a great extent neglected the most important factor, the human element. Do not let us fall into this same error in our new efforts, because one-half the ills to which industry is heir have their root in this factor. The problems that we have before us in dealing with this branch of the industry are extremely difficult of solution, but they are not insoluble; but if they are approached patiently and with that wider vision which comes from an earnest study of the underlying causes, they will themselves show us their true solution.

Undoubtedly we do not get the best out of people by herding them together in the great modern works. Contact between craftsmen on one side and semi-skilled and repetition workers on the other inevitably leads to friction and unrest. It may be difficult to put our fingers on it, but it is there none the less.

All mass production workers should be effectively separated from craftsmen. The foundry of the future will be a series of well-lighted and lofty buildings, where the jobbing moulder will be well away from the repetition worker, and the latter work apart from the coremaker. The jobbing moulder will be a highly skilled craftsman, and will be paid well for good work, and it will be required that he shall prove that he is a moulder in another manner than by showing his Union card.

Another thing that will be essential if we are to learn more of our trade is that proper records must be kept of jobs of the medium and heavy type. A proper system of collating and filing this information would relieve the foundryman of a good deal of his worries, and obviate the necessity of racking his own and other people's memories in an effort to find what was done previously on a similar job. Memory is very illusive, and we want something better than hoary traditions on which to base our practice.

Formerly these matters were discussed at some length in the poor man's club (the public house), with varying results, but modern founding demands something better, and if such records are available it will tend to greater efficiency. It would, of course, be necessary to chronicle our failures even more clearly than our successes. We must tell the whole truth, for it is by our failures that we rise to better things. Given these records, we should still need the highest skill and experience in both the actual making and the supervision of the jobs.

Cast-Iron Research Association.

The formation of the British Cast Iron Research Association is due to the untiring efforts of our Institution. The list of officials and members shows it is well represented, and we are confident that it will prove a practical and permanent benefit to our trade. It certainly behoves us to take a keen interest in their work, for it will be most helpful to us. It is the intention of the Association to study the apprentice question, and try to evolve some scheme for special educational training in connection with a graded workshop course. If this difficulty is solved it will have overcome one of our greatest concerns, the supply of bright, well-educated boys for the foundry.

A higher standard of education for our boys is an obvious necessity if we are to progress; intelligent and receptive minds will be needed to absorb all that it is imperative to know. It is to be regretted that even to-day there are very few moulders who can read a drawing, and obviously the moulder's work would be far more interesting if he had an intelligent idea of the laws and forces that govern the exercise of his craft.

The pamphlet sent out by the Research Association sets out a comprehensive programme. The list is long and formidable, and it will need the close co-operation of all interested parties to achieve the object.

Metal founding is one of the oldest crafts, but founders have until lately been content to grope about in an atmosphere of mediæval gloom, and have not made much effort to improve methods with the times. In some of the smaller foundries, and even in some large ones, we see types of tackle and methods of moulding which might have been introduced by a Minister of Munitions of the time of Cæsar. Our trade has recognised this, talked about it for years, but has done little towards altering it until comparatively recent times. Even now we have not cleared the cobwebs from all the corners of the industry, and we shall have to leave it to the stress of an actively competitive business world to do this. Undoubtedly the Cast Iron Research Association will fill a great space that has been waiting for it, and thus will leave our own Institution unfettered to deal with matters of equal importance that lie in other directions.

The Institution.

The Institution of British Foundrymen has made great progress since its inception, in spite of great handicaps. The leeway created by ignorance and apathy in past days is being rapidly made up. Each year sees it enter on a period of greater activity. The successful conference held at Sheffield in 1918, after a lapse of three years, gave it a great impetus. In attending the Council meetings in various parts of the country one is impressed with the zeal, ability, and public spirit of the members, who often travel long distances to attend to the business of the Institution. There is every reason to be proud of having such men in our craft, and we were especially fortunate in having such a man as Mr. Riddell for President last year. This year one of our own Branch members, Mr. Oliver Stubbs, has been appointed to this high office. We congratulate him heartily on this signal honour, and we are confident that he will worthily maintain its high traditions. The Branch Council are determined to make the year of Mr. Stubbs' office a memorable one, and rely on the assistance of all members to make this possible. The first thing to do is to increase our membership. It ought to be possible to double our numbers. We must bear in mind that as time passes it will become increasingly difficult to become a member. The Royal Charter, when obtained, will give a much higher status to the Institution.

There are abundant signs that we are making our presence felt in the engineering world. A gratifying acknowledgment of our work has recently been made by the Ironfounders' Employers' Association in making a grant of 200 guineas to our Institution. Owing to generosity of some of our members, a scheme is afoot to grant medals and diplomas for good work done for improvement and education within the Institution.

Branch Conditions.

Turning to the Lancashire Branch, it is desirable that our members should submit any suggestion they may have for increasing our sphere of usefulness. Undoubtedly it would help all round if we could get more discussion and interchange of views at meetings. It would also be a great help if we could get our younger members to take a more active part in our meetings and discussions, for youth is synonymous with enthusiasm, and enthusiasm can accomplish much if it is tempered with the advice of the older and more experienced members.

The Lancashire Branch covers a very wide area, and it is the duty of the members to see that the Branch Council should be as widely representative as possible. It should be feasible to arrange small groups in various districts and appoint some rendezvous where they could meet and talk things over. The results of such meetings could be brought before the usual monthly meeting in this room, and would no doubt prove invaluable in extending and amplifying our work

It may be possible to arrange to have half an hour devoted to discussion of current problems; for instance, the types of pig-iron, coke, sand, etc., and it would make meetings more attractive and informative. It would be useful to have our members' experiences of some of the strange brands of pig-iron that are on the market at present. Much of this iron is bought through the office without the foreman moulder's knowledge, and he is then called upon to make the best of it, which he does, but with very variable results.

Such questions as these have an immediate interest to the bulk of the members, and we must bear in mind that the chief value of our Institution is in the free diffusion of the experience and knowledge of our members. In the difficult period through which the industrial world is passing it is of the first import to us that we should come more closely together to try by the exchange of thought to do our part to bring about a more stable state of affairs.

Improvements Sought.

A question of much interest to us, raised at the Conference, was the need for greater co-operation with the moulders. Hitherto there has been a suspicion that our only concern was to obtain an increased output. While this is one of our chief objects, we must make it known that we intend to achieve this largely by improved plant and organisation and by better understanding, not by taking it out of the workman. To-day, social economics are very much to the fore, but we leave these severely alone; whatever ending these controversies have, we shall still need better foundries and better foundrymen. Taking an impartial stand, we can press steadily on with our task, and ask the help of the better elements of all interested parties. We have inherited much from the work of our forefathers; our plain duty, therefore, is to do our best to leave the craft in a higher position than we found it.

Unemployed Members.

In Mr. Stubbs' Presidential address he laid stress on the need of a register of our members who are unemployed. This is a question we have discussed often at our Branch meetings, and without doubt something ought to be done in this direction.

The very fact that our members devote part of their leisure time in endeavouring to improve themselves and the craft by attending our meetings entitles them to prior consideration when applying for responsible posts in the foundry. Some sort of a register is supposed to be kept at present, but the idea requires the consideration of the whole of our members. The more widely known the scheme becomes the greater will be its efficacy.

In connection with this, it may be mentioned that the proprietors of THE FOUNDRY TRADE JOURNAL have offered four free advertisements to any of our members who are subscribers and have the misfortune to be out of employment.

MR. HOGG (the Secretary), in moving a vote of thanks to Mr. Meadowcroft for his address, said it was to be regretted that Mr. Meadowcroft could not be present on this occasion to put them before the members himself. He was not alone in that; other leading men in the Institution held the same view. They desired to encourage among the members a spirit of mutual aid, and an example of that was the offer of Colonel Cheesewright, referred to in the address. Whilst he had acted as Secretary many vacancies had become known to him, and in some cases he had been able to pass the information on to other members, to their advantage, but as the meetings were only held once a month and the firms who had vacancies to fill were usually anxious to do so quickly, it was too large a matter for one person to tackle, and he hoped some scheme would be brought forward. Personally, he saw no way of dealing with it without establishing a register.

THE CHAIRMAN (Mr. J. Haigh) seconded the motion. He agreed that the Presidential Address gave them a good deal to think about. He hoped the members would show the same spirit as the President, and try to carry out the aims and ideals which had been placed before them, and make the Institution known in every foundry, not among the foremen alone, but also among the workmen, thereby creating a better atmosphere. The past ten years had seen more improvements in foundries than the previous fifty years, and there had sprung up a desire for better things. The industry could not move faster than according to the knowledge and education of the people with which they were dealing, but they must be ready to take advantage of that desire whenever it showed itself.

The vote of thanks was carried unanimously, and the members proceeded to the consideration of some technical questions.

Birmingham Branch.

SOME PRINCIPLES UNDERLYING FOUNDRY PRACTICE.*

By H. Field.

The Sphere of the Scientific Worker.

The word "academic" is not rightly applied to the scientific worker who is directly in touch with industry, but he rather prefers the much plainer name "technical." The former word has its use, and is strictly applicable to the pure science or laboratory worker rather than to the "works" man. There is a tendency on the practical man's part to call all things beyond the scope of his knowledge and intelligence by the name "academic," with which he associates "unnecessary," because unknown. To some, my own outlook on foundry work may be so classified, but I plead that all of us may show tolerance and even respect for the unknown. The true technical man stands in a midway position between the practical and real academic worker, inasmuch as it is his place to grasp the significance of work done by this latter and apply it to the tasks of the former.

The practical man is to be envied, and all tribute paid him for his skill and craftsmanship, which I entirely lack, and if to-day he will not see my point of view, the time will come when we shall work fully together. The motto of our Institution, "Science hand in hand with labour," is the only one which the foundry can adopt with any hope of complete success.

Scientific Research.

It is not proposed to discuss the general proposition that the foundry is far behind other branches of the engineering trades in the matters of standard practice, scientific methods of working, and production of uniform qualities of goods over long

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* The Presidential Address delivered before the Birmingham Branch on October 8, 1921.

periods. This point has been well brought out in the propaganda work of the Cast Iron Research Association, and the formation of this body is an admission that foundry workers can make no further progress until science and research have come more fully to their aid. That it should have recourse to such an outside body is only natural, and is an economic use of existing resources, for the practical, technical, and research worker has each his work to do, and no man can work along all these lines at one time.

In surveying the whole field of foundry work there is one point which should appeal more strongly than any other as showing the need for further work, that is the lack of standard practice. It is to be hoped that the logic of the next statement will be accepted—that there is and can be only one best way of doing a thing—whatever the thing may be.

The ideal of the scientific and technical man is a very high one: to make every process subject to law, and in everything to be exact. One of the most eminent foundrymen of the last generation, W. J. Keep, said " there are too many unknown factors to allow of the metallurgy of cast iron being made an exact science," but although the number of unknown factors is large, it is inadvisable to subscribe to the conclusion drawn by Keep. The aim of science and research must be to make the metallurgy of cast iron an exact science, and from the varying ideas and methods to which every foundry adheres to raise up for the use of every foundryman a standard practice, of which it may be said that every operation is done in the one best way. Have not many of us lost sight of the fact that there can logically be only one best way—for everything?

Leaving foundry practice for a moment and referring to the geometrical systems which were evolved so long ago by Euclid, and only built up after certain axioms were allowed to be taken as granted, it must be conceded that in foundry practice we take as an axiom " that there is only one best way," and this only can be the basis of standard practice, which must be a collection of the best ways of doing every single operation which the production of perfect casting includes. For the most part this "best way" is not at present followed, and in most cases it has not yet been discovered. The very diversity of method followed by those of us who are endeavouring to reach the same goal must of itself prove the contention, for all our ways cannot be the best, and it must follow that nearly all of us are following a way other than the best, and are therefore working along lines which are wasting effort, energy, time, material, and money. Until it be discovered and agreed as to the one best way standard practice cannot be put forward. Naturally, as foundry practice includes so many varying classes of work and of so many sizes it could never be possible to adopt one uniform practice for the whole of the industry, but if the object in view be the manufacture of any one type of casting—for instance, a chilled roll or a motor cylinder—then it can be maintained that for each of these types there is one analysis of iron, one mixture of pig-irons, which is more suited to that particular casting than any other can be. Take it that this was agreed on, and imagine the different products which different founders would obtain when they melted the agreed standard mixture, showing that melting practice needs standardising with each phase of work. It is consequent on such considerations as these that it is urged in the first case what may seem an idealistic realisation that there is only one best way. Inasmuch as many harbour in their minds that they are already following this way, it will not be agreed to, for standard practice implies co-operation. No adoption of agreed systems could remove the uncertainty of the human element, but it is just because of this that it can be put forward, for it is not at all in harmony with the ideas expressed to convert this human element into a machine, and the performance of our daily tasks would still involve as much or more thought and intelligence as to-day.

Let it be clearly understood that no claim is now made that the technical man is necessarily any nearer the best way than the practical man, but by reason of the method of his training he is much more likely to admit, or rather to insist on, its existence, and where the practical man will often rest satisfied with that which is "good enough because it serves the purpose," the technical man will rarely conform to any such proposition.

Beyond the truth that every problem has its solution and every effect its cause, lies the further fact that every system or process has its appropriate laws, definite and inflexible, by which it is governed. The scope of science in industry is to discover, firstly, the laws which govern every process, and, secondly, to devise means whereby these laws, governing the production of perfect work, may be kept unbroken. It is beyond question, when logically considered, that as often as any process is carried out under exactly identical conditions, just so often must identical results be obtained, and yet the founder is constantly puzzled by varying results from apparently unvarying conditions. The argument that nothing has been altered is quite untenable, and the alternative must be adopted and ignorance admitted of the governing laws in their entirety. In other words, in few cases has there been discovered all conditions which influence the result, let alone mastered the art of keeping those conditions constant. Hence the varying results in foundry work, and the considerable degree of uncertainty which faces the ironfounder when he attempts any particular casting—a degree of uncertainty which is far greater than when the engineer essays to make an engine. The measure of this uncertainty is the measure of our ignorance, and the foundryman probably meets with more puzzling phenomena than any other craftsman, revealing the necessity for the extension of his knowledge through research. To admit the existence of such definite laws as have been referred to is to recognise that at some future time foundry practice may be as much an exact science as is the multiplication table.

Variables in Cast Iron.

Taking the case of cast iron, which occupies the premier place amongst the metals used in the foundry, the final condition in which the metal is found in the casting is influenced by a large number of factors. To enumerate these under main headings we have:—Initial conditions of manufacture in the blast furnace; composition; cupola conditions, including quality of fuel; casting conditions, including length of time in ladle and temperature of casting. The influence of blast-furnace conditions is important to the foundryman, but is usually outside his information, whilst the heading "composition" may be sub-divided into at least five items. In seeking to diagnose a fault, information is desirable on all these points if possible, and the result of insufficient knowledge of any of them may be the forming of a wrong and misleading verdict. The effect of variation in any one of these many influences is fairly well understood, but it is possible for several of them to deviate from the standard in the making of any one casting, and then it becomes exceedingly difficult to get to the root cause of troubles. Many workers, both practical and technical, have laid certain troubles at the feet of certain influences without being sufficiently sure that variation has not taken place in any other factor; results of work of this kind have frequently been published and have misled other workers and helped to make that confusion and uncertainty which surrounds the founder. Slow progress but certain is the only safe method, and the assurance that there is some real definite knowledge gives much confidence.

Basis for Experiments.

Probably the chief reason why exhaustive experiments, leading to definite knowledge, have not been more largely carried out on a practical scale is the very large expense involved. Experience has shown that of the very large number of experiments made on a small scale, only a few when applied to commercial practice are of any use. More particularly does this refer to crucible and cupola melting. The cupola has such immense influence on the metal passing through it that information as to the properties of pig-iron, either individual brands or mixtures, when obtained from small pot-melted heats, is no guide to the results to be obtained from cupola practice. If any are not in agreement with this it is only necessary to refer to crucible-malleable versus cupola-malleable for an illustration, but it can be supported by personal experience with pot and cupola and by having endeavoured to put into practice on the cupola the results obtained by other workers with the crucible. The comparison between crucible and air furnace is, of course, more valuable, and since air furnace practice is gradually extending, such experimental work as has been referred to may yet be worth while. For the present, however, the cupola holds sway, and it is to be hoped that the Research Association will not endeavour to solve the foundry troubles put up to them with the aid of a crucible or to set on foot new work along these lines, for it is not wanted, but rather investigations on practical lines. This is another factor largely contributing to the uncertainty of foundry work, but it has no doubt arisen in an endeavour to avoid expense.

Fracture and Analysis.

It having been shown that the final character of the iron is dependent on the relative strength of a number of influences, of which chemical analysis is only one, it is obviously illogical that knowledge and control of analysis alone can remedy all ills and avoid all defects. But on the other hand it has been shown that chemical analysis is one of the factors influencing final condition, and it is therefore equally illogical to argue that without analysis effective control can be maintained. No sooner, however, is the question of analysis raised than it is followed by its relationship to fracture and the degree to which each is to be admitted as a governing factor in the purchase and utilisation of pig-iron. It would appear, at any rate, that the makers of pig-iron are not yet prepared to concede that analysis is one of the determining factors in making good castings. Nowhere are we farther from standardisation—in the ordinary run of practice no two batches of iron appear to be exactly similar, no mixture can be exactly repeated over any length of time, and any attempt to adopt a standard mixture to give a standard product soon breaks down through lack of uniformity in the constituent irons. The same mixture may be used where brand or fracture is the guide, or a different mixture may be used where a standard analysis is worked to, but the resultant iron is found to vary considerably. As a first essential in the work of the Research Association and in the building up of standard practice, it should become incumbent on every blast furnace to produce and put on the market standard irons within standard limits of analysis. If the foundry trade as a whole would insist, then this object might be easily accomplished. A similar state of affairs would not be tolerated by the steel or non-ferrous industries, and as a result these metals can be bought to any desired analysis. In the case of pig-iron the blast-furnace people are found offering tables of analyses, coupled with such declaimers as:—(1) We sell this iron to analysis, but do not bind ourselves; (2) we do not sell to analysis, these figures are only approximate; (3) we do not sell to analysis, these figures are for your guidance.

These are a few actual quotations and could be multiplied very largely. Compare this with a prospectus issued by an American agent, with guarantees, and we see the difference between the founders' position in the two countries. Approximate figures are little less than useless, since there is available too much experience of being guided by them, and firm guarantees are needed. To-day in the foundry industry there is no option but to accept what the furnaces send, and those who have objected know how difficult it is; indeed, little or no redress is obtainable even in cases, by no means infrequent, where the material sent is absolutely unuseable by the founder, let alone just outside specification. If fracture be the guide it is difficult to find two men who will prescribe the exact limits of any grade, or classify similarly any dozen or so different fractures, so that without having definite standards of fractures no redress could be expected when the buyer is dissatisfied with his purchase; but analysis does provide definite standards to which it can easily be seen if any sample conforms. Sale by analysis will not leave the blast furnaces with a good deal of unsaleable iron, for, generally speaking, all iron is good iron when properly used; if it were indeed found that certain iron were unsaleable because there was no good use for it, then who amongst founders will grumble? It can readily be understood that even amongst founders this view of the case is not universally accepted, because to some who have failed to keep pace with modern developments an analysis conveys nothing whatever. This in spite of the facilities which have long been available at little cost in the shape of trade literature, evening classes, and the work of this Institution, which together have familiarised members and others with the terms and meaning of a chemical analysis. The method of grading by fracture has been on trial for a long time, and having failed to give the required degree of certainty to ironfounders, it is doomed to give place to the method of analysis. It may be that this, too, will prove a failure, or perhaps insufficient in itself, and will in turn have to give place to some new method propounded by research, such as a simple but informing physical test. But such a possibility must not forbid its trial. In plain terms, what is required is a means of ascertaining the value of any iron for making castings and of obtaining in quantity an iron which will give desired and certain results.

Inherent Qualities.

Referring back, it is worthy of repetition that the same logic which forbids us to claim for analysis a complete power of control also forbids us to ignore the power that it does wield. Everyone who has handled analyses knows that samples with the same apparent chemical analysis may vary widely in character, but it is also known that mixtures made from irons with the same fracture may vary in character too. Seeing that there are other factors, such as blast pressure, etc., it is only natural that such samples should vary. These irregularities are chiefly due to the working conditions of blast furnaces at time of manufacture and casting of the pig-iron. For the same reasons various pig-irons, even of the same analysis and from the same district, will be found always to vary in character. It is true, too, that some pig-irons mix one with another better than others, a fact which has not yet been explained satisfactorily; but all these facts, detracting as they do from the value of analysis, do not destroy its value. The ultra-practical man uses them for this purpose, but amongst all the factors which influence iron, the most important is undoubtedly its chemical analysis.

Casting Temperatures.

Next in importance, although equally ignored, is casting temperature. Ignored is not altogether meant, because it always has to be considered in its relationship to running and soundness. Little research on practical lines has been published, but strict attention to mixing and analysis shows that many irregularities in the past have been wrongly attributed to these latter factors, and compel attention to be given to casting temperature. Under this head occur those bewildering differences in the same heat of iron from the cupola, which in the main are certainly not due to differences in the iron itself, but often to the temperature at which it was cast. It has been shown in a Paper* on "Semi-Steel" that the tensile strength from very hot metal may be double that from cold of exactly the same composition, and this applies to all grades of iron. This important factor, however, appears to be more difficult to control than does analysis, for although melting temperatures may be regulated, this is by no means the same as casting temperature. This applies particularly to light snap-flask work, where each box weighs only a few pounds and a 5-cwt. ladle takes a considerable time to empty. It is not correct here to say that analysis gives no help in the solution of the problem. Without a knowledge of the analysis there is no certainty that these and other phenomena may not be due to variations in the iron; but if it be proved that the various samples are of identical analysis, then by a process of elimination attention is directed to other possible causes which may be proved, one at a time, to be varying or unvarying as the case may be.

In any system of grading by analysis chief attention will naturally be paid to silicon, as this element exerts more influence on the iron than any other. So much is this the case that if iron could be obtained of guaranteed and required silicon content a sufficient trial could be made of the system of "grading by analysis" without regulating other elements; a trial which would enable the giving a verdict on its value, and in the event of its success would justify a grading throughout. Phosphorus, although an important element, is not a difficult one with which to deal, because its amount very rarely varies to an impor-

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* See Proceedings, 1920-21, p. 312.

tant extent in any one make of iron. It is because of this unvarying quality, and not because of the unimportance of its influence, that it causes little worry to the ironfounder, for knowing the required percentage of phosphorus in any class of castings this can be easily obtained. If other elements were as reliable, it may be concluded they would cause no more worry, and this is certainly an argument in favour of the analysis system. The subject of phosphorus is, of course, not to be dismissed in these few sentences, but the contrast between this case and that of silicon is in our knowledge of requirements. So much attention has been paid to this latter element that its influence is well understood and desirable limits for almost all classes of work are known fairly accurately. But more light is desirable on the amount of phosphorus which is best for heavy work, automobile work, and chilled castings, and it is from this side rather than the blast furnace that work must be done.

The Sulphur Question.

In the case of sulphur, this element is almost invariably best when lowest. There are those who lay every evil to its account, and others who maintain it to be almost harmless, whilst even again there are cases where, according to Longmuir, sulphur may be advantageously added to low sulphur Swedish iron. The field of foundry practice is so wide and diverse, and the classes of castings made by various workers so different, that it is possible that the adherents of both sides are right for their own practice. In the case of light castings where surface and skin are of the utmost importance and which frequently have to be machined all over, there is a very definite limit, and that not a very high one, beyond which clean, sound, easily machinable work cannot be made. For such work, the lower the sulphur the better, and it would certainly be beneficial if never over 0.06 per cent., although this does not mean agreement with the passing of iron through an electric furnace, to bring the sulphur down to 0.01 per cent. or thereabouts. In normal times the sulphur can with care be kept round about 0.08 per cent. and easily below 0.125 per cent., which can be considered the limit of safety. But from the commencement of the coal strike in April last there was practically no limit to the sulphur in foundry cokes, and it has been quite impossible to keep within bounds. It must be borne in mind that some foundry practice involves the use of 50 per cent. scrap, and sulphur therefore rapidly mounts up. It can be readily understood that in the manufacture of large castings on which no fine machining or finish is essential that sulphur is sometimes a good friend, because it increases combined carbon and hardness and hence tensile strength. Our experience has shown that with such high sulphur contents the tensile was usually above the average, and against this it must be borne in mind that the iron was often sluggish and rarely normally hot and fluid. The transverse, however, shows a decided decrease, showing that brittleness is also increased. Therefore, although there is such diversity of opinion, ironfounders generally will agree that the past six months, with its excessively high sulphur, has been an unusually troublesome period, and it is to be hoped that coke-makers will return soon to normal.

Cupola Slags.

In this connection some reference to cupola slags may not be out of place. The chief purpose of such slags is undoubtedly to gather together all the refuse found inside a cupola at work; separate this from the metal, and hence allow the latter to come away clean at the tap hole. Many slags, however, contain, besides unwanted refuse, too much iron and too much of the lining of the furnace, both being sources of waste. Comparatively little work has been done with regard to cupola slags. except that the cupola man studies its colour and nature and tries to relate these to furnace working. Surface colour is a very unreliable guide, but the powdered slag gives the true colour, and is far more informing. It is not desirable that in cupola working the slag should exert on the metal such an influence as it does in the blast furnace, converter and open-hearth furnaces, but there is one direction in which much more is desirable, and that is in the removal of sulphur from iron to slag. The very high percentage of sulphur now being met with in foundry coke is a matter of serious concern to the ironfounder, and a control of equilibrium between sulphur in metal and slag would be highly advantageous. The mere addition of limestone has a slight effect in this direction, but not an appreciable one when sulphur contents such as those just referred to are being handled. Manganese also has the power to carry sulphur into the slag, but this, too, is an inadequate remedy. As to "patent medicines" for this purpose, it has not been surprising to find that these expensive remedies fall far short of the claims made for them. Undoubtedly there is room here for scientific treatment of the problem.

An American worker, J. W. Bolton, has suggested that to increase the bulk of slag present may be an efficient means of reducing sulphur in the iron. If the slag made in a certain heat contains, say, 0.50 per cent. of sulphur, then if the total weight of slag be synthetically increased by 25 per cent., and the percentage of sulphur therein remains the same, then a greater weight of sulphur will be carried from the cupola by the slag, and less will remain for distribution in the iron. It is proposed to charge sand, limestone, etc., as the basic constituents for synthetic slag-forming, and at first sight this may appear cumbersome, unscientific and costly, but it may still be worth trying, for the total extra volume of slag to be melted would not be great. The same worker shows that high cupola temperature also helps in the same direction. This Paper,* which only came to my notice a few days since, appears to be an excellent one, and amongst the most informing on the subject, since it contains the results of technical work on a practical scale.

The mode of occurrence of sulphur in coke and slag is very striking. In the case of the coke, that sulphur, present as sulphate, is fairly harmless, and hence it does not follow that the coke highest in sulphur gives most of this element to the metal. Sulphur once in the slag as sulphate is probably there permanently, since calcium sulphate is not readily reduced under cupola conditions, but that present as sulphide probably may pass to and from the sulphide to sulphate form, and *vice versâ*, depending on the degree to which the cupola atmosphere is an oxidising one or otherwise.

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* "The Foundry," September 1, 1921.

A New Aspect of Chills.

Although in the production of light castings chill is one of the worst enemies, yet to many engaged in roll making, the production of chill is the very essence of the business. So far as the use of chillers is concerned, every iron is a chilling iron to some extent, but there are, of course, ranges of composition which are most suitable for the work. In the cupola, too, almost any iron may be chilled to whiteness if maltreated. a fact which is, perhaps, better known by those who are trying to keep their iron soft. For the production of this class of work it was formerly the custom to use charcoal iron or cold-blast iron, but this is by no means so universal to-day. These irons are somewhat out of the ordinary in their analysis, principally with regard to total carbon, and they are not easily matched exactly in composition by modern hot blast irons. Also they possess physical properties of higher value than ordinary irons of approximately similar analysis. To a certain extent, the older irons owe their popularity to-day to a mistaken notion on the part of their users that no other iron can equal them, an exaggerated idea, which is supported also by the makers, as certainly they have been equalled by the "refined" irons on the market. It is certain that all cast-iron assumes its normal state when melted, and that any chill, closeness of grain or other distinct qualities do not reappear except from the cause which originally produced them in the pig. Light ironfounders, if they will have faith and take the risk, will find that iron which has been chilled until white by external causes, such as chillers, dampness, etc., and not by any change in composition, can be remelted under normal conditions and cast perfectly grey. It is, of course, only when the analysis is known to be that of a normally grey iron that it can be definitely said the chilling is due to external causes, and reference is only made to such. But if this be the case, it is not at all clear, and no reason has been yet given that will convince anyone who only believes what is proved, that cold-blast irons in the foundry are necessarily superior to other irons of similar analysis, such irons or the scrap from them being subjected to repeated remeltings in the foundry.

In no class of castings is there a clearer field for the use of analysis, and yet the chilled-roll industry has been singularly neglected. A chill may be perfectly hard and white, and yet be useless, for other properties are required of it, and unless a check be kept upon the iron in use such must not infrequently occur. Admitted that artificial chillers will always be essential, but the control of the depth and character of chill lie not so much with the chiller as with the iron. When deep chills are required, as in a large roll, it is necessary to resort to very low silicon of the order of 0.5 per cent., and in surveying the range of irons with such low silicon it is found that this is almost always accompanied by high sulphur, itself a chilling agent. The chill from high sulphur is weak and brittle, and ends abruptly, and is often associated with those hair cracks which in the end ruin a roll, and the surface is also often freely scattered with blow-holes. Sulphur should be kept low, but if the pig-irons are high in sulphur this is not possible, and there is room for low silicon irons, lower in sulphur than those now regularly obtainable in quantity. It is partly on this account that the possibility of semi-steel for this work should appeal, as the silicon may be reduced by steel scrap without effect on sulphur, and a somewhat different pig-iron used initially. Phosphorus is kept low, because this shortens the period of solidification, and hence aids chilling, and, of course, because high phosphoric iron is much more brittle. Manganese is advantageous, and although it is said that it is an expensive element to add, in the case of high-class rolls, this is a negligible factor, and manganese should certainly be present up to 1 per cent. A manganese chill, unlike that of sulphur, spreads out into the core of the casting in fibres, and the interior itself is always tougher when this element is present. The high total carbon of the charcoal iron is not easily matched, but when steel is melted with the pig the total carbon usually increases, contrary to general opinion, and here again we are faced by semi-steel, for high total carbon is an important factor, reducing the liability to contraction and also lowering the melting point, which, by reducing the range of solidification, causes an increase in chill. In high-class American chilled castings such as car wheels, which are so extensively made in the States, nickel and chromium are also used as additional chilling agents, chiefly on account of the strength they give to the iron.

Since the preceding remarks were written in August, two articles of note have appeared in The Foundry Trade Journal which entirely substantiate my conclusions. The first one deals with chilled car wheels, and it is shown that whereas wheels which failed in service contained an average of 0.188 per cent. sulphur, those showing longest life had an average of 0.142 per cent. sulphur, and the wheel selected as having actual longest life only 0.120 per cent. There is much that is comparable in chilled wheels and chilled rolls, and experience in one should be applied where possible to the other. The second article relates to roll practice, and it is shown how essential it is if best results are to be obtained that sulphur in chilled rolls for hot rolling should be under 0.08 per cent., a figure unobtainable in low silicon irons, cupola melted, whether in this country or America. These articles are merely quoted in support of the statements already made.

Conclusion.

By these general considerations it has been the object briefly to show how far the control of composition may control the depth and character of chill, and although it is apparent that the production of these rolls is the task of highly skilled craftsmen there is much room for improvement and for a greater degree of certainty in the obtaining of successful results. It is my purpose not so much to instruct in the art of making chilled rolls as to open out for inspection the factors on which this depends, that those who to-day are neglecting such factors may view the field of the unknown.

In bringing this address to a close, it is apparent that in some respects the matters on which I have touched may be thought of only minor importance. It cannot, however, be denied that in considerations of quality the most important factor is the iron. Without good iron good castings cannot be made, and the best of labour, effort and thought in other directions is merely thrown away. No amount of skill in other branches of the foundry industry can compensate for the deficiencies of the raw material used, or of the melted iron produced, and it is to these that attention should be called.

Discussion.

The Chairman (Mr. F. Holberry) said they had listened to a very able Presidential Address, and he thought it a pity that courtesy demanded that they should not discuss it that night.

In proposing a vote of thanks to the President for his address, **Mr. H. L. Reason**, Senior Vice-President of the Institution. said everybody appreciated the thought and time devoted by the Branch-President to the collecting of data and placing before them so many aspects of foundry work. He had practically dealt with all the main points in the foundry, commencing with the value of science in the foundry, passing on to analyses of irons and also dealing with the standardisation of pig-iron and the important matter of chilling. The address suggested foundrymen were at a disadvantage, as they had no means of ascertaining exactly the nature of the material they were using. In fairness to the blast furnace it should be said that, considering the way in which pig-iron was made, it was wonderful how some of the blast-furnace managers and chemists brought out such a good product. Take the ordinary blast furnace, which looked nothing more than a glorified cupola, the coke and ore put in at the top by mechanical means, after which it was left to Providence to bring the iron out to the correct analysis at the other end. Undoubtedly it was at this end of the business that scientific help was required. With reference to the question of pig-iron of the same or equal analysis giving widely different physical properties, the Branch-President stated that grading should be done by analysis, fracture and physical properties, everyone with a knowledge of irons knew that analysis did not tell them everything. It was possible to have pig-irons of the same analysis with high and low physical properties.

The question of the standardisation of pig-iron associated itself with the question of standardising test-bars, and Mr. Young pointed out at the Convention that they were up against a difficult problem. Chemists were unable to locate the whole of the ingredients in pig-iron which affected the physical properties, so that there was quite a wide field for research. As the Branch-President had pointed out, those interested in the ironfounding industry were looking forward to receiving a great deal of help from the Research Association, whose work, he believed, was going to place the industry on a higher plane than it had ever previously occupied. It was going to take them along the road of progress. They had now arrived at a certain state of proficiency and excellence in their productions, but without the application of science to their work they would stay where they were. They must either go forward or lose ground, and, in view of the work which was being taken in hand by the Research Association, he had every confidence that their industry was going forward so that they would hold their position in the industrial world and regain the position of being the first industrial nation in the world.

Mr. W. J. Flavell, in seconding, said he was rather impressed by a letter he read in The Foundry Trade Journal, and was very much surprised when he read it, because it seemed to strike what he thought was a note of discord as to how the Blackpool Convention was carried on. The writer apparently thought that they ought to go there, as some came to the Branch meetings, looking very serious, and perhaps savage, because they had made up their mind that they would attack the reader of the paper. Were they to sit at the Convention day after day listening to nothing but papers? He thought they would agree that at the Institution's Annual Conventions they were not only called together to receive instruction by the reading of technical papers, but that it should be regarded as an annual gathering where perhaps friends who had not met for a long time might renew the friendship, so making the Convention not only interesting and instructive, but pleasurable as well.

Lancashire Branch.

A DISCUSSION ON HARD CASTINGS.

At the meeting of the Lancashire Branch of the Institution of British Foundrymen, held on October 1 at the Manchester College of Technology, **Mr. J. Pell** (Rosegrove), who opened the discussion, said the problem of how to avoid hard castings had caused much trouble to foundrymen during the last few months. Having become accustomed to the use of material which gave excellent results, they suddenly found the supply of that material stopped, and it was replaced with materials about the qualities of which they knew nothing, although they might have heard that the character was not good. The foundryman had then to ask himself: What results shall I get? Must this material be used in the same proportions as the previous material? That was the type of thing which happened during the recent coal strike. The ordinary supply of foundry coke was stopped, and they had to use coke of an unknown quality, but they were expected to produce castings up to the usual standard. He would give the members an account of his own experience in the hope that their comments would afford some guidance for the future.

When the stocks of coke gave out a fresh lot was procured which, in his opinion, was very high in sulphur; it was very friable and would not carry the accustomed load. Much more had to be used than would be necessary with proper coke. On the first occasion it was used he made careful observations. The first 6 or 7 cwts. of the metal were poured into castings which did not require machining and were kept separate from the rest. The following morning, on examining them, he found that the first metal poured was quite hard. Taking the castings in the order in which they had been cast, that hardness diminished, and the last castings, although not in accordance with the former standard, could be drilled, filed, or machined. On the following days he adopted this procedure: The first 4 or 5 shanks of metal (about 7½ cwts.) were poured into castings of little importance; it did not matter whether they were hard or soft. Operations were then carried on in the usual way, and although the fluidity of the metal was not what could be desired, they were fairly successful and they were able to carry on. In charging the cupola he had to lighten the charges and use more coke in order to procure metal sufficiently hot to run the lighter castings. Usually they melted 15-cwt. charges with 1½ cwts. of coke, but with this high-sulphur coke they used 1¾ cwts. to a 12-cwt. charge. The bed was increased to help to carry the burden. He had no means of ascertaining the exact sulphur content, but it could be assumed that it was anything up to 0.1 per cent. Taking it at that figure, there should be, roughly, 1 lb. of sulphur in a bed charge of 12 cwts. His opinion was that during the melting operations the first 7 or 8 cwts. of metal, in its descent through the coke bed, absorbed a large quantity of the sulphur, and by tapping at very short intervals they clarified the coke bed somewhat. Something of this nature must have happened, because the metal that was afterwards brought down could be machined. If he had allowed much metal to collect in the cupola he would have had more hard castings. He might be mistaken in supposing that sulphur was the factor which determined the hardness of the metal, and that was the point on which he wished to hear the views of the other members, many of whom must have experienced the same difficulty. Whatever the cause was, no such trouble occurred when using local coke. He could usually take metal from the cupola two or three minutes after melting commenced and get machinable castings.

He made a visit to a foundry which had been engaged on the same class of work but had to shut down. The same poor coke was used, and the results were alarming; a number of the castings cracked in cooling. It was generally understood that light textile castings, in particular, required sand that was only sufficiently moist to bind together; if wet facing sand was used hard castings were sure to make their unwelcome appearance.

In this case the trouble was not due to wet facing sand, nor to the mixing of the iron; care was taken every day to ascertain how the castings were for machining. As soon as possible each morning some of the lighter castings were tried, by mutual agreement with the foreman of the turning shop. The mixture he was using at the time the hard castings were produced was a fairly good one, the approximate analysis being:—Graphitic carbon, 2.95; combined carbon, 0.40; silicon, 2.68; sulphur, 0.060; phosphorus, 0.98; and manganese, 1.07 per cent. It was taken from a stock in use previous to the strike; in fact, nothing was changed except the coke.

The Chairman (Mr. Haigh) said he was sure that many of the members who continued working during the coal strike experienced difficulties similar to those described by Mr. Pell. Judging from the analysis the mixture should have given a machinable casting.

Mr. Hill said about 18 months ago, when furnace coke was scarce, he experimented with a soft coke showing a high sulphur content, and resulted in similar trouble to that to which Mr. Pell had made reference. The metal was hard for the first 10 cwts. In his opinion there was no real remedy so long as that coke was used; he thought the metal melted too low in the furnace and became oxidised. To the eye it appeared to be oxidised; it had a different appearance from ordinary white iron. In the middle of the blow it would become grey, but still it was harder than usual. What it was at the end of the blow they never knew, because when they had melted about 3 tons it bridged over. Under such conditions good results could not be expected. Two furnaces were used on alternate days, and a gang of men were employed in clearing out one for the following day. The castings were full of holes as well as being hard. The trouble persisted until a fresh supply of coke was obtained. If a ½ cwt. of the hard metal scrap thus obtained was added to a 10-cwt. charge when only *good* coke was used, it would turn the whole charge white.

The Chairman: What was the appearance when you tapped it out?

Mr. Hill said when the hottest metal came down it seemed initially white hot, but quickly became dull, pasty looking, and poor running. The hottest metal would come down after they had melted about a ton, after which the metal gradually became worse, and so long as tapping was possible it was associated with a skin of greasy appearance, which never cracked. The metal was usually "blown."

The Chairman: How do you account for the oxidation which you suggest had taken place? Was the blast increased?

Mr. Hill replied that they had adhered to their usual practice. There was only one row of tuyeres. The melting was slower, and since bridging was encountered he concluded that melting was at a point lower than normal.

The Chairman: You would say then that you had oxidation owing to the metal being in contact with the blast for a longer period than usual.

Mr. Hill: Yes; melting too low.

Mr. Pell remarked that in his case they were not melting too low, because he had taken the precaution of increasing the coke bed by 6 in.

Mr. Hill added that another man put coke on until he could only get one ½-cwt. charge to the charging door, but still he had the same trouble.

The Chairman: He ought not to have been troubled very much with oxidation.

Mr. Barnes said he was interested in the smallest size of castings, ranging from 1 oz. to 40 lbs. at the most. During the coal strike they had bad coke, and they found that the best way to deal with it was to burn it in the furnace the day before using it. They thus eliminated much of the sulphur. When used for melting, the method was to run for a time with full blast and then reduce it to half. When making carpet-sweeper wheels, which had to be drilled from the solid boss, but before they had experimented by burning the coke the day before it was used and reducing the blast, they could not be machined even with high-speed steel.

The Chairman: Do you mean that you fired the coke in the cupola?

Mr. Barnes: Yes; the cupola was filled up not quite to the charging hole with the bad coke; it was then fired and allowed to burn to a red heat, and as the charge became red through it was withdrawn from hearth. It was just slaked and left to dry out itself, and was used the day after. The trouble was splendidly overcome in that way. No accounts of the percentage of loss were kept. At the time the coke was burned the fan was kept going. The men could not stay while the charging was going on because of the sulphur that was evolved.

The Chairman said if the whole of the trouble was due to sulphur, one would expect the coke samples to show an abnormal sulphur content—say two or three times the ordinary amount. Could anyone say what the sulphur content of the coke was?

A member remarked that he had known coke to contain 0.2 per cent. of sulphur, which was 2½ times as much as the usual proportion.

Mr. H. Sherburn said the problem was impossible to solve on account of insufficiency of evidence. Certainly several factors had been given, but as long as those stood alone the information was inadequate. They were not told the composition of the coke, the height of the bed, or whether the analysis of the pig-iron was similar to that used the day before. Until more definite chemical data was available they could only express opinions. That was one of the difficulties often experienced in the foundry. A very doubtful suggestion was the probability of oxidation being the cause of the trouble. It had not been established that oxidation was the cause of iron being turned white. The proportion of silicon would have some bearing on the problem, which emphasises the necessity of an actual analysis being available. If the sulphur content in the casting was given it would provide an avenue for exploration, but as the evidence stood, opinions, which had slender foundations, could only be expressed.

The Chairman said they had no evidence which enabled them to say definitely whether the trouble had been caused by excess of sulphur in the coke, by oxidation, by slow melting, or by some other action. Unfortunately, Mr. Pell had not been in a position to command expert advice, and they had not an analysis of the metal after melting.

Mr. H. Sherburn said in ordinary practice, using a good coke, the correct bed charge might easily be determined by noting the time taken for the first molten metal to appear from the time when the blast was started. It was, however, courting disaster to apply the same practice with a new coke without previously obtaining some knowledge of its chemical composition, particularly sulphur and ash. Further information should be sought as to its mechanical properties.

Mr. Pell remarked that metal was being "brought down" in 11 to 12 minutes.

The Chairman remarked that if the metal was appearing in 11 minutes the melting would be satisfactory as far as the time was concerned. If melting became slow after that, something had evidently happened to the height of the coke bed; it was either falling or getting harder.

Mr. Hill said in his case the mixture was never altered. With one lot of coke good results were shown, but when this consignment was exhausted and a fresh supply obtained the trouble described arose, indicating that the mixture was not at fault. The mixture referred to was made up of equal quantities of pig-iron and scrap, a reliable brand of Scotch iron forming 30 per cent. of the whole charge.

Mr. Jowett, after being assured by Mr. Pell that the coke on breaking revealed the presence of brown specks, remarked his firm had had similar coke which contained over 0.2 per cent. of sulphur, and the chemist attributed the brown spots to sulphur.

Mr. Pell: If the trouble is a matter of oxidation, why does not a similar state of affairs exist when using good coke?

Mr. H. Sherburn suggested that the question whether the trouble was due to sulphur could be settled by analysing the raw materials used and the iron which came out. People who were managing foundries should have at their disposal all the knowledge available. If by making an analysis they could get a clearer idea what the cause of the trouble was it was far better to do that than to dismiss the subject by casually blaming the coke and, what is more important, the position would be improved for handling a similar situation should it ever again arise.

The Chairman said conditions could not be considered normal as regards good quality coke if it contained 0.1 per cent. of sulphur. In Mr. Pell's case all would agree that the trouble arose from the change in the coke, but on purely scientific grounds a definite conclusion could not be drawn, because the evidence was insufficient, and he was afraid the members could not help matters forward. The axiom of a practical man was—using the same brand of pig-iron and the same blast, the same results are obtained. Sometimes they were, and sometimes they were not, and the reason was not clear. It was here that the chemist should intervene. Until there was a system of working laboratories in connection with a number of furnaces, so long would these troubles arise, which the practical man, however good he might be, could not solve, and so long would they be in the hands of the people who sold material to them. During the coal strike his firm got some bad coke, and they overcame their troubles in various ways. They found it was useless increasing the coke bed. It might be necessary to reduce the proportion of iron in the charge, but a solution could not be obtained by maintaining the standard proportions. They worked to a standard bed. They did not raise the bed more than 6 in. after the trouble began, but they reduced the charge of iron 15 per cent. for the same weight of coke. When they had finished, the same analysis, the same machineability, and the same tests were shown. If a foundryman used the standard proportion of iron with coke of that description, he would have constant trouble, and would be compelled to rearrange his mixing. For instance, he might have to increase the manganese. It was to be deplored that some foundries had to shut down owing to inferior coke. If proper information had been available those foundries could have continued working. Such information could be procured through the Cast Iron Research Association. Indeed, during the coal strike thousands of tons of castings were brought out to standard analyses, and passed through all the tests. In the case under discussion, perhaps the trouble was due to oxidation, and it was possible that it could not be cured by any of the remedies which were advertised. Evidently something had happened to the coke, but what it was could not be established until they knew the analysis of the castings.

Mr. J. Masters asked whether Mr. Sherburn had any experience of arsenic in coke.

Mr. H. Sherburn said that it was unusual to estimate arsenic in coke, but no doubt it might sometimes be present, although it is doubtful if the amount would ever be sufficient to have any material effect on the metal melted with such a coke.

The Chairman pointed out that the arsenic in an ordinary foundry coke was negligible. In the case under consideration the coke was high both in sulphur and ash, and the latter might affect the resultant mixture.

Mr. Key said the chemist would probably tell them the percentages of the ingredients which were usually found in terms of carbon, ash, volatile matter, and sulphur. Admittedly, this was helpful, but it was as far as the chemist would go. A firm were making a certain kind of casting. They made 24, which were apparently sound. The following blow, carried out under identical material, melting, and moulding conditions, another 24 castings were made, but not one of those was fit to machine. Samples of the two lots were taken to the laboratory, and the analysis did not show the slightest difference. This hopeless condition left the industry in a state of chaos.

The Chairman said that point was brought out at the Blackpool Conference. Mr. Buchanan compared the production of a pig-iron to the birth of a child, and said just as two children might be outwardly alike and yet have different qualities, so also might two castings. One could make a casting that was quite satisfactory, and then produce another that was unsatisfactory, although chemically they might be absolutely the same.

Mr. H. Sherburn: Is Mr. Key opposing the utility of chemical analysis?

Mr. Key, replying in the negative, stated that the chemist analyses for definite ingredients, but goes no further. The analyst will not touch the question of oxidised iron, owing to insuperable difficulties. Doubtlessly, sulphur is the primary cause of the condition of the iron exhibited. The speaker could show 40 tons of iron which contains 1.24 per cent. of silicon, which has exactly the same hard appearance. The sulphur percentage is 0.4 per cent.

THE CHAIRMAN: Unless that iron has absorbed a large amount of sulphur to bring it up to that. it would not normally take place with a cupola.

MR. KEY: The rest of the analysis is normal, and characteristic of the district from where it was obtained, except that the manganese is 0.3 per cent., which is lower than usual. In Mr. Pell's case no doubt sulphur has been the cause of the trouble.

MR. MILES said as the Cast Iron Research Association had been mentioned, it ought to be made plain that that body did not work for the members of the Institution unless a payment was made.

THE CHAIRMAN said the Cast Iron Research Association would take up any problem submitted to it by the subscribing members. The results of its work would not be public information, but would be the property of the members if the problem was of general interest. If it was a special problem, the work would be of a more or less confidential character.

MR. PELL said he wanted to know whether there was any way of avoiding these hard castings, and he had carefully explained the matter, but it was practically impossible for him to obtain some of the details desired, because a chemist was not employed at the works. He believed in the foundry chemist, and would be glad to have one associated with him in his work. The proceedings concluded with a vote of thanks to Mr. Pell.

Lancashire Branch.

DISCUSSION ON THE SLOW-FILLING OF MOULDS

This subject was also discussed at the opening meeting of the session. The question was opened by MR. MEADOWCROFT, who wrote that at the present time in the foundry trade journals quite a number of new developments in working practice were being dealt with. The investigations of M. Ronceray, of Paris, into the question of small gates and the abolition of risers were interesting. It was necessary to know what changes took place in the mould during this slow filling, and, from his own experience, he thought it would be beneficial in some jobs with a deep section and a small superficial area, but on jobs with a large superficial area, such as tank plates, it was desirable to fill the mould as quickly as possible in order to obviate cold shuts. In plate castings 2 in. or 3 in. thick many failures were due to slow filling. The exposure of the cope face to the great heat of the metal over too long a period brought about the collapse of the cope before the metal reached it. The investigations of M. Ronceray were a step in the right direction, and many of the knottiest problems the foundryman had to tackle would vanish if the theories put forward by the brilliant French foundryman were proved to be correct. The craft would then become more of an exact science, and great assistance would be given to the practical foundryman.

THE CHAIRMAN (Mr. J. Haigh) observed that the slow filling of moulds was an interesting question. A short time ago it would have been thought a revolutionary suggestion. As he understood it, the idea was that, instead of running as quickly as possible, which was the general practice, a number of very fine runners formed a kind of sieve through which metal was poured. Mr. Meadowcroft suggested that the exposure of the cope face to the great heat of the metal over too long a period brought about the collapse of the cope before the metal reached it. He believed that was so. Whether that could be overcome by the employment of a large number of small runners was another question.

Mr. R. A. Miles (Newton Heath) remarked that the illustrations given in The Foundry Trade Journal showed mainly small castings.

The Chairman said he thought the writer did not intend to write about large castings with big exposed areas, but to deal with smaller castings. One illustration showed a thick section and a thin section. In that case the usual practice would be to put the runner where the thick section would receive a large feed; but M. Ronceray put a number of small runners—three or four—instead of one large runner. He should say it would be impossible to carry that out with large castings; it might do with small castings.

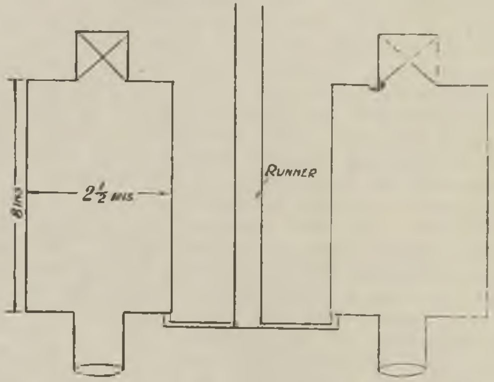

Fig. 1.—The Fast Running of this Casting results in a Sink Hole in the Position Shown.

Mr. Miles: Pig-iron with high phosphorus runs slowly into the mould and remains fluid a long time. It would be better if further information were available as to such metal setting solidly before commending or condemning the method of pouring as suggested by M. Ronceray.

The Chairman: What appeared interesting was that a casting with a lot of small runners of different lengths was shown.

Mr. Hogg (Burnley) asked if it were possible to run a pipe of ½ in. to ⅜ in. in section very slowly, as such pipes were frequently made in his works.

Mr. A. Sutcliffe (Bolton) described a casting about 2¼ in. wide and 6 in. to 8 in. long, with lugs at each end for turning purposes, one a square lug and the other round. Such a casting must be run slowly to get it solid. An attempt to run it quickly would result in a "sunk" casting, as shown in Fig. 1. He believed the main point was the situation of the runner. He referred to a flywheel arm which was run at the end, and in the centre of it there was a section 4 in. thick, 18 in. deep, and 15 in. wide, which was scabbed all over at the opposite side to the runner, as shown in Fig. 2. The reason for this was the running at the end, which was undoubtedly the wrong position. The correct position is indicated in Fig. 2. The speaker explained that a 30-in. lathe bed must be cast with hot metal quickly, from one end only, otherwise the flats will be defective. Running from both ends, either in the case of a lathe bed or planing-machine table, is liable to show a cold shut at the place where the two streams meet.

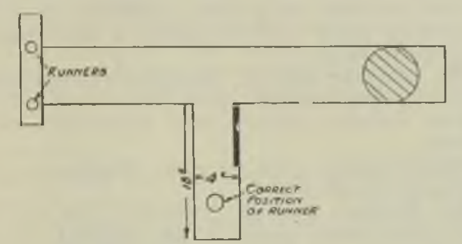

Fig. 2.—A Flywheel Arm Scabs if Run from the End, and should be Cast from the Position Shown.

The Chairman said this was a common practice in a shop he knew, where they had a casting 8 ft. long of a box section, about 9 in. sq. with cores in. They would run that with two runners, about 2½ in. deep and ¼ in. wide. The metal was run in at one end and had to travel over 8 ft. The castings came out very well, presenting good machining properties. He was convinced that many scabbed moulds were due to the runners being too large and the metal entering at too great a velocity. The best method of running depended upon the length, size, and shape of the casting. No particular place of running can be definitely established for all castings.

A MEMBER instanced carding-machine cylinders. Some firms ran those with a box runner put down the inside of the core and a flat runner in the mould. Others, with equal success, adopted pouring at the top with 10 to 12 small inlets, but they did not pour slowly.

THE CHAIRMAN: No, it is not always a question of slow pouring. It is more a question of a large number of small runners against a small number of large runners.

MR. MASTERS said M. Ronceray's article stated distinctly that castings up to 2 cwt. were run with a ⅜-in. circular runner—that would be a single runner.

THE CHAIRMAN: But he gives illustrations of a series of runners.

MR. MASTERS said M. Ronceray gave one definite illustration where it was ingated in the bottom with a runner 2 in. long and ¼ in. wide. The downgate was about ¾ in. dia., so that the runner was bigger in area than the downgate. That casting came out well. It was circular and weighed just under 2 cwt., and it had the appearance of a piston ring. He thought there was no reason to suppose that M. Ronceray wanted a series of small runners. One could run a fairly big casting with a single runner.

THE CHAIRMAN said he knew three foremen who had different methods of running a similar pulley, and they each got fairly satisfactory results. It could not be laid down dogmatically that there was one way of doing it, and one alone. It was quite possible to run a casting of 2 cwt. with a runner of 1½ in. × 1¾ in. The discussion showed that there were a good many things yet to be found out in foundry practice—that they had not yet arrived at finality.

London Branch.

PRESIDENTIAL ADDRESS.

The first meeting of the session was held at the rooms of the Institution of Marine Engineers, Minories, London, on October 13, the Branch-President, Mr. H. O. Slater, in the chair.

The Branch-President, in opening the proceedings, said that a vacancy had occurred on the Council through the resignation of Mr. Gaskin, owing to ill-health, and he proposed that Col. Cheesewright be elected to fill the vacancy.

This proposition was seconded by Mr. T. D. Robertson, and carried unanimously.

The Branch-President then read his Presidential Address.

Gentlemen,—

In opening the first meeting of the session as Branch-President my first duty is to extend a hearty welcome to all members and visitors, though it has been customary to leave this until the end. It is sometimes well to depart from ordinary formal procedure, for it is obvious that that has been one of our greatest faults. Our meetings have been too "cold"; members and visitors simply attending, listening to the lecture and discussion, and departing without even an introduction. That should be our first reform. Some hold high and influential positions, others quite humble ones, but by the mere fact of their attending the meetings of the Branch indicates a keen interest in their craft and the engineering industry and entitles them to the respect of all.

Undoubtedly the London Branch is at a disadvantage by the fact that it spreads over such a large area. Members seldom come into contact with one another except at the meetings, and there are quite a number who cannot attend except on very special occasions. As a Branch we must set out to know one another.

On entering the Branch 11 years ago with the object of increasing the number and possibly gleaning some information that would elucidate some of the apparent mysteries of the iron-founders' craft, from both the practical and scientific standpoint, it was evident the Association possessed men of capacity on both sides. Undoubtedly my ideas and membership have been justified. The information gained, coupled with practical experience and observations, have been helpful in opening up a clearer vision of foundry matters and made me more interested and observant than perhaps I would otherwise have been.

Even in the greatest distress a member can be happy in the knowledge that he has the whole of the members of the Institution at his back from whom he can seek advice in a confidential manner. That being one reason we should, as members, do our utmost to develop the social side of the Institution so as to know whom to approach for advice on a particular subject. Through being in constant touch with the members so long, I am convinced that even in the London Branch there are men capable of giving sound advice on every detail of foundry procedure, practice, and problems.

The Control of Buying and Selling.

Every foundry foreman should know, without reference to the cost office, exactly what his productive and non-productive costs are. He should be aware of the purchase price of his materials and have their selection, for he knows the quality necessary for any class of work he has on hand. It is one of the most essential items of foundry efficiency. This is asserted with all due respect to buyers, very few of whom have any real knowledge of the pitfalls of foundry life.

Except for large firms, who have their buying departments entirely independent from other parts of the works, it is usual to find one man controlling both buying and selling prices. Here is the incentive for procuring inferior material, very often unsuitable for the purpose for which it is required, and when this procedure does not turn out satisfactorily the foundry foreman has to shoulder the burden, and if he complains that the defects arise from cheap or unsuitable material, the climax resembles the explosion of a "Jack Johnson."

It frequently occurs that for the sake of trade a fairly large order would be accepted at a low selling price, irrespective of whether it be intricate or heavy work. In this case, too, the commercial man can cover himself, for the onus of cheap production falls on the foundry foreman.

Cheap production may cause misunderstanding or even serious trouble between employer and employee, and unless the foreman can prove his case with actual figures, it is difficult for him to retain his position. It thus becomes essential that any foreman should carefully scrutinise all charges and itemise all branches of production. The establishment of an accurate system places the foreman in a position to co-operate in ascertaining the real cause of a trouble or a high cost.

By having figures and facts at hand, opponents are less likely to take advantage, and shop matters run smoother than if ignorance prevails on one side. It may be thought that these conclusions are merely theoretical, but they are based on personal experience, and have induced me to advocate incessantly the better education of the foundryman in commercial matters. For the successful management of a foundry one must be well equipped commercially, practically, and temperamentally.

The Objects of the Institution.

The objects of the Institution as laid down in the Rules are rather vague, the wording of Rule 2 can mean anything, and could be interpreted so as to restrict our activities. My conception of the objects of the Institution were rather more definite and more inclined to follow the impression one would get from the crest, "Science Hand in Hand with Labour." I believe that the founders of the Institution could see that the fusion of the two elements were necessary to national efficiency in the foundry industry, and no doubt realised that they had a real and difficult problem to surmount, for even to-day there are still suspicions lurking in the minds of many as to possibility of reconciling the two, and there certainly exists a section who believe them to be diametrically opposed.

It is here where the real work and interest of the Institution lies, in bridging the gulf that exists. This can only be accomplished by getting into contact with all concerned in the foundry industry and bringing to the top those that would otherwise remain in the mire. To accomplish this scientific and practical papers cannot be depended upon, but it must also be demonstrated by the institution of better conditions in foundry life. for obviously there is still much to be desired in this direction

The Apprenticeship Problem.

It has been customary in the past for Branch-Presidents to refer to the vexing apprenticeship problem. Instead of propounding personal views, it may serve a more useful purpose to outline the successful scheme operating at the works of Messrs. J. and E. Hall, of Dartford, who have kindly consented to its publication.

The scheme, which is diagrammatically outlined in Fig. I., follows in some respects the published reports of the Continental organisations, in so much as it incorporates a pre-apprenticeship period.

Knowing the British boy as I do, this pre-apprenticeship period should attract boys to the foundry instead of driving them away, as is said to be the case on the Continent. An interesting feature is the fact that during this period the boys attend for one day each week at the local technical institute, there to follow up such elementary subjects as lead up to the science of engineering.

Before signing any indentures the boys are required to pass an examination, and, additionally, other suitable boys may sit, but if successful they are required to spend six months in the works before being bound.

Each boy thus selected will be bound by indentures as an apprentice to a trade and start upon a regular five years' course. During the first year the boy receives a varied instruction in one department, and attends technical classes for two evenings each week. After the first annual examination those boys who receive the highest number of marks are awarded a "D" certificate, which enables them to undergo a higher training during their second year, including one day per week at the technical school. Other apprentices continue with their shop training, supplemented by evening classes.

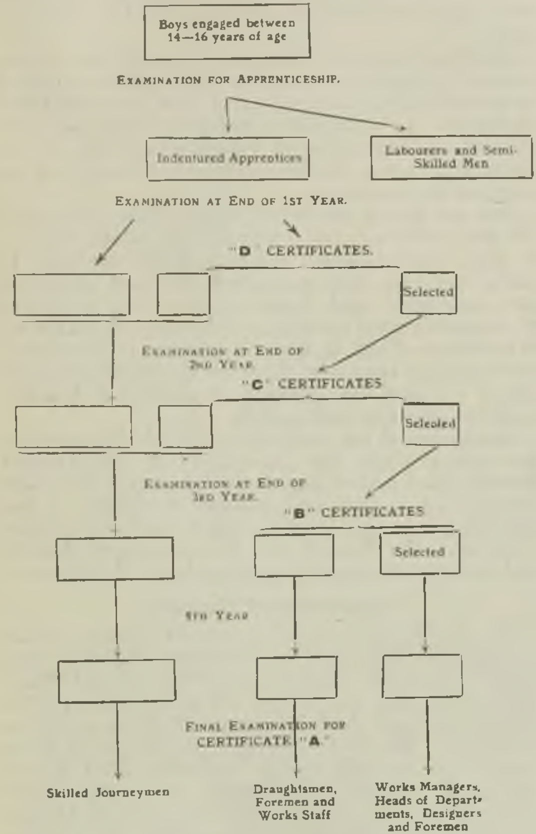

FIG. 1.—THE EDUCATIONAL TREE OF MESSRS. J. & E. HALL, OF DARTFORD.

Similarly, after the second year's training, the more successful apprentices who gain "C" certificates will be allowed two days per week at the local or some other approved technical college. The third year's examination is for a "B" certificate, the gaining of which entitles the holder to be graded "Engineering Pupil," and still higher studies are planned for his advancement.

Briefly, the basic difference between the system devised by Messrs. J. and E. Hall and most others is that a bright youth with ambition is not destined to become a fully-fledged skilled workman on completing his time, but is fitted to assume an important position in the technical direction of an engineering works.

One great step towards bridging that gulf would be the stabilising of employment, unemployment is most demoralising; it has a great tendency to make bad men worse and good men bad, energetic men apathetic, and to rob them of the incentive of becoming good parents and trustworthy citizens. We cannot afford to lose the interest of these men if we are to keep our place in the world markets, for if we lose the interest of good skilled workmen we lose national wealth.

Gentlemen, I am exceedingly proud this evening, for never since the inception of the London Branch has a meeting been honoured with the presence of a past and present President of the Institution on its opening night, and I sincerely trust that the Branch will be encouraged thereby and make good progress during the coming session.

Co-operation of Members.

Mr. A. Willis moved a vote of thanks to the Branch-President for his Address. He was very pleased to see Mr. Slater in the Presidential Chair, because he was one of the oldest members of the Institution, and had been one of its most active members. He had been very much struck by a remark in the Address, to the effect that it was useless to expect the Council to do the entire work; they could not do anything without the co-operation and help of the members. He remembered, during his term of office as Secretary, that the Council decided to do certain things; they sent out notices and endeavoured to get the members to say whether they would take part, but they did not meet with much success, because the members did not co-operate. He hoped Mr. Slater would be able to infuse some enthusiasm and interest into the members on the social side as well as on the lecture side, so that they would have greater success during the present session, as obviously there was likely to be less trouble in the labour world. There had been, during his term of office as Secretary, two coal strikes, two railway strikes, three or four moulders' strikes, and so forth, and they had had to put off various functions because of these incidents. In connection with the organisation of visits to works, which was a good idea, during the last two years they had had to drop off to a certain extent owing to the excessive railway fares. However, he thought that they should now be on the upward grade.

Mr. A. R. Bartlett, in seconding, said the Address was of very great interest, and he had brought out points which, he was sure, had interested all those present. As Mr. Willis had said, the point which affected them most was the question of their organisation in London; they wanted to get the co-operation of every member as far as possible. He agreed with Mr. Willis in his remarks about the lack of attention on the part of the members. He was rather disappointed at the meeting that evening; there should have been more, especially having regard to the fact that they had the President of the Institution present.

The Branch-President, in thanking the members, said that they must go farther back than the present. If he had worked enthusiastically for the Institution he could see in the Institution another way, for those interested in the welfare of the industry, of helping towards better conditions. What he meant by going further back was that he had had the good fortune of starting in the foundry under Mr. Ellis. Mr. Ellis was a very enthusiastic man, and it was during his time if anything went wrong he was given good advice, and that was a principle which every foundry foreman should follow; they must not use coercion, but must persuade a lad to do the right thing, and if he inadvertently, or even mischievously, did wrong, they must correct him in a fatherly way. He hoped, when he vacated the office of President, the membership would be twice as large as at the present time, and that the meetings would also be very enthusiastic. He was going to try to recover some of the enthusiasm which Mr. Willis had said had been lost. He had taken on the Secretaryship when they were absolutely at their lowest ebb, and he felt that he (Mr. Willis) must take the credit for any success with which the Branch has met.

He then called upon the President (Mr. Oliver Stubbs) to address the members.

The Presidential Discussion

MR. OLIVER STUBBS said he realised the difficulty they had in the London Branch in getting good meetings, owing to the wide area over which the members were spread, but if they only got a small number, who were sincere in the work they were doing, their efforts would not be in vain. He would like to associate himself with the President's remarks with regard to Mr. Willis. He had met Mr. Willis on many occasions in connection with Council work, and he had certainly always been very struck with his enthusiasm and his sincerity. He thought they would agree that the work they were now setting out to do was of the utmost importance, and there were, to his mind, many questions upon which they could dwell with advantage. If he were to offer them a word of advice, it would be to this effect, that whatever they did in their Branches, they must not make their Papers and discussions of such a nature that they were going to cut out the man who was working in the foundry and so stifle that criticism and exchange of opinions which, to his mind, had been the foundation and the upbringing of the Institution. They must encourage by all means discussion from all their members. He believed that the best work of the Institution was to make the humblest member feel that he was of the utmost importance to the success of the Branch. They should discuss questions that were relative to the success of the foundry business. The British Cast Iron Research Association should deal with the more scientific side of the industry, because there was no getting away from the fact that they were only going to be employed by their employer so long as they were able to keep his confidence and show him a return for the services for which he was paying them. Dealing with the smaller number of apprentices entering the foundry nowadays as compared with the past, he suggested that the members should consider in their own Branch what were the reasons that they were not attracting the youths to the foundry as they did in the past. The foundry was looked upon as a dirty place. At the same time, it was a very important industry, and they were not making the apprentices to-day in anything like the proportion required to carry on the industry. The question of getting more members to the meetings of the London Branch had also been referred to. He was bound to tell the members of the Branch, however, that they had just as good members in that Branch as any other. He had borne testimony at the Convention at Blackpool to the very efficient manner in which one of their members, Mr. Robertson, had read Mr. Elliott's Paper on Electric Furnaces. If they had men of that calibre among them it was their own fault if they did not make their Branch a success, but every member must feel that he was personally responsible for doing something to make it a success. It was no good saying, "Don't you think it was a rotten meeting?" without saying to themselves, "How much have I done towards making the meeting a success?" They must all carry their fair share of the work of the Branch, and he was convinced that if they did, they were going to have in London a very much bigger Branch than they had in the past. Continuing, he said he wished to refer to the action of Colonel Cheesewright, who had very generously and kindly offered that if any members of any of the Branches of the Institution, who were subscribers to the official organ, unfortunately, should be in want of employment, provided their subscriptions were not in arrears, he would be pleased to give them four free insertions of an advertisement in THE FOUNDRY TRADE JOURNAL. He (Mr. Stubbs) did not want the members to lose sight of this opportunity. He had an idea that many firms of ironfounders in the country had not been supporting the Institution as they should have done. He believed they were all agreed that the Institution was the means of training foundry foremen and managers, and they were doing so to the benefit of those who were fortunate enough to employ them afterwards, and he felt that foundry employers should give them more support. He had much pleasure in handing to the President a nomination, duly proposed and signed, for a subscribing firm, which, he believed, was the first received by the London Branch. He referred to the Rodney Foundry Company, Limited. That was only one, and a good many of them, if tactfully approached, would follow their lead.

The **Branch-President** proposed a vote of thanks to Mr. Stubbs, the President of the Institution, for attending the meeting.

Mr. Ellis (a past-president) seconded, and commented on the hard work involved in carrying out the duties of the Presidency. There had been a danger, it seemed to him at times during recent years, of the Institution getting rather too academic. An enormous number of papers were read at the Branches and at the Institution Conference, and they all seemed to tend too much towards the scientific aspect, whilst the moulders who had not had any education in science sometimes wondered what the speakers were talking about. He felt quite certain that that was the case even that evening, and there were some of them who were moulders purely and simply and had not had an opportunity of studying the higher branches of their craft, although they were deeply interested in them. He was certain that they could rely upon the President, during his term of office, to raise the status of the foundryman, and all papers, if they were to be scientific, must be in some way applicable directly to the foundry, so that the average foundryman could grasp what the scientist was saying.

Mr. Stubbs, acknowledging the vote of thanks, expressed the hope that as the result of that meeting the London Branch would become very much stronger. His whole aim and object was to encourage the Branches in their work, because if the war had taught us nothing else, it was that the time had come when we should mix with one another much more than had been the case in the past. Another thing it had taught was the usefulness of cast iron; owing to the difficulty experienced in getting non-ferrous metals, they had learned a wonderful lot, and to the foundrymen of this country they were largely indebted.

Coventry Branch.

SOME NOTES ON PATTERN PLATES.

By J. E. Bates.

This Paper can be regarded as an amplification of the lecture submitted by the Author to the December, 1920, meeting of the Coventry Branch of the Institution of British Foundrymen, and printed in Vol. 23, No. 224, of THE FOUNDRY TRADE JOURNAL. In this Paper the Author dealt very briefly with three kinds of pattern plates—double-sided plates, transfer plates, and sectional plates.

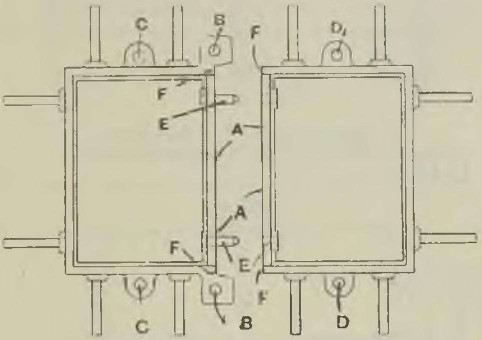

FIG. 1.

In describing sectional plates, which are of a particularly useful type, their adoption can confidently be recommended, especially in small repeat orders. The making of this plate calls for more care than any other type of plate, and it is proposed to relate experiences, both painful and otherwise.

The sectional plate is part of one complete plate, which is in two, three, or more sections as is most convenient and desirable. At first this plate was cast with a thickness of $\frac{5}{8}$ in.—that is, the same thickness as the complete plates—but it was found possible to make them 7-16 in. thick, which shows several advantages, and makes the production of this plate a still cheaper proposition by preventing the locking up of valuable metal.

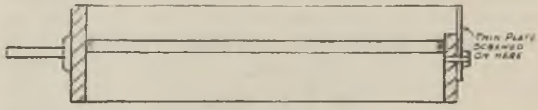

FIG. 2.

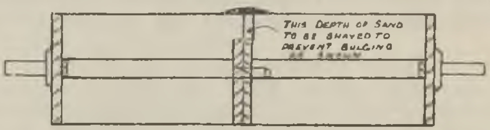

FIG. 3.

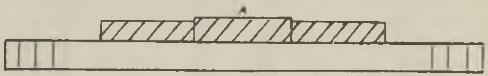

FIG. 4.

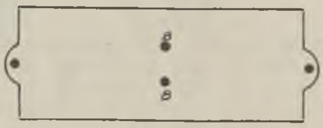

FIG. 5.

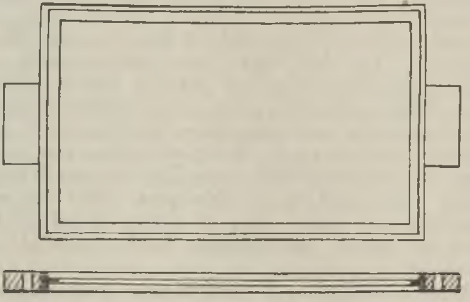

FIG. 6.

It is of vital importance that the machining of this tackle be dead accurate. This is illustrated by reference to Fig. 1, where the machined faces

A must finish dead accurate on the centre line of the pin-holes B; the distance between A and C must be the same as between A and D; the centre between E and E must be the same as the

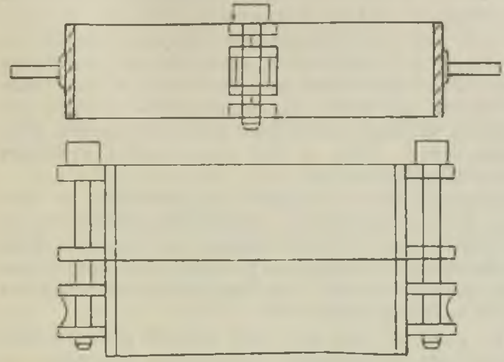

FIG. 7.

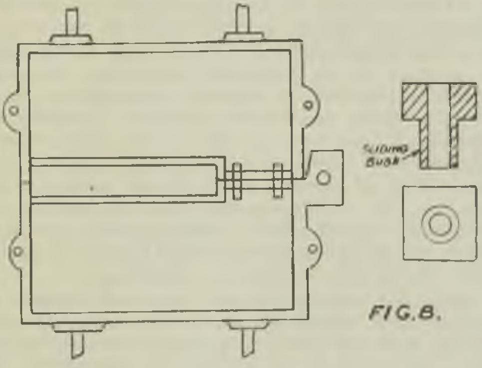

FIG. 8.

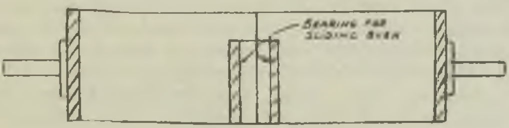

FIG. 9.

centres between C—C and D—D; there should be no step at F when the boxes are together.

It is the practice in some foundries to allow a tolerance of 1-64 in. between the bore of the box pin-hole and the diameter of the pins themselves. Whatever it is decided to allow in the production boxes, there should be not more than 5 or 6 thousandths of an inch in pattern-plate tackle. It is also a distinct advantage to have the box pins casehardened, both in the plate tackle and also in the foundry tackle.

Assuming that the tackle is accurate, a thin plate is first screwed on each of the half-boxes on the joint side. This is shown in Fig. 2. This is necessary in order to prevent the sand from being rammed out of the box during the time the mould is being made.

The patterns are now laid out on the odd side to the best advantage. Care must be taken to keep within the limits of the frame. The ramming up of the mould is important, and, where it is possible, the bottom mould should be rammed up on a machined plate. Where this is impossible on account of an irregular joint-line, the joint, especially towards the outside of the plate, should be as level as possible to obtain a satisfactory joint-face. Needless to say, the mould must be rammed dead hard—the harder the better. Even the matter of parting sand should receive attention, as the ordinary shop parting sand is not sufficiently good for pattern-plate moulding. There are on the market several brands of parting sand which can be used to advantage.

When the complete mould has been rammed up, the patterns should be preferably rapped through the top part in order to prevent uneven rapping, which occurs when the moulds are separated. The thin plate that was temporarily screwed on is now removed, and the depth of sand that is now exposed is shaved with a sharp trowel, as shown in Fig. 3. This is necessary, as there is a probability that where the two moulds are laid alongside and clamped together the sand will bulge, and this would be fatal.

When the boxes are clamped together there will be visible the joint-line. This has to be carefully filled in and finished. The patterns are now withdrawn, the runner cut, and the mould is finished and completed. In this type of plate it will be advisable to run the plate through the mould.

A flat machine plate, correctly drilled, is laid on a bed of sand. This particular plate has two small locating studs or pins on the centre line of the box pin-holes. Two fixed bushes are now placed over these pins. The frame is located on this plate, and the mould is then closed over the whole.

Too much attention cannot be paid to the question of weighting or clamping the whole to prevent straining during casting. It is of vital importance that the thickness of each individual section plate does not vary in thickness, as any variation means "flashing" on the joint of the one that is thicker than its fellows. This is shown at A, Fig. 4.

In all plates, especially of this type, it is desirable to have efficient risers to ease the strain.

The tackle shown applies to the transfer or single-sided plate. The foregoing remarks also apply to the double-sided plate, but, of course, the tackle is somewhat different

Instead of being located by drilled bushes cast in the centre of the plate, these studs are solid when cast in, and are afterwards drilled to a jig. This is illustrated in Fig. 5, where A and B are the positions of the locating studs in double-sided and single-sided plates respectively.

The moulding-machine frame is slightly altered, the principal alteration being the removal of the centre bar, as shown in Fig. 7. The reason for its removal is that it interferes with the range of patterns that can be utilised for this type of plate. The locating pins are altered, of course, to suit the plate.

At present tackle limits the Author to a plate, all the sections of which are all of one type. It is hoped shortly to improve slightly and arrange that transfer and double-sided sections can be used at the same time.

Another type of plate mentioned was the complete plate on the transfer principle. Fig. 1 shows the moulding box for this plate.

An interesting article by Mr. Heggie recently appeared in THE FOUNDRY TRADE JOURNAL, in which he described what he called a reversible plate. All these methods of casting this type of plate have to resort to drilling by jig or "M.O." after the plate is cast. The less drilling of the plates after the casting the better it will be. But on the transfer system, drilling to jig after casting is fraught with danger, besides being an expensive operation. The defective jointing of the casting can be due to this cause.

By using a steel frame of a tee section (Fig. 6), with lugs already drilled to jig before casting, ensures a perfect joint, assuming, of course, the plate tackle is machined accurately.

One method that is sometimes used for locating the special box when it is laid side by side is that the box pin lugs interlock with each other, the box pins passing through four lugs instead of two. It is suggested that the method adopted in this special box is more satisfactory because there are no interlocking lugs with a double depth of lugs, say 9 in., through which the box pins have to pass, and it requires very accurate drilling to ensure correct location, together with freedom from the trouble of the box pins binding with this depth of lugs. Comparative methods are illustrated at E, Fig. 1, and in Fig. 7. To ensure the pins passing through both sets of lugs there would have to be at least 1-64 in. clearance in the pin-holes. This is certainly too much, and 5-1,000 in. should be the correct allowance.

One of the greatest objections so far advanced against the general adoption of the transfer plate is that in the case of machined castings there is 50 per cent. of the unmachined faces in the top of the box. There is much to be said in support of this objection. There is this also to be stated—that a good number of castings have to be machined all over, and apparently it only requires a little more care to ensure clean machine-made castings.

Hitherto the fact that a fresh set of tackle for each size of plate has caused some to hesitate upon its adoption, because the tackle is more expensive, and, further, if the box pin centres varied the tackle would not duplicate. In order to obviate this, a box was made that is as near universal as possible. In the main this box

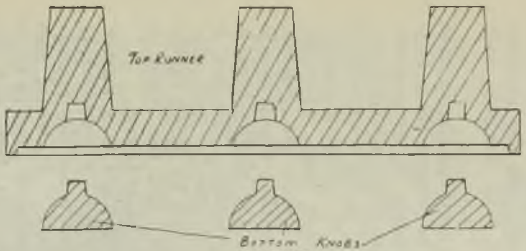

FIG. 10

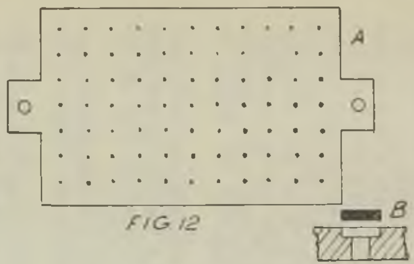

FIG 12

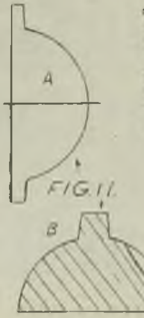

FIG. 11.

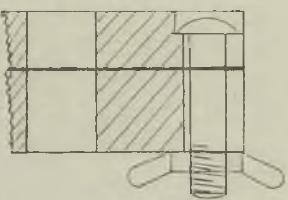

FIG 14

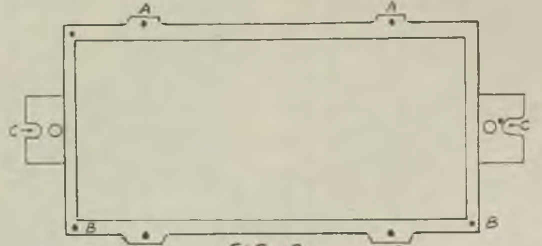

FIG 13.

is similar in principle to the one previously referred to. The dimension of this box should be of a size to accommodate the largest plate. Figs. 8 and 9 illustrate its construction.

It will be observed there is only a lug at one end of the box. This is drilled to a standard size to accommodate varying diameter pins. The shanks are all of the standard size just mentioned, and the effective part of the pin is of the diameter required to suit the boxes which will be eventually used in conjunction with the plate. The peculiar stepping of the walls of the box is shown in Fig. 9.

When the two half-boxes are laid alongside each other the stepped walls form a bearing for a sliding bush, which is also drilled similar to that of the fixed lug on the end of the box.

In making the plate in this box the patterns are arranged so as to come within the limits of the plate to be made.

In setting out, the job must be worked from the end of the box which has the fixed lug, when the moulding operation is identical with the previous box. The half-boxes are then laid alongside each other.

One of the box pins of the required size is fixed in the fixed box lug, and the frame (Fig. 6) is fitted on; the position and centre of the opposite pin-hole is then marked on the sand, which is cut away until the bearing slide (Fig. 9) is exposed to receive the sliding bush (Fig. 8). This is cleaned free from sand, and the sliding bush with the second pin fitted is then placed in the bearing slide. To get the correct position the frame is again placed over the mould; the sliding bush is then brought to its exact position. The box is then clamped together, which firmly fixes the bush. The mould is then finished by filling in the sand around the sliding bush, and the frame is closed by a flat mould and the plate is cast.

An accessory to the pattern plate is a master runner, shown in Fig. 10, which is particularly useful for plates which are made for the production of malleable iron castings. It would also apply in a lesser degree to aluminium, and in some instances could be applied to cast iron and the yellow metals.

To those connected with the malleable iron industry it is common knowledge that special and additional methods of running have to be adopted in order to produce sound castings, the runner in the top being much heavier and different in section from the runner in the bottom. To use the shop phrase, "feeding knobs" have to be provided.

In making the transfer plate, obviously the runner in the bottom mould is the same as in the top. If the runner is made to suit that which is required for the top, then it will be in the bottom, and this will undo the work of the top runner. So it becomes necessary to make the runner to suit the bottom mould, and then to fit a loose supplementary runner which fits over the bottom runner, and when the top half of the mould is made this supplementary runner is used. When the bottom is made it is omitted. There is an objection to having separate runners for each plate. When repeat orders are received the plate can be found, but very often the supplementary runner is missing, or has become damaged or broken. To overcome this a master top runner was made. It is suggested that there should be three sizes of the runner, as follows: (*a*) One suitable for light castings, (*b*) for medium, and (*c*) for heavy castings. The one shown in Fig. **10** is of the medium size.

Three iron patterns were made up of a semicircular section $\frac{7}{8}$ in. radius, with a locating peg cast on. These were in halves and dowelled together, as at A in Fig. 11. When the transfer plate is made, the using of Pattern A, Fig. 11, produces a runner such as is shown in section at B, Fig. 11.

When making a transfer plate they are arranged on the centre line of the box at a distance of $4\frac{1}{2}$-in. centres. The patterns are arranged on the odd side in the position most convenient to the runner; when the mould is made the ingates are cut into the spherical knobs. The top runner, which is the master runner, is made of cast iron, the section of which is made according to past experience. The centres of these knobs are identical with the centres of the bottom knobs, and the under side of the master runner is shaped to fit over the bottom knobs.

The use of this runner can be well imagined, the moulder only needing one of each size and shape, it being understood that the pattern-plate moulder makes his plates to suit the master runner. This method can also be used in the double-sided plate. Obviously, the adoption of this method of runners means that the plate will be lighter for handling, and there will be considerable economy in the use of pattern metal.

A type of plate which, for the want of a better name, is referred to as a master transfer plate. The flat plate is of cast iron of the required dimensions, and is machined on both sides. The plate is then drilled to the moulding box jig. A centre line is then scribed on the plate and the exact centre is found between the box pin-holes. One $\frac{1}{4}$-in. hole is then drilled, and then at every given centre further $\frac{1}{4}$-in. holes are drilled equidistant from each other. When the plate is drilled correctly it is desirable to recess the holes, say to a depth of 3-16 in., and then fit small blank washers for the purpose of blanking off the holes not covered by the pattern when the plate is in use. This master transfer plate is shown in Fig. 12.

When there is a pattern or series of patterns to fit on to such a plate, these patterns are drilled to a jig, a good plan being to supply the pattern-maker with a jig, and let him fit his dowels by the aid of the jig, so that when the pattern is received in the foundry it is only necessary to fit it on the master plate.

Castings have been made on this type of plate which have given a perfect joint, but so far the author has not been successful in obtaining a plate in which all the holes are correct.

In conclusion, a new arrangement made for fastening pattern plates to the "Adaptable" machine may be of interest. A frame is made and machined both sides. It has two lugs, one on each end, which are identical with the lugs on the pattern plate. Each lug has a U-shaped slot at its outer end, as is illustrated in Fig. 13, where AA are holes for screwing the frame to the machine; BB, pattern-plate adjusting screws; and CC, U-shaped holes for fastening the pattern plate to the frame. When the pattern plate is fitted on the frame the two are fastened together by coach screw-bolts and wing nuts. To free the plate it is only necessary to loosen the nuts, and the bolt and nut will then slide out. The frame is fastened, in the first place, to the machine. Fig. 14 shows an enlarged view of method of holding and screwing the pattern plate to the machine frame.

Provision is also made for adjusting the plate in case it is not sitting quite level. This is done by means of four sets of pins, two on each side in convenient positions (B, Fig. 13).

Discussion.

The Chairman (Mr. G. E. Roberts), in inviting discussion, said that he thought they would all agree that there was plenty of food for thought in what they had listened to that night.

Mr. C. Dicken (Vice-President), after expressing his interest in the lecture, asked three questions. (1) What metal did the author consider the best for pattern plates? (2) What clearance did he consider should be allowed in pin holes to bring out a perfect casting, say a round job 12 in. deep and cut in halves? (3) Did the author advise that a 5,000th part of an inch clearance was the best to work to for pattern plate making, and was it sufficient for cheap jobs? So far as sectional plates were concerned, some twelve years ago, he believed, there was one brought out by Wilkinson and patented, which was somewhat similar to the one which had been described. Further, did the lecturer think it wise to draw a hard and fast rule with regard to the master runner? A master runner for different jobs was in his opinion not a good practice. Every job should have a master runner of its own. Also, had the lecturer any experience of V-shaped pins? Such pins, he believed, were used in the most up-to-date works, with an adjustable nut in the back of the pin hole as used on the box part, so that in case of any variation in the pin hole, or wearing of the pin hole in the box part, it was overcome by an alteration of the register.

Mr. F. H. Hurren, A.I.C. (past Branch-President), remarked that one thing in particular had struck him. He would like to know what exactly were the advantages in the sectional plate, as it seemed to him that this method was rather an expensive one, even for small repetition orders. It occurred to him that to prepare sectional plates, which were undoubtedly ingenious, it was necessary to use rather a large box, and he should have thought that for small repetition orders it would have been cheaper to have made a single plate and use a small size box. The lecturer did not refer to plasters, and for cheapness the plaster pattern plate could not be beaten, but, unfortunately, it was fragile. The universal box which Mr. Bates mentioned was certainly quite unique to him, and one which he thought was capable of great development. Like Mr. Dicken, he could not quite see the value of the master feeder and of placing all their patterns on the plate to suit the feeder, whereas the feeders should be made to suit the patterns. Plates for three- or four-parted jobs, and the details of manufacture of some really intricate castings would have formed an interesting section of the Paper. The lecturer suggested pins and lugs should be case-hardened, and it would be interesting to know the effective life of the parts so treated. It was found that even with a case-hardened pin after a considerable time in the shop these showed a certain amount of wear.

Mr. Abraham asked what the lecturer considered to be the cheapest method of making a plate for a pattern with 100 to make up?

The Lecturer's Reply.

Mr. Bates, in reply to the points raised, stated that the composition which he had found most useful for metal for the purposes he had described was 85 of lead, 10 of antimony, and 4 or 5 of tin. If they desired to cheapen the metal a little, then they could eliminate one of tin and substitute one of antimony. With this metal he had found the contraction very constant at 1/32nd of an inch per ft. By introducing bismuth the contraction could be reduced very considerably, but, unfortunately, at the same time, the cost was appreciably increased, because much bismuth had to be added to make any real difference in the contraction. Mention had been made of boxes, and a suitable tolerance for pins on boxes of 6-in. deep. He thought that for close-jointed work, even at that depth, they should attempt no more than 0.010 in. clearance. The suggestion that a sectional plate had been placed on the market by Wilkinson led him to remark that if, if he was correctly informed, this sectional plate depended for location on a V-groove. The lecturer said this sectional plate was cast with a male V, and then the frame fitted on the machine had a female V. The obvious objection to this was that they were depending on the contraction for their location. In this instance the plate had a male V, and the end of the frame was open, and they were slid in. There was no means except the contraction for getting the side location. There were no means at all in this method except by putting each plate against another to get the end location, which did not seem a very desirable method to adopt. Further, this particular article of Wilkinson's only referred to double-sided plates. Personally, he did not see how it could possibly refer to a transfer sectional plate. Another objection was that if there were four plates all sliding into this frame and No. 1 was completed, in order to remove it, Nos. 2, 3, and 4 had to be taken out first. Now by using those which he had shown with the pins on the frame, each one was entirely independent and could be separated and removed without disturbing any of the others. With reference to the master runner being unnecessary, he insisted that in a number of cases, probably 20 to 25 per cent. of these plates, these master runners could be used. Master runners were *not* good for every type of plate he had made—it all depended on the job. The master runner had its limitations, but within them it could be used to advantage, always being sure that the section of the master runner was on the heavy side. He did not think he would be justified in displacing the diameter pins by V-shaped ones, as he had not had much difficulty with the former. With reference to the expense of sectional plates, a box of 14 in. × 11 in., arranged in three sections, would allow for each being about 4½ in. wide. In the transfer plate they had a pattern plate, moulding a box of a size 4½ in. × 5½ in., and he suggested that to make a plate and using such a box was not an expensive operation. He did not know whether it was the practice to use very small boxes on the machine; the smallest boxes he had seen used to any extent were 12 in. square, assuming that the 14 in. × 11 in. size was one of the smallest boxes used. Then for a small job or order, such as 100, provided it would go in that section of 4½ in. width, the cheapest way was to make a sectional transfer plate. As to the life of case-hardened pins, when using ordinary pins, they had to be frequently replaced, since introducing the case-hardened pin, some a year ago, he had had to replace none, and the resultant castings were quite good in respect to the jointing.

The lecturer understood from Mr. Dicken at the close of the meeting that the composition of the metal which showed a contraction of only half a millimetre to the foot, was 50 per cent. lead and 50 per cent. tin.

A vote of thanks to the lecturer closed the meeting.

Birmingham Branch.

ELECTRIC FURNACES IN THE FOUNDRY.*

By D. Wilkinson.

Since the inception of the electric furnace industry rapid progress has been made, and to-day there are over 1,000 electric furnaces of various designs used in the metal industries of the world. They are used in the manufacture of every variety of tool, alloy and constructional steel, for steel castings, for high-grade cast-iron, and for melting brass, bronze and non-ferrous metals generally.

In discussing the subject of electric furnaces the writer has considered it better to omit any detailed description of the construction of various furnaces. Views and diagrams are common in the technical papers.

Nature of Current Used.

In the early days of the electric steel furnace there was keen rivalry between the arc and induction type of furnace. There was little or nothing to choose between the quality of the product from either furnace, but the comparative structural simplicity of the arc furnace gave it so much advantage in first cost and in maintenance, and also in operation, that the great majority of furnaces in use to-day are of the arc, or modified arc, type. In discussing furnace construction the question is sometimes asked why alternating current is exclusively used. One very convincing reason is that it is cheaper to generate. But in addition to its extra cost, there is another reason why direct current is not used, although this second reason is perhaps more a theoretical than a practical one. Direct current passing through a compound liquid bath of any description always exerts an electrolytic effect. A familiar example is the ordinary electro-

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* A Paper read before the Birmingham Branch on November 12, 1921.

plating operation, where, on passing the current, metal is dissolved at one pole and deposited on articles suspended from and in electrical contact with the other pole. Another example is the abovementioned furnace, in which aluminium is manufactured. This furnace is, in effect, a carbon trough, in which is melted alkaline aluminium double fluorides. In the molten material is dissolved prepared alumina. Direct current is passed through the bath, and the net result, omitting all intermediate chemical reactions, is that aluminium is liberated at one pole, and carbon monoxide gas at the other. If, in either of the above examples, alternating current were to be substituted, all action would cease. The current, reversing or alternating its direction of flow anywhere from 20 to 50 or 60 times per second, each alternation would exactly reverse the work of the previous one, and so no electrolytic action would be possible.

The theoretical objection to the use of direct current in an electric steel furnace is that there might be a tendency for metalloids to accumulate at one pole, and this accumulation would reduce the speed of refining, and would also make the finished steel less homogeneous. Whether or not this would actually occur in practice the writer cannot say, but certainly the possibility is there. In any case, to the best of the writer's knowledge, alternating current is invariably used in commercial electric furnace work, direct-current being used only in a few experimental furnaces.

The Efficiency of the Electric Furnace.

There are several arc furnaces on the market capable of producing excellent steel. They vary a little in shape, in the arrangement and number of electrodes used, in the way they are connected to the transformers and in the character of the lining, but their differences are in minor structural details rather than in principle. Each type possesses what are claimed to be well-marked advantages over other types, but local conditions under which current can be obtained will frequently be the deciding factor in settling the most suitable furnace. Very low current consumption per ton of steel is frequently claimed for new designs, but usually low current consumption depends far more upon careful operation than upon furnace construction. The man who is tempted by very low figures may find his ideal elusive. On the point of current consumption some furnace salesmen are incurably optimistic. Figures obtained by the writer over a series of 1,100 runs show an energy consumption of 797 kw.-hrs. per ton of steel in the ladle. The furnace was worked with one slag only, and the steel was required very hot. Another set of figures from a furnace of a different type working with two slags showed a current consumption of just over 900 kw.-hrs. per ton of steel in the ladle. In each case the figures were obtained by dividing the total consumption, as shown by the furnace kw. meters, by the total weight of steel in the ladle. Figures are sometimes published showing an energy consumption, melting cold charges, as low as 550 kw.-hrs. per ton of steel. An overhaul of the kw. meters should be recommended in these cases.

It is not a difficult matter to obtain a rough idea of the minimum current consumption per ton of steel. Taking the ordinary calorie and omitting all calculation, we may say that in one ton of steel at a temperature suitable for castings there will be at least 375,000 calories. The slag will contain 600,000 calories per ton. As the total weight of slag, when working with two slags, will be approximately 18 per cent. of the weight of the steel, we have another 108,000 calories. Taking the heat equivalent to the kw.-hr. at 865 calories gives 483,000 ÷ 865 = 558 kws. required to furnish the heat contained in one ton of steel ready for pouring. A certain amount of heat is generated, and some is absorbed, by chemical action within the furnace, but very much more than is generated by refining reactions will be lost through unavoidable causes. These are:—(1) Electrode losses; (2) radiation losses; (3) cooling water losses; (4) losses during skimming; (5) losses during charging and fettling; (6) variable losses while the furnace is standing and when it is relined.

All these items have to be paid for, so should appear as current consumed in figures giving this information. Heavy heat losses obviously occur during the skimming of the first slag, and during fettling and charging the furnace. The losses in the electrodes will sometimes amount to as much as 10 per cent. of the current used. Economical operation is more likely to result from attention to these details than from minor variations in furnace design. When working with one slag only, the heat losses from skimming will be cut out and the reduced weight of slag will require less current, but when all is considered, it is safe to say some of the figures occasionally published do not represent the amount of electricity required, over a period, to produce one ton of steel with the sulphur and phosphorus reduced to a minimum.

The Chemistry of the Process.

The lining of the furnace may be acid or basic. The acid lining is made with silicious refractories, and is used where the materials to be melted are considered sufficiently pure to require no refining. With careful working a slight reduction of sulphur and phosphorus may be obtained, but the reduction is not great, and is difficult to obtain regularly. Generally speaking, however, the primary object in using an electric furnace for steel melting is to reduce these elements to their lowest amounts, and in this case a basic lining is essential.

Phosphorus and sulphur can only be removed from a molten bath of steel by a slag containing a high percentage of lime. Such a slag cannot be used on an acid or silicious lining. Exactly as the limestone in the cupola fluxes the silica, or sand, on the iron, so the lime in the slag would flux the silica in the furnace lining, and the result would be its rapid and complete destruction. To avoid the fluxing action of the lime, a basic lining is used. Generally this is made of calcined dolomite. Upon this material the lime in the slag has no chemical action.

The charge, within reason, may be composed of practically any sort of steel scrap, but as a lengthened refining period means a reduced output and an increased current consumption per ton, it is usually found better to select a good quality of scrap. It is less costly to use good scrap than, with an inferior scrap, to use more current and obtain less steel per day. The slag-forming materials, lime, sand, iron ore and a little fluorspar, should be charged into the furnace with the scrap. Using a good scrap of a fairly regular composition, the writer has found it best to charge, say, 10 per cent. of the scrap, then add the slag forming materials, followed by the remainder of the scrap. By carefully proportioning the lime and ore and mixing them with the charge, the phosphorus and carbon will both be reduced to the required percentage by the time the metal is melted and sufficiently hot enough to skim. With good scrap containing carbon 0.4 per cent., and phosphorus 0.06 per cent., the phosphorus will be reduced to about 0.005 per cent., and the carbon to under 0.1 per cent. In the presence of a sufficient amount of lime the phosphorus in an oxidised bath forms phosphate of lime, which is a stable constituent of an oxidised basic slag. The carbon is oxidised to carbon monoxide, which escapes and burns. The removal of the phosphorus is the result of reactions, at a low temperature, between ferrous phosphide, oxides of iron and lime. Stead, Ridsdale and others have shown that phosphorus exists in a basic slag as an oxide in combination with four atoms of lime. The following equations express the reactions:—

$$\text{I. } 2Fe_3P+5Fe_2O_3=3FeO.\ P_2O_5+11Fe+2FeO.$$
$$\text{II. } 2Fe_3P+8FeO=3FeO.\ P_2O_5+11Fe.$$

Probably both of these reactions go on together during the oxidation of the bath. The combination of the ferrous phosphate with the lime is expressed by the equation:—

$$3FeO.\ P_2O_5+4CaO=4CaO,\ P_2O_5+3FeO.$$

The result of the above reactions is the formation of tetra basic phosphate of lime, which, as noted above, is a stable constituent of an oxidised basic slag. The oxidation of the carbon is according to the reactions:—

$$\text{I. } 3Fe_3C+Fe_2O_3=3CO+11Fe.$$
$$\text{II. } Fe_3C+FeO=CO+4Fe.$$

Both of these reactions go on together. Usually, during the melting down, about 15 to 20 per cent. of the sulphur is eliminated, but this does not always occur. The bath should be skimmed immediately it is sufficiently hot to stand the heat losses due to this operation. The skimming should be thorough, as any slag left behind will return its phosphorus to the steel during the deoxidising period. It may be of interest to note the writer has found the bath sample invariably lower in phosphorus than the finished steel, no matter how carefully the skimming was carried out. This is due to the lining holding a thin coating of slag at the slag line and on the portion of the back lining exposed when the furnace is tilted for skimming. During the reducing period of the run the phosphorus is reduced from this slag and returned to the steel. While the steel is free from slag it will be found of advantage to add a little ferro-silicon to deoxidise it and so speed up the operation of the second slag.

The second, or reducing, slag is now added. It consists of lime, sand and a little fluor-spar. With the heat of the arcs above and the steel below these materials speedily combine and melt. When they are melted, and the surface is completely covered by the newly-formed slag, a mixture of ferro-silicon and carbon is sprinkled over it. The carbon should be as free as possible from sulphur. The material usually used is a form of retort carbon obtained during the distillation of oil, and known as oil cake. Its first action is to complete the deoxidation of the steel. It is to shorten this period the ferro-silicon is added after skimming. When deoxidation is complete the sulphur removal commences. Under the intense heat of the arc, the lime and carbon form calcium carbide, and this reacts with the ferrous sulphide of the steel forming calcium sulphide, which is a stable constituent of a non-oxidising or reducing slag.

$$3FeS+CaC_2+2CaO=3Fe+3CaS+2CO$$

At this stage, a sample of slag taken out of the furnace and quenched in water will disintegrate to a white powder, and will give off a distinctive odour of acetylene gas. It is important to maintain reducing conditions in the furnace, as if any oxidation takes place sulphur is returned to the steel. Calcium sulphide readily oxidises to sulphate, and in this form it reacts with the iron forming lime, sulphide of iron and oxide of iron, both of which latter are taken up by the steel.

$$CaS+2O_2=CaSO_4.$$
$$CaSO_4+4Fe=FeS+3FeO+CaO.$$

Sulphur is also removed by the ferro-silicon. The reaction is somewhat involved and rather technical, but the ultimate result may be written as:—

$$2\,CaO + 2\,FeS + Si = 2\,CaS + SiO_2 + 2\,Fe.$$

Either carbon or ferro-silicon alone will effectively desulphurise the steel, but the writer has found this operation to be under better control when they are used together. It may be noted that desulphurisation cannot be carried out until the slag and bath have been thoroughly deoxidised. If oxide remains in the slag the stable formation of calcium sulphide would be prevented by the following reaction:—

$$FeO + CaS = FeS + CaO.$$

The resulting ferrous sulphide would be returned to the bath.

When the steel has acquired the casting temperature and the slag is white, the finishing alloys should be added and the steel cast. The weight of ferro-alloys added will, of course, depend upon the percentages of silicon, manganese, etc., required in the steel. With a well-finished heat the proportion lost is not serious. It may be noted here that deoxidation can be carried out so thoroughly in the electric furnace that it is possible, before the ferro-alloys are added, to take a spoon sample and cast a test ingot which shall be sound and perfectly free from any trace of blowholes. The writer has done this with a metal containing 99.8 per cent. iron.

The physical characteristics of electric steel, as compared with ordinary steel, are greater homogeneity and freedom from segregation, a higher elastic limit and yield point, and a more marked resistance to fatigue both in use and on the testing machine. This last characteristic is also indicated by an increased contraction of area in the tensile test. All these characteristics might be expected to result from the removal of phosphides and sulphides, with their usual hardening and embrittling effects. Any required tensile strength may easily be obtained by varying the carbon content of the steel.

Non-Ferrous Electric Furnaces.

The electric melting of non-ferrous metals has lately come to the front, especially in America.

Obviously, the type of furnace suitable for melting steel would not be suitable for melting brass, bronzes carrying lead, aluminium and other metals and alloys easily vaporised or overheated. Some bronzes, and the nickel alloys, may be successfully melted in furnaces of the steel type; but, generally speaking, non-ferrous metals are not successfully melted by allowing the arc to strike the charge. The intense heat of the arc, between 3,500 deg. C. and 3,800 deg. C., will readily vaporise even copper; and losses by volatilisation are heavy. As zinc boils at 930 deg. C. and lead at 1,580 deg. C., it is evident these must be kept from contact with the arc when melted. Copper is volatile at 2,310 deg. C., so there is a greater margin here: but even this metal will readily vaporise when the arc plays on it after melting. Basically, it is a question of the ratio between the heating effect of the arc and the conducting power of the metal. When the energy input is higher than the rate of heat conduction through the metal, the temperature under the arc rises rapidly, and volatilisation occurs. If the heat can be poured before the metal under the arc reaches its boiling point. losses will be small; but alloys containing zinc, lead, antimony and other metals of low boiling points will suffer heavily.

Indirect arc heating is successfully used in several furnaces. One type consists of a cylindrical shell, with small doors located on the axis at each end. The electrodes enter through these doors. At one end is a tapping hole, and, with the exception of this hole and the doors, the walls of the cylinder are unbroken. This enables the furnace to be rotated upon its axis, and during melting this rotation takes place. The arc is struck between the ends of the two electrodes, and the rotation of the furnace, by rolling the charge over, continuously exposes fresh surfaces to the heating action of the arc and the heated lining. This results in a very even temperature gradient during the melting and in the maximum heat transfer to the metal. The melting loss in this furnace is said to be under 2 per cent., even when melting turnings and borings.

Another successful type has a trough, made of carborundum, crossing the furnace above the hearth. This trough is filled with carbonaceous material, and the electrodes enter it from each end. The resistance of the material in the trough to the passage of the current generates heat which is radiated on to the charge beneath, directly from the resistor trough and indirectly from the roof and walls. As there is no arc in this furnace, the risk of losses by volatilisation is considerably reduced.

Several other interesting types are on the market. Obviously, with the cutting out of crucible costs, the greater cleanliness of the furnace operation, the reduced metal losses (granting these are achieved), and the high thermal efficiency which can be obtained as compared with ordinary crucible furnaces, there should be an extensive field for the electric furnace in the non-ferrous foundry.

The Electric Furnace in the Iron Foundry.

At the present time attention is being directed towards the electric furnace as an iron foundry appliance. From the earliest days of electric furnace development pig-iron has been reduced from the ore by various types of furnaces; but the use of the electric furnace either to replace the cupola or as an adjunct to it, has only recently been seriously considered, but the time has not yet come for the cupola to be ousted from its present position. It is quite conceivable, however, that for certain purposes the increased cost of electrically-treated cast iron might be compensated for by its improved quality, always granting that the improved quality exists in the casting and not in the imagination. It is easily possible to obtain as poor an iron from an electric furnace as from the cupola. When properly handled, the resulting improvement is so marked that for certain classes of work the increased cost should not be prohibitive. But for general castings the increased selling price would quite prevent sales, and no good purpose can be served by improving a material in a manner that puts it out of the market.

The replacement of the cupola by the electric furnace may be considered along the lines of what is now known as the manufacture of synthetic cast iron.

In 1915, when the shortage of hematite was very acute, the writer, in a search for supplies of this material, went over a small works where synthetic cast iron was being made in an ordinary electric furnace. Various grades, from white to all grey, were being produced. The fractured surfaces were all very finely grained, and the tensile strength of the grey iron was said to be 20 tons per square inch. The venture, despite the abnormal demand for hematite, was not a financial success, doubtless owing to the size and unsuitable design of the furnace.

The production of synthetic cast iron was developed on a large scale in France during the war for the manufacture of cast-iron shells. A description of the process was given in a Paper read before the Iron and Steel Institute at the September meeting, 1919, by C. A. Keller. This gentleman was among the earliest patentees of processes for making cast iron direct from the ore by electrical methods. The synthetic iron process is simple in principle. Steel turnings, mixed with carbon in the shape of small coke or charcoal and a proportion of lime and sand, is charged into an electric furnace. As the charge heats up the carbon combines with the steel, reducing its melting point considerably. The lime and sand serve a double purpose. They reduce the high conductivity of the charge, and so enable an ordinary voltage to be used in the furnace. The lime, under the strongly reducing conditions resulting from the amount of carbon present, combines with the sulphur in the steel and carries it into the slag. The silica of the sand is reduced to silicon by reaction with iron and carbon, and results in the production of grey cast iron. The process can be closely controlled, and yields a really excellent cast iron. As much as 300 tons per day of this material is said to have been made by this method at Livet, France, where there is a very large installation for the generation of electricity by water power. The current consumption is stated to have been as low as 675 kw.-hours per ton.

According to figures given in the Paper a remarkably strong iron was obtained. The following composition is given:—Carbon, 2.90 per cent.;

silicon, 1.75 per cent.; manganese, 0.50 per cent.; sulphur, traces; phosphorus, 0.05 per cent. From this iron a tensile strength of 50 kilos. per sq. mm. is said to have been obtained. The remarkable strength will be recognised when it is calculated into British terms. The resulting figure is 31.74 tons per sq. in. It certainly seems an almost incredible tensile strength for a cast iron of any description or composition. While the writer has obtained some excellent tensile results with electrically-treated cast iron, this figure goes far beyond the best he has ever seen.

Synthetic cast iron can be made in any ordinary electric steel furnace, and during the period of the war the writer assisted in carrying out trial runs which, so far as product was concerned, were very satisfactory, but the cost was too high. In these trial runs, the turnings contained carbon 0.42, silicon 0.21, manganese 0.79, sulphur 0.066 and phosphorus 0.058 per cent., and the coke carbon 88.40, volatile matter 1.36, sulphur 0.93 and ash 9.21 per cent.

It is necessary to use turnings and to mix thoroughly the ground coke with them in order to economise energy. Ordinary foundry or forge scrap does not expose sufficient surface to the carburising action of the coke mixed with it to complete carburisation before melting. If the charge melts before carburisation is complete, it can only be completed by solution of the carbon in the molten metal, and the solution becomes slower and more difficult the higher the percentage of carbon rises. To introduce about 3 per cent. of carbon into the resulting cast iron, 5 per cent. of ground coke is necessary; 5 per cent. of lime and a little sand is added to form a desulphurising slag. This mixture is charged on the preheated hearth of an electric furnace and the current switched on. Carburisation begins at a dull red heat, and becomes more rapid as the temperature rises. As the charge becomes semi-molten, the action is very energetic, and by the time fusion is complete, in the neighbourhood of 3 per cent. of carbon, will usually have been absorbed by the metal. By the action of the lime, the sulphur will be considerably reduced, and the resulting metal will be a good quality white iron. In operation it was found more economical to add the silicon by means of ferro-silicon rather than by the reduction of silica in the furnace. When, after adding the ferro-silicon and rabbling, a test sample showed a grey homogeneous fracture, the metal was poured out and cast.

The composition of the product showed the sulphur was reduced considerably; the phosphorus was not altered, and the manganese lost usually about 10 per cent. of its content. To replace this loss a few pounds of 80 per cent. ferro-manganese were added to the ladle. The analysis of one heat was:—Combined carbon 0.47, graphitic carbon 2.16, silicon 2.28, manganese 0.84, sulphur 0.022, and phosphorus 0.060 per cent.

The Physical Properties of Synthetic Iron.

Tensile tests taken on material of this analysis gave the following results: (1) 21.5, (2) 19.9, (3) 21.2, and (4) 21.0 tons per sq. in.

Transverse tests taken on a bar 2 in. × 1 in., with 3 ft. centres, gave 39.2 cwts. with 7/16 in. deflection, and 39.4 cwts. with 7/16 in. deflection. The specific gravity was 7.53. As the average specific density of grey cast iron is about 7.2, the higher specific gravity of synthetic cast iron shows it to be of a considerably increased density. The conditions under which it is made ensure its perfect deoxidation; and its freedom from other dissolved, occluded or combined gases will be rendered certain by the temperature to which it is raised, and the strongly reducing slag covering it while in the furnace. Microsections showed the graphite in an extremely fine state of division and uniformly distributed in a matrix of pearlite and silico-ferrite.

The metal is intensely hot and very fluid. Moulds cast with it had to be prepared with great care if smooth castings were to be obtained. When poured into the moulds it remained fluid for a considerably longer period than cupola metal; and its feeding qualities were obvious when the sinking down of the runners and risers was observed. The castings were close grained and sound, and the high specific gravity resulting from the close grain marks it as being suitable for light castings to resist internal pressure. Its fluidity was such that the runners were reduced in number and in size without the slightest tendency towards cold shuts or mis-runs. Dry-sand moulds had to be closed with great care and cottered very tightly to prevent runouts, and if a runout did occur it was very difficult to stop it.

The Duplex Process.

The use of the electric furnace as an adjunct to the cupola will effect a considerable saving in current consumption, and the quality of the resulting metal can be brought up to the figures obtained from synthetic cast iron. If the electric furnace is to be developed in the cast-iron industry, it will be essential to obtain the utmost economy, as when everything has been done to cut down the cost to the minimum the metal will still be expensive. The purchase and maintenance of an electric furnace and the high price of electric current add a serious item to the costs of grey-iron castings. Melting in the cupola is certainly cheaper than melting in the electric furnace, and in the interests of economy this should be done. As regards the composition of the metal thus treated when compared with synthetic cast iron, the use of hematite would give an equally low phosphorus; but, in the writer's opinion, a moderate amount of phosphorus would not be objectionable. In fact, he is inclined to believe that phosphorus up to 0.3 or 0.4 per cent. would be an improvement, as it would increase the rigidity of the metal and yet not be sufficient to induce brittleness This percentage could readily be obtained by the use of a medium phosphorus pig and steel scrap.

The writer's experience leads him to think a basic lining in an electric furnace is not at all suitable for iron foundry requirements. The furnace itself could be so modified that it would be much cheaper to erect and maintain, and more convenient for use with cast iron than any that has as yet come under his notice. Few foundries require molten iron more than three or four hours daily. The foundries requiring molten iron continuously, that is, for 20 to 24 hours per day, are so few that they do not enter into the general question. This intermittent demand for metal is a source of serious trouble and expense with a basic lined furnace. Unless a basic lining is kept constantly hot, it rapidly disintegrates and is destroyed. At the temperature required for cast iron, a basic hearth in continual use would last at least several months; but if it were allowed to cool off each night it would not last many days, owing to the severe strains set up by alternate expansion and contraction, cracking the lining and making it spall off when re-heated.

The writer would suggest, instead of a basic hearth, a neutral one made of carbon. This would not be possible in steel melting, as the steel would attack and destroy it; but cast iron already heavily charged with carbon, would have no action on it. The calcareous slag required would also, if properly proportioned, be without chemical action upon it. The furnace itself should be built up after the manner of an air furnace; well braced with buckstaves and side plates There is no need for an electric furnace handling cast iron to be tilted. A furnace, solidly built, with walls and roofs of the highest quality firebrick, having a hearth about 5 ft. × 2 ft. 6 ins., with well-tapered sides about 1 ft. 8 ins. deep, would hold three tons of cast iron, and the slag required to refine it. The electrode holders could be either attached to the walls or built up separately. At one end a tapping hole and spout should be located, and at the other end a charging spout should be fixed. This spout should be sloped gently upward from the top level of the hearth, and should be closed where it enters the furnace by a small door. The roof should, preferably, be movable to facilitate repairs. A door on the side opposite the electrodes would allow the refining to be controlled, and would also enable the slag to receive all the handling it would need. The hearth should be made of ground coke mixed with hot pitch and tar in suitable proportions and solidly rammed into place. Two electrodes only would be required, with Scott connections to three-phase current at the transformers (Electro-metals system). Such a furnace would, with care, last as long as an air furnace, and would be considerably cheaper to build than an ordinary electric furnace. Also, it would not come to any harm however frequently it was cooled down. A furnace on these lines could easily handle 20 tons of cast iron during an afternoon. The writer has not heard of a furnace of this description in operation; but if there is one he would be very glad to receive particulars of its working, as he is of the opinion it would be economical in upkeep and in current consumption.

A proposed process of such a furnace in an ironfoundry would be as follows:—About two hours before the cupola would be put on blast, the furnace, cleaned and patched after the previous day's run, would be charged with about one ton of small scrap from the last heat. A liberal amount of ground coke would be spread over the iron. Current would be applied slowly at low power initially, gradually increasing as the furnace warms up. After from 1½ to 1¾ hours, the scrap would be melted and covered with the ground coke, and the furnace would be fairly hot. The lime, sand and fluor-spar to form the slag would then be charged, and by the time the cupola was delivering metal the slag would be melted, the furnace would be hot, and the iron already in it would be in good condition. From the cupola two tons of metal would be tapped and poured down the charging spout into the furnace, mixing with the iron and slag already there. The full current, from 700 to 800 kilowatts, would be switched on, and refining would begin. The first heat would probably require about half an hour's run. Experience would soon show the correct time to start the furnace so that by the time the first heat was refined the furnace would be at the full temperature. Two tons would be tapped out, and another two tons brought from the cupola and poured into the remainder of the charge left in the now highly-heated furnace. Deoxidation and desulphurisation would be rapid under the action of the hot active slag. At intervals, as the slag became spent, it would be partially raked off and new slag-forming materials added. By adding carbon, fluor-spar and lime as required, a strongly reducing slag could readily be maintained. By working in this manner, taking out only two tons per tap, leaving the remaining ton to mix with the fresh cupola metal, it would be possible to make a tapping every fifteen minutes, taking off two tons of thoroughly deoxidised, desulphurised and superheated metal. The metal, as drawn off, would be at such a temperature that, if covered with blacking, it could be kept until the next tap was made, and still be sufficiently hot to satisfy the most exacting demand for hot iron. With good cupola practice and treatment under these conditions, metal of faultless composition and properties could be relied on.

In conclusion it may briefly be noted that iron for malleable castings treated in this manner would be certain to give a tensile strength, and an elongation after annealing that would be a revelation to founders accustomed to the present quality of castings. Within a very few years one may venture to state great developments along these lines will occur, with advantage both to founder and consumer.

DISCUSSION.

The Chairman said in Birmingham they were very unfortunately placed with regard to electric furnaces, as there were not many in operation, and it was not an easy matter for those interested to see them. In Sheffield, however, and other towns they were much more numerous, and doubtless in those areas their members would be more familiar with their practical working.

Decarburisation of Ferric or Magnetic Oxides.

Prof. Turner, in proposing a vote of thanks to Mr. Wilkinson for his Paper, said Mr. Wilkinson had given them the reactions that took place in the furnace and more particularly in reference to the melting of steel. There was only one little suggestion he would make. Mr. Wilkinson stated that the two reactions—the reaction with ferric oxide and ferrous oxide—both went on together. That was perfectly true. The ferrous oxide did not melt without decomposition and ferrous oxide was unknown to them as a pure substance. What happened was that the ferric oxide and ferrous oxide combined together to form a fluid magnetic oxide which was the active agent, and if they examined the slag under the microscope they saw this magnetic oxide which had been in solution thrown out in its characteristic crystalline form. In explaining what went on in the furnace he generally combined these two reactions, instead of putting them separately, and worked out what occurred on the basis of magnetic oxide. It recalled what was quite an active discussion of some 25 or 30 years ago, the question being what was the agent which led to oxidation in the puddling furnace or in the steel furnace, and as to whether it was really ferric oxide or magnetic.

The Choice of a Furnace.

In connection with the introduction of electric furnaces, the author had well said that the conditions under which the current could be obtained often determined the furnace to be employed. Where they were dependent, as they were in the Midlands, upon supplies of electricity which were designed for other purposes primarily they met with difficulty. He questioned whether the Birmingham Electricity Committee would be prepared at the present moment, or whether they had the necessary machinery and the necessary power available to provide current for metallurgical purposes on anything like a large scale. They remembered, for instance, in Sheffield what tremendous developments were necessary to meet requirements during the war. He was informed that a furnace was recently purchased and brought into the Birmingham district—a furnace of the type to which Mr. Wilkinson had referred—for the melting of non-ferrous alloys. Single-phase current was required, and difficulty was met with on account of the interference with the general electric system of using furnaces of the size of the one in question, taking a ton charge. The result was that the furnace had not been used. There might be other reasons connected with the state of trade and so forth, but, at any rate, that was the reason given to him. The purchase of an electric furnace where they had not a supply of electricity guaranteed and ready at hand was a very small part of the total expense in many cases. At the present time he had small and large types of furnaces—he meant large for the laboratory, though very small in comparison with the furnaces of which Mr. Wilkinson was speaking—ten or a dozen of them, and every one of them wanted either a different kind of current or a different quantity of current. For some he required a direct current, while in others he required an alternating current.

He began with a voltage of something over two, such as was used for aluminium decomposition. Another furnace required a voltage of about 20 to 25, while for iron and steel he needed, say, 75 up to 150, according to the circumstances. The result was that in his case he required to tap off from one source of supply all these different voltages.

Non-Ferrous Electric Furnaces.

For the non-ferrous trades in the Birmingham district there was an enormous possibility in the direction of electric melting. In America he understood that the largest works at the present time had practically given up coke melting, and he believed he was correct in saying that over 400 electric furnaces were employed in connection with the non-ferrous metal industry, many of them melting a ton at a time or more, in the U.S.A. and Canada. It was not merely the cost of electricity here, though that was, of course, an important point. But speaking not as an electrical engineer but as a metallurgist it appeared to him that for manufacturing purposes what they required was a definite supply of electricity suitable for their purpose and more or less devoted to that purpose if they were going to carry on a large metallurgical industry dependent upon electric melting. There were several furnaces working in the Birmingham district at present, but his anticipation was that in future, and in the not very distant future, there would be a very large increase in the amount of electric melting, not only in the iron and steel trades, but also in the non-ferrous industries. There had been a distinct set-back, of course, since the war. During the war expense was comparatively of little account, and there was a great demand, but a number of furnaces that were working during the war had closed down not merely because many branches of the metal industries were almost at a standstill, but because at the close of the war a number of furnaces would have been closed down even under normal conditions because they were not economical. When, however, one saw how flexible and adaptable electric current was under suitable conditions, and how losses were diminished and quality improved, one could not but feel that there was a great future for electric melting in various directions. He saw a photograph the other day of an installation by Keller for the synthetic production of cast iron, showing a long row of electric furnaces used for this purpose, and it was an extremely impressive picture. Those furnaces, like others of which he had spoken in our own country, he believed were not at work at present because the special necessity for them had passed.

Mr. H. L. Reason, in seconding the motion, said he could corroborate Prof. Turner's statement that an electric furnace in Birmingham could not be used owing to difficulties regarding the supply of current. He agreed with Prof. Turner that if the non-ferrous industry was going to abandon the present method of melting and take up electric melting special arrangements would have to be made for the supply of current. If suitable current could be supplied for melting economically non-ferrous metals by electricity on a commercial basis progress would be made, because when melting metals in cupolas or open furnaces all sorts of troubles were met, and after blaming everyone attached to the foundry it was finally found to be the method of melting which was responsible. There was no question that electric melting was the correct method. Mr. Wilkinson had established that the results obtained from electrically-melted metal were far superior to metal melted in a cupola and the same remark applied to the non-ferrous trade.

The vote of thanks was warmly accorded to Mr. Wilkinson.

Scientific Control.

Mr. E. N. Wright said that the cupola was altogether too little under control for making the best of ironfounding. Part of the success of the electric furnace was no doubt due to the scientific control, and it was up to them as foundrymen to apply the same care to the use of the plant that they already possessed. He had not the slightest doubt that the product of their cupolas could be very much improved by the application of more scientific control. The cupola was a dust and smell-emitting contrivance, which they generally placed as far from themselves and their office windows as they possibly could, and it obviously was in a position in which it was very often neglected. If the cupola man turned up to his work regularly and nothing very terrible happened he was afraid he was very often left to carry on as best he could. That was not right, and one lesson to be derived from the Paper was that if they could not have electric furnaces they could at least make better use of the furnaces already installed.

Mr. F. Holberry asked the lecturer if direct castings could be made in electric furnaces from the ore. If that was so there were vast possibilities ahead of the electric furnace in the cast-iron industry. Mr. Wilkinson also mentioned the melting of steel turnings in conjunction with small coke in an electric furnace, and he would like to know what would be the result if cast-iron turnings were melted in the same manner.

Electric Furnaces for Roll Making.

Mr. Arthur Parsons said the lecturer spoke of initially charging one ton in an electric furnace which was melted and supplemented by two tons from the cupola. Supposing they were required to fill a ladle holding ten tons? The lecturer, he understood, said the heat would be sufficient to allow of waiting until the next two tons came along, which would be practically fifteen minutes, and so on until the quantity of ten tons for the roll was obtained. Before casting a chilled roll it was very necessary to take a sample for ascertaining the chill. This took a considerable time to cool before it was ready to break in such a manner as to give an opportunity of judging the chill. He asked Mr. Wilkinson if there would be sufficient time, after filling the ten-ton ladle in the manner he suggested, and then have half an hour to get the sample broken? If the metal would remain fluid enough for casting a roll after that half-hour had expired, he thought that the electric furnace, in conjunction with the cupola, was a proposition well worth trying by roll makers.

The Chairman asked the author to give power consumption which would apply to the refining of cast-iron under the duplex process. The general consensus of opinion was that the electric furnace was unlikely to replace the cupola and air furnace as a melting unit, but as a refining medium it was a valuable adjunct. His own estimate was between 200 or 250 kw.-hours per ton would be required for the refining process.

The lecturer's closing remarks with regard to malleable iron were interesting, because they opened up a large field in the direction of making black-heart malleable, it being impossible to keep the sulphur sufficiently low in cupola melting. The few people who were making it at the present time in this country were making it not from the cupola but from the air furnace. Apparently black-heart malleable iron was a metal which in the very near future would be more popular in this country very largely on account of the successes which the Americans were able to show with that material. Those who had seen recently the amazing reports from the American research departments and the figures given could have no doubt, whatever engineers might say, that black-heart malleable castings were equal to the European material. The electric furnace was not only able to melt metal without any addition of sulphur, but it gave them an opportunity of decreasing it where that might be necessary. A point on which Mr. Wilkinson might have laid more emphasis was the extra fluidity given to the metal. The electric furnace gave them an opportunity of heating to any extent, but they had under control, simply by the adjustment of the amperage, the possibility of raising the metal to practically any desired degree above the melting point. They had not that advantage by any other means, and that was a most valuable quality of the electric furnace in the case of cast iron.

The Author's Reply.

Replying upon the discussion, MR. WILKINSON admitted that the electric furnaceman did have tribulations, especially in his early days. If all the expense could be cut out, or if expense was no object, he had no doubt that in less than ten years there would not be a melting furnace of any description save electric furnaces in the whole world. The difficulties were easily overcome by intelligent application, and there was no questioning the ease of operation. When the metal was melted electrically, difficulties still existed. There was a new set of characteristics to be learnt before the best way of handling the metal was ascertained in order to secure sound castings. Electrically-melted steel did not always set and cool along the same lines as steel melted in either the open-hearth or converter. Unless extreme care was taken electric steel was much more liable to cracking on account of its excellent quality. As to the cost of non-ferrous melting, he was of opinion, on the whole, that it would be cheaper to melt in an electric furnace than in a crucible furnace. The efficiency of a properly designed furnace used for non-ferrous alloys would be about 80 per cent. The losses judged by the published figures would be not more than 2 per cent., and taking into consideration the control over the metal and the entire absence of draught—the melting all being done in a closed chamber—it would be realised that a very much lower melting loss would be experienced. Even with current round about 1d. a unit, he was of the opinion that it would be cheaper to melt brass in an electric furnace than in a crucible. The actual handling could be entrusted to a man who would use his intelligence. As to whether segregation would occur one could hardly say short of testing the matter. On the question of size, he said electric steel furnaces handling a 30-ton charge were not exactly common, but there were ten or a dozen in the world at present, and there would be no difficulty at all in designing a furnace to melt 30, 40, or even 50 tons of cast iron. As to the use of cast-iron turnings, he did not know any reason at all why they should not be used.

In reply to the Chairman's question, he expressed the opinion that a furnace run on the lines he indicated would not consume more than 95 to 100 kw.-hours per ton for refining—150 kw. per ton would be an outside figure. In many places troubles were experienced with grey-iron castings, which would be entirely avoided if electrically-prepared metal were used. Motor car cylinders would be very much better made from electric cast iron than ordinary cupola metal. Referring to black-heart malleable iron, he remarked that ordinary British irons treated in the furnace would have the sulphur reduced to such an extent that there would not be the slightest difficulty in getting black-heart material, and they would obtain a metal superior to the average metal produced in America. In the malleable iron industry the electric furnace would have a much better opening than in the cast-iron industry. Light steel castings were comparatively dear, and malleable iron could be made that would give results approaching 75 per cent. of the results obtained by steel casting, both in tensile strength and elongation, and, moreover, it could be produced at a price so much below that of steel castings that there would be no difficulty in finding a market for it.

Sheffield Branch.

At the opening meeting of the session, held on October 21, Mr. John Watson, the newly-elected Branch-President, occupied the chair. Mr. Watson was elected to the Branch-Presidency during his absence, and the meeting was his first appearance amongst his old colleagues, who accorded him a very hearty welcome.

PRESIDENTIAL ADDRESS.

The Apprenticeship Question.

Mr. Watson prefaced his Address by thanking the meeting for the honour they had conferred on him, and called the attention of the members to the very attractive programme which warranted a good attendance at the future meetings. He would like to bring to their notice one or two things which in the near future were sure to be discussed by the General Council, and these were matters upon which every Branch should express its opinions. There was, first, the old question of apprentices and how they were to obtain competent workmen. To some that might appear to be a question which had been thoroughly thrashed out, but much nonsense was now being put forward about the technical education of apprentices. After twenty years' experience he thought a long apprenticeship was a great mistake. The period of training in the shop should not be more than from four to four and a half years, and after that period he should be competent and turned adrift to make a man of himself. The age of 14 years was the best time to get a lad into the shops. At 16 a lad's ideas were changing very rapidly, and when he had been highly technically educated he usually came into the shop with a certain amount of conceit, which destroyed his usefulness and his chance of becoming a really good workman. It must not be taken that he was without ideals, but after all it was necessary to keep the facts and realities before them. The great fact was that a boy or man went into the works to earn money for himself and to learn to become a good workman. At present apprentices were given far too much liberty in mixing with the men. They should be trained apart from the men, because in nine cases out of ten the youths to-day learned much that was no use to them. When the boy had been grounded in the essentials of moulding it was then the time for him to work amongst men, to learn how to build up the moulds. His long experience showed that the best results were obtained from boys who were trained away from the men.

Technical education should be carried out at the works. When a boy was working all day he did not feel inclined to go to the technical college whilst his brother went to the pictures. Not more than one in every 100 lads went to a technical college for the sake of instruction. The majority went because they were forced to do so. The result was they got a smattering of knowledge which was no use to them. He thought the better plan would be to give a lad a certain amount of instruction each day in the works in technical subjects, and show him when a thing arises how his technical knowledge would help him. It could there be better explained to him why, for instance, certain jobs were run one particular way. He should be told that technical knowledge alone was not going to make him a good workman and one qualified to earn his livelihood. Some may think that that was a waste of time, but it was a greater waste of time to learn technical subjects outside the shop.

The Production of Castings.

In the Institution of British Foundrymen anything that savoured of politics was out of order, and they were entirely concerned with the technical side of their business. But they must see what was happening all round them. Unless a larger production per man was to be obtained from British foundries they would put themselves out of the world's trade. Foundrymen could aid in the matter of production by "hammering away" at buyers to simplify their castings. If designers would only work hand-in-hand with the practical foundryman much work which now has to be made by hand could be made by machinery. If this were done eventually most of the present day foundry work would be done by machines. Big strides had been made in the use of the machine in the moulding shop, and before long he believed there would be greater strides still. One of the first things that would happen was that the ramming machine would be entirely superseded. Quite recently he had studied a novel kind of machine in which there was neither ramming nor jarring. The sand was projected into the mould and an excellent mould with a good face was obtained. It was a new development, and should be watched. He was hopeful that the British workman would see that it was better for himself that he should be paid on results. If he were they would soon regain a hold on the world's trade.

Continental Conditions.

In France they were working very hard. The product was excellent, the prices lower than those prevailing in this country and, moreover, the foundries were full up. They were making money and the men were working very hard. In Belgium the men were working harder than in 1914. All that was very disturbing, but he hoped they would soon get settled times, which would come about when the men themselves realised the importance of output. Since he had returned from New Zealand he learned with pleasure from a British foundryman that the few men who were working were doing much better than in the past. That was a source of pleasure to him, because he had a great love for the British workman, and after his ten years' experience in Sheffield he did not know of men capable of turning out better work than the Sheffield moulders.

DISCUSSION.

Mr. Darley, in opening the discussion, said that he agreed with the President that something needed to be done on the apprentice question. At his works the foundry apprentices and those in the pattern shop went to classes two or three afternoons a week, and they also effected exchanges—the boys in the pattern shop going into the foundry and *vice-versâ*. There was no doubt, however, that there was a great need for improvement. In their works they were working the boys under the control of one man, who received extra remuneration for instructing the lads. The practice had been in operation only six months, but he believed it was producing good results. It was intended that lectures should also be given to the boys. He was a great believer in the moulding machine, and had recently seen the sand thrower at work, and he thought it had excellent points. The chief objection was the dislike of the workmen to them. He failed to see the reason, because it obviated much hard work. Until the men were prepared to work by results he was afraid the moulding machines would not get a fair chance.

Moulding Machines.

Mr. Bradley, after endorsing the President's views on the subject of apprentices, said that in some cases employers wanted to get too much from the boys instead of teaching them how to work properly. With reference to moulding machines eliminating a certain amount of labour, at his works they were not getting the hoped for results from the machines, but perhaps with a little more experience in their handling they would be able to get good results in the future. He could say, however, that the men were working much better now than in the past.

Mr. Dawson said he was not capable of expressing an opinion on the apprenticeship question, but he thought that what the President had stated with regard to what was happening in France and Belgium was right from what he had seen himself. There was no comparison in the way the French and the Belgian workmen worked with the British.

Technical Classes at the Works.

Mr. Shaw, after thanking Mr. Watson for his address, said that the apprentice question was a vital one, but it had two aspects if Mr. Watson's ideas were put into force to which he desired to draw attention. The first was that the employers might simply use these boys to cheapen production. That was not fair to the boys. Again, the employer who might give the technical tuition during the day time and pay something specially for supervision during his moulding time might leave at the end of four and a half years, just when the boy became most useful. That obviously would not be fair to the employer. He thought the only way to obtain the special training was to make it compulsory for every employer to give special technical training for so many hours per week up to 18 years of age. It would also tend to make good citizens if a portion of the boys' time was devoted to the study of economical questions. With regard to production, the use of moulding machines was generally restricted to repetition work. To cope with either American or Continental practice, semi-skilled workers should be employed at least on the ramming, even if the finishing and closing were left to the moulders. The very lack of apprentices would force the more extensive use of machines eventually as it had done in America. The teaching of apprentices is compulsory in Germany.

Faulty Systems.

Engineer Capt. Moorshead, R.N., said that he was not well qualified to speak on the subject of foundry apprenticeship, because there were many difficulties in such training that did not obtain elsewhere; he had, however, had considerable experience of general engineering apprenticeship.

He called to mind two particular cases in large firms. In one, where premium apprentices were taken, the firm definitely stated they undertook to teach them nothing; in the other, where the premium bonus system was successfully in operation, the apprentices were exploited to increase production without regard to training.

Such methods were of the past, for if boys were brought into the works and regarded as merely commercial machines to get as much out of as possible, they must dismiss the question of any improvement. That was not playing the game with the boys.

With regard to the point the Branch-President referred to of allowing them to work with the men, they must not overlook the fact that any proper training must be on systematic lines and methodically carried out under ample supervision, and just detailing a boy to work with a man did not meet the case.

Definite theoretical instruction was necessary during working hours, and this insured a certain general standard, but should be regarded as subsidiary to the important technical instruction that was available in a city like Sheffield.

As regards age, the President suggested 14; he thought 16 was early enough, and the two years' extra school education was important.

The late Lord Fisher's idea in introducing the new scheme of training of officers in the Navy was that an early age of entry was most important, but this has subsequently been modified and a later age adopted, while a system of entering public school boys at 17 or 18 had been attended by most successful results.

Mr. Bradley said with regard to the question of educating the apprentices classes had been formed at Messrs. Osbornes and Daniel Doncaster's works. There the boys were taught during working hours in a school, and were paid for their time.

Coventry.

GAS IN THE EOUNDRY.*

By A. Docking.

Towns gas has for many years been a keen competitor of solid fuel, but to-day its high cost and low calorific value has made its use on a large scale prohibitive, and consequently many industrial consumers are installing their own gas-making plant. Two large plants have recently been installed in Coventry, with a result that the Gas Committee decided at their last meeting to reduce the price to their large consumers to 2s. 6d. per 1,000 cub. ft.

The figures in Table I. are based on the returns of the Gas Department at the year ending December last. From these figures it will be seen that the loss per 1,000 cub. ft. sold will be 7½d., and, as stated at their last monthly meeting, a loss of revenue of over £34,000 per annum.

The figures for the cost of suction gas made on the consumers' premises from anthracite coal show that town's gas at 2s. 6d. per 1,000 cub. ft. is still 9½d. per 1,000 cub. ft. dearer than suction gas, and that with this reduction it pays the large user to instal his own plant. The price of Coventry gas at 2s. 6d. per 1,000 cub. ft. will be the cheapest gas in the British Isles.

The reason why gas can be produced on the consumers' premises cheaper than at the gasworks is that the latter have always given more attention to the manufacture of by-products than to the manufacture of gas. The total B.Th.U.s in a ton of coal is 31,340,000, and the amount taken from this in gas at the gasworks is only 6,000,000, or less than one-fifth, the remainder being left in the coke, tar, etc. The amount produced from the same ton of coal by a suction gas

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* A Paper presented before the Coventry Branch on November 16, 1921.

TABLE 1.—*Cost Comparison between Coventry Town's Gas and Producer Gas.*

Town's Gas, per 450,000 B.Th.U's.			*Producer Gas, per 450,000 B.Th U's.*	
		Pence.		Pence
Coal and equivalent		30.90	Coal and equivalent	12.05
Purification		0.32	Purification and water	0.63
Salaries		1.04	Salaries	—
Wages		3.06	Wages	1.89
Maintenance		10.66	Maintenance	1.20
Collection		0.52	Collection	—
Stationery, etc.		0.50	Stationery, etc.	—
Miscellaneous		0.38	Miscellaneous	0.24
Rates and taxes		1.25	Rates and taxes	—
Capital charges		6.04	Capital charges	2.40
			Power	2.00
Reductions :—		4/6.67		
Sale of Coke	11.73			
Sale of Tar	2.26			
Sale of NH_3	2.34			
Stoves, etc.	0.35			
Miscellaneous	0.45			
		1/5.13		
		3/1.54	Total	1/8.41
37.54 pence.			20.41 pence.	

plant would be over 26,000,000, and, therefore, if gas undertakings wish to compete with suction gas they have to supply a low-grade gas made by the complete destructive distillation of the coal. This low-grade gas, known as suction gas, is not novel as applied to industry. Thousands of plants are in daily use in this country for the driving of gas engines, and it has given the same satisfaction as town's gas at one-third the running cost. In the same way, as B.Th.U.s can be applied to the driving of internal combustion engines so they can be applied to industrial heating. Obviously one B.Th.U. is as good as another, and that whatever town's gas can do, so can suction gas.

Heat Value of Fuels.

Fig. 1 shows the comparative number of heat units, from different fuels, that can be purchased for a given sum of money. The size of each illustration is in direct proportion to the heat units available, so that it can be seen at a glance that petrol is the most expensive, and gas coke the most economical, method of producing heat units. It will be noticed that although oil contains 4.5 times the heat units of petrol, per unit cost, nevertheless it only contains about one-third the heat units of gas coke.

Combustion of Solid Fuel.

The process of the direct burning of coal and similar solid fuels may be divided into three stages, the first being the driving off of volatile matter in gaseous forms which takes place at a comparatively low temperature and independent of any air supply. The second stage is that of the residue—which is mostly carbon—burning with what is called primary air. The third stage takes place when the volatile gases, already being given off, combine with the oxygen of what is called secondary air, and burn as a flame on the top of the fire. Combustion of these gases only takes place at a relatively high temperature. Hence. if the top of the fire is cold combustion will not take place, in which case most of the gases from this volatile matter will pass into the flue in an unburnt condition.

Disadvantages of Solid Fuel.—With all forms of solid fuel, whether employed for direct or indirect firing, the fuel has to be handled, generally by hand, to the furnace, and the clinkers and ashes have to be removed at frequent intervals, which work involves both time and labour. In one engineering firm in the Leeds district the coal and ash wheeling alone amounts to not less than £2,000 per annum.

The temperature of the solid-fuel fire is continually fluctuating, and the opening of the furnace door and feeding with fresh fuel will always cause a drop in the temperature, and when the fire is completely burnt through the heat given off is then in excess of that required.

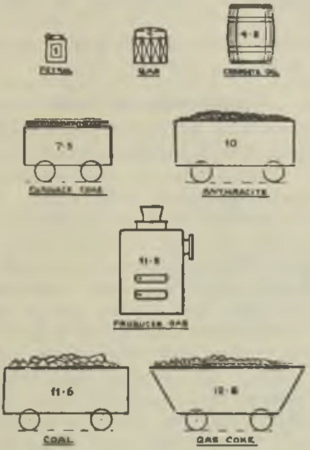


Fig. 1.—The Purchasing Power of Money Expressed in Heat Units of Fuel.

Pulverised Coal.

Many of the drawbacks of solid fuel can be eliminated by the use of pulverised fuel. With this system the coal is first crushed, then dried, and conveyed to the pulveriser, where it is powdered to a high degree of fineness. It is fed to the furnace through suitable piping by means of compressed air. Very high efficiencies and uniform temperatures are obtained with this system of firing, and low-grade fuels with a high per cent. of ash can be used. Although pulverised fuel has many advantages, it can only be used in very large works, as otherwise the initial outlay on plant is very heavy, and the saving effected, after allowing for all on cost charges, would not be a business proposition.

Gaseous Firing.

Fig. 2 shows the distribution of B.Th.U.s after distillation of coal, according to modern works practice.

The calorific value of the gas is approximately 450 to 500 B.Th.U.s per cub. ft.

Classification of Gases.

Fig. 3 shows the different gases which may be produced from the bituminous coal or anthracite. The direct distillation of coal produces coal or coke-oven gases together with coke. When coke or anthracite is used in a gas-producer plant, and steam is passed through the fuel bed, water gas is produced. When, however, air and steam are passed through the fuel bed alternatively, in opposite directions, semi-water gas is formed. By passing air and steam through the fuel bed in one direction only the gas known as producer, or suction, is made. In certain metallurgical operations air comes into contact with incandescent coke, and this produces what is known as blast furnace gas. It will be seen from Fig. 3 that the calorific values of these gases vary from 500 to 100 B.Th.U.s per cub. ft., but after the requisite amount of air has been added the calorific value of the mixtures varies from 83 to 70 B.Th.U.s per cub. ft. apart from blast-furnace gas. Although there is a considerable difference between the calorific values of the original gases, yet after each gas has received its correct volume of air to ensure complete combustion the final mixtures contain almost the same number of B.Th.U.s.

Generation of Producer Gas.

The first stage for the production of producer gas takes place in the combustion zone of the generator where the carbon of the coke combines with the oxygen of the incoming air and forms carbonic acid gas, which passing through the central portion of the fire, called the reducing zone, splits up into carbon monoxide and oxygen. The latter combines with a further quantity of carbon, and again forms carbon monoxide, whilst the volatile gases are driven off in the distillation zone. When, however, there is a presence of water in the form of steam, the oxygen of the water combines with a further quantity of carbon again forming carbon monoxide, releasing hydrogen which is consequently also present in the gas. The nitrogen of the atmosphere passes through the fire unaltered.

No separate boiler is required for modern plants, as the steam required for passing through the fuel bed can be generated by the heat of the gas made inside the generator. This arrangement increases the efficiency of the plant, besides making the generator a self-contained unit. The gases after leaving the generator pass through a scrubber, in order to remove the foreign matter present. A scrubber generally consists of a vertical bed of coke through which water is sprayed, and the irregular path of the gas through this bed causes particles of tar to be deposited, the latter being washed away by the water. When additional cleansing is required the gas passes through a purifier comprising a number of trays filled with iron oxide or other suitable material.

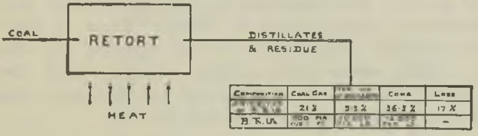


Fig. 2.—Distribution of B.Th.U.s after Distillation of Coal.

Advantages of Gaseous Firing.

Gaseous firing possesses distinct characteristics of its own, and in recent years has become increasingly popular for heating purposes. It is both reliable and labour-saving, besides ensuring more uniform quality than can be obtained by the use of solid fuel. Additionally, it is clean to use, can be distributed to any desired point, and is undoubtedly the cheapest of all fuels in this country. Moreover, it can readily be used for internal heating, which is often a very desirable feature as against external heating, which is necessary with solid fuel. When furnace work is required, the operator has merely to turn on the supply and light up. Practically no further attention is required. and the temperature can be regulated to within close limits with the assurance that it will remain constant. Producer gas is most economical, as it can be generated at approximately one-third of the cost of coal gas after allowing for capital outlay, maintenance and depreciation.

Applications of Producer Gas in Works.—There is, indeed, an enormous scope for gaseous firing. not merely for engineering purposes, but for all industrial applications of heat. Thus it can be conveniently and economically applied to chemical, glass, salt, wire, sugar, textile and metal-smelting works, besides being particularly adaptable for breweries and bakeries.

Perfect Combustion.

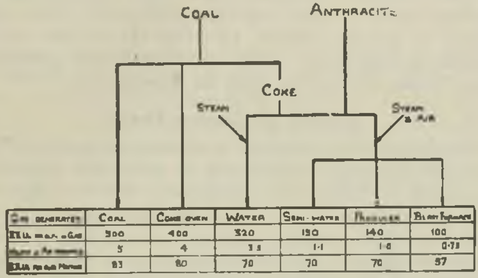
Perfect combustion only takes place when the gas receives a full and sufficient supply of air, and under these circumstances it does not matter whether the flame is white, straw or blue, for in each case the whole of the B.Th.U.s contained in the gas will be converted into heat. It therefore follows that if each type of flame produces the same amount of heat, then the heat of the white flame, being spread over a greater area, is not so intense as the heat of the blue flame, which is shorter and therefore more concentrated.

A low intensity flame cannot be used for high temperature heating, hence in cases where intense local heat is required, the blue or colourless flame should always be used. Providing, however, that the whole of the B.Th.U.s contained in the gas are being utilised for doing useful work, it does not matter what kind of a flame is employed.

Perfect combustion depends upon the correct mixing of the gas and air. When a white flame is employed the correct adjustment can be easily determined by its luminosity, for a flame which is producing its maximum amount of light is having all its B.Th.U.s completely burnt. When a blue or colourless flame is used, the proportions of gas and air should be adjusted so that the small adjacent portions of brickwork or other refractory material give out the greatest possible amount of luminosity. When this obtains, the maximum amount of heat is being produced.

Imperfect Combustion.

Complete combustion cannot take place without heat. If, for example, a coil of wire be passed over a candle flame the latter will be immediately extinguished. If the gases, in gaseous firing, impinge upon a cold surface before proper combustion has taken place, combustion will be arrested and B.Th.U.s will be wasted. This can be exemplified by placing a kettle with a clean metallic bottom, filled with cold water, over a Bunsen flame. At the commencement, when the water is cold, the gas flame stretches beyond the bottom and up the sides of the kettle. This is due to the fact that there is a relatively cold zone of unburnt gases underneath. This zone of unburnt gases is a poor conductor of heat, and prevents a rapid increase in temperature. When, however, the bottom of the kettle has warmed up improved combustion will result, and this can be observed by watching the contraction of the flame. It will be readily appreciated that a cold surface in the vicinity of combustion produces waste



Gas generated	Coal	Coke oven	Water	Semi-water	Producer	Blast furnace
B.Th.U. [illegible]	500	400	320	150	140	100
[illegible]	5	4	3·5	1·1	1·0	0·75
B.Th.U. [illegible]	83	80	70	70	70	57

FIG. 3.—CLASSIFICATION AND THERMAL VALUES OF GASES.

which might lead to a serious loss if permitted on a large scale. In modern boiler construction provision is made for a large flame area, so that the relatively cold plates of the boiler will not interfere with combustion.

In the reverberatory furnace a long, white flame is often used. But it has been shown that when the air is added outside the flame the latter extends a considerable length, and, owing to the volume occupied by it, has little intensity. Hence when it comes in contact with a cold body the combustion of its hydrocarbons will be arrested and free carbon deposited. Thus, upon lighting up the furnace carbon is deposited upon the cold walls. The same takes place when cold material is put in the furnace, and this deposition of carbon is a direct loss of B.Th.U.s. This tendency of a white flame to drop its carbon is disadvantageous, and, when circumstances permit, a blue flame should be used in preference.

Systems of Gaseous Firing.

There are four distinct methods of applying gas and air when gaseous firing is used for industrial purposes. These are generally known as: (1) Low-pressure gas; (2) high-pressure gas; (3) gas and air blast; (4) gas and air mixture.

Low-Pressure Gas.—Ordinary coal gas is supplied at low pressure, and in this system it is used exactly as it leaves the town's mains. This, in many cases, is very uneconomical owing to the primary air having to be induced into the burner. The amount of induced air naturally depends upon the pressure of the gas, and, consequently, varies with it. Coal gas requires, approximately, five times its own volume of air, so that, unless the pressure be reasonably good, an insufficient amount is induced. The air thus added, however, does not intimately mix with the gas, so that, in order to provide sufficient oxygen for complete combustion, a considerable excess of air is required, the heating of which is a source of loss. Constant adjustment of both gas and air is required, consequently the control of the furnace is entirely in the hands of the operator. Economy with this system is therefore very difficult to obtain.

High - Pressure Gas. — High - pressure gas is another system which is sometimes employed, but this does not give satisfactory results. The mains and internal fittings have to withstand this excessive pressure (which is generally 3 to 12 lbs. to the sq. in.), and the amount of leakage taking place is a continual source of trouble. The cutting action of the gas, passing at a high velocity through a relatively small nipple, causes the latter to enlarge, thus upsetting the correct adjustment. In the high-pressure system, the nipple has to be renewed from time to time to keep the consumption approximately constant.

The difference in the density of the two gases, *id est*, air being 1, gas being 0.5, makes it impossible for them properly to diffuse or mix together in the limited space between the nipple and the burner nozzle, consequently imperfect combustion is the result. Could the stream of gas and air entering the furnace be seen, it would be found to consist of layers of gas and air alternately. This stratification cannot be avoided in the high-pressure system, with the result that a considerable portion of the gas passes through the combustion space in an unburnt condition, with subsequent combustion usually taking place in the flues.

Gas and Air Blast.—Another system is that of separate gas and air under pressure. Whilst this system gives a greater intensity of heat the control is, like the foregoing, also in the hands of the operator. The gas and air have little opportunity of intimately intermixing, and the gas consumption cannot even be approximately guaranteed, as if both gas and air cocks are not properly adjusted the consumption will be out of all proportion to the work done. The gas and air cocks require constant adjustment, as the town's pressure or the demand in other parts of the works affects each individual furnace.

Gas and Air Mixture.—The fourth system is that of intimately mixing together a definite quantity of gas and air in their correct theoretical proportions in accordance with the calorific value of the gas. Thus a definite mixture is always maintained even under fluctuating conditions of gas pressure and load on the service mains. The operator cannot change the gas and air proportions, which, when once set for perfect combustion, always remain fixed. It is impossible to get excess of either gas or air, hence waste fuel and oxidisation are avoided. The avoidance of excess gas or air is, however, practically impossible with the three systems already referred to. The system of definitely mixing gas and air is the only practical solution to the problem of gaseous firing.

The advantages claimed for the system are:—(1) The gas and air, once set to give a predetermined mixture and pressure, is automatically kept constant under all conditions; (2) it is independent of the town's pressure; (3) it is independent of the operator; (4) it gives greater ease of manipulation, together with a large saving in gas consumption; (5) it gives perfect combustion at all times; (6) uniform temperature is ensured.

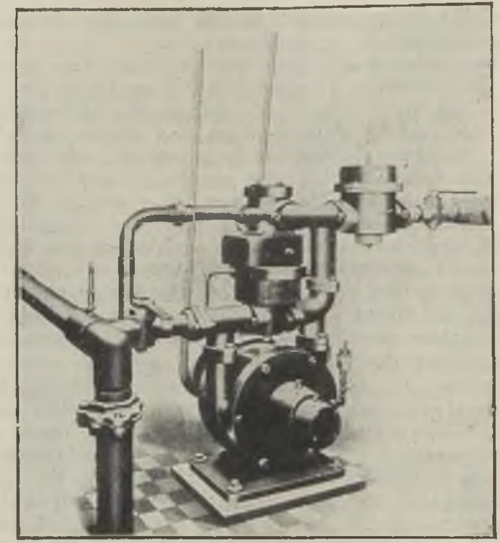


FIG. 4.—GAS AND AIR INCORPORATOR.

Gas and Air Incorporator.

Fig. 4 shows a special type of gas and air incorporator made in accordance with the Docking patents. Gas and air enter the (Fig. 5) valve A by means of separate passages, after which they pass along the passage B and so enter the mixing chamber C. Due to the action of the rotary fan D both gas and air are intimately mixed together, and are then discharged, under a slight pressure, through the delivery port E to the service mains.

In order to secure a mixture of gas and air at a predetermined proportion and pressure, it is necessary to ensure that gas and air enter the incorporator on equal terms. To attain this, air is taken direct from the atmosphere, while the pressure of the gas is reduced to neutral by passing it through a governing device.

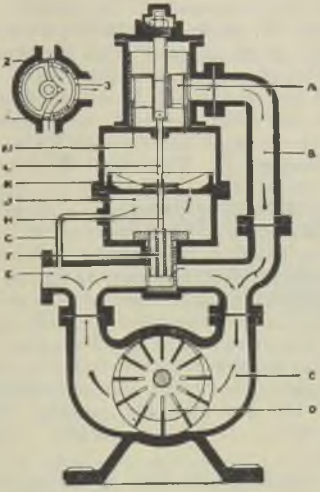


Fig. 5.—Section of Gas and Air Incorporator.

Having reduced the gas to the same pressure as the incoming air, both are now allowed to pass into the mixing valve located at the top of the machine. Fig. 5 also shows a sectional plan of the mixing valve, and it will be seen that this consists of inner and outer sleeves, in which are cut three ports, 1, 2, and 3 for gas, air and mixture respectively. The suction set up by the machine induces gas and air through their respective ports, which are cut in such a manner as to allow of modification of their proportions by rotating the inner sleeve, according to the calorific value of the gas. This is indicated by a small test-burner fitted on the mixture outlet pipe. Ordinarily this adjustment is made by hand, but by fitting special temperature-control devices this regulation can be made automatic. The pressure at which the mixture is delivered is determined by the relief valve F, which is attached to diaphragm K by means of the spindle H. When the machine is started up the pressure rises in the service pipes E, and this pressure is communicated to the chamber J (by means of the pipe G), so that the diaphragm K is raised. This movement lifts the relief valve F, and allows the surplus mixture to pass back to the lower end to the delivery passage B. The end of the spindle H projects beyond the diaphragm K, and connects with the spindle L, upon which is mounted a mixing valve sleeve M. This ensures that each movement of the diaphragm actuating the relief valve is also transferred to the mixing valve, thus automatically covering and uncovering all the ports in that valve simultaneously. It will be seen that these two movements are synchronised in such a manner that as the pressure tends to rise, in the service mains, above its normal value, so the volume of the gas and air passing through the mixing valve is automatically reduced to correspond.

When a cock is opened, allowing mixture to leave the service pipe, the momentary drop in pressure allows the diaphragm to fall, partly closing the relief valve, and partly opening the mixing valve. The amount which these valves are opened and closed depends on the amount of mixture taken from the service pipe, up to the full capacity of the machine.

The machine is constructed so that it is impossible to get a mixture weaker than three volumes of coal gas to two volumes of air. Since coal gas is not explosive when mixed with air in this proportion, the mixture delivered is perfectly safe. When lower-grade gases are used the machine is adjusted by the makers to ensure a non-explosive mixture, thus rendering the system absolutely fool-proof in the hand of the most careless operator.

This system is now in use for all classes of industrial heating: Heat treatment of metals, drying of cores, tube manufacture, brazing, and similar work. The same incorporator will supply a mixture which is suitable for high-speed steel furnaces, carbonising and re-heating furnaces, lead pots and cosletising baths, temperatures being obtained from 1,500 to 100 deg. C.

Furnace Designs.

The supply of fuel in gaseous firing is under such perfect control that temperatures can be maintained by the expenditure of just the amount of B.Th.U.s required to perform the requisite heating. In the case of solid-fuel furnaces, however, it is necessary to burn a much larger amount of fuel than is required for heating the work and furnace, the surplus going to waste merely in order to secure uniformity of temperature. The feeding of the fire with fresh fuel must of necessity reduce the temperature of the furnace, hence the need for providing for the maintenance of a fire so hot that the drop in temperature resulting from stoking will not bring the furnace below the required temperature. This method is wasteful, besides demanding constant and watchful attention on the part of the operator in order to maintain a reasonably constant temperature. The work to be heated must be kept far enough from the fires in order to avoid damage from the

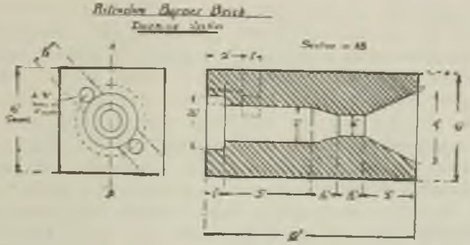


FIG. 6.—REFRACTORY BURNER BRICK DOCKING SYSTEM.

products of combustion. This consideration demands, in many cases, complete isolation of the work in muffles or chambers. This system is extravagant, because the whole of the brickwork containing the fire, together with the brickwork of muffles and flues, must be raised to a considerably higher temperature than the work demands before the work itself can reach its required temperature. It is quite true that many gas-fired furnaces are built on these lines, in order to exclude the products of combustion, although in these cases the gas flame is allowed to impinge directly on to the walls of the muffles, which is a distinct advantage over the solid fuel fire. It should be noted that with such work as re-heating, annealing of brass, etc., carried out in a chamber in which open gas flames are burning, come to no harm from products of combustion when the ovens are operated under a system which ensures perfect combustion. The evils which usually accrue from an excess of oxygen cannot exist if the gas is supplied mixed with exactly the correct amount of oxygen needed for combustion and no more. The products of combustion are carbon dioxide and water, and if the gas used is reasonably clean neither of these can do harm to steel or brass. In any case, they are less harmful than oxygen, which is always present in a muffle chamber.

In all furnaces the heating of the brickwork is a considerable source of loss. It should be borne in mind that every cubic foot of brickwork which has to be raised to 1,000 deg. C. requires 0.42 pence worth of coal gas (at 4s. 2d. per 1,000 cub. ft.). This obviously points to the necessity of keeping the heating chamber as small as possible, consistent with the size of the work to be heated.

Having found that metal burners quickly wear away, thus necessitating pulling down of the firebrick lining at frequent intervals, a carborundum burner has been designed, which obviates this necessity. Carborundum will stand a temperature of 2,200 deg. C., and has a tensile strength four times that of firebrick, so that this burner will outlast the lives of several firebrick linings. This is illustrated in Fig. 6.

Table 2 shows the manner in which the heat units are distributed in a melting furnace, using gas and electricity respectively, and compares their costs. It will be seen that out of a total of 1,575,000 B.Th.U.s, 842,000 are used for heating up the brickwork, 32,000 are lost through radiation, whilst the waste gases carry away 265,000 B.Th.U.s. Thus the actual heating of the metal only requires 26.7 of the whole, so that in order to increase the efficiency of this plant the B.Th.U.s required for heating the brickwork must be considerably reduced, whilst the waste gases should be utilised. The former implies that better refractories are required. Experiments are being made in this direction by making special refractory bricks of a porous nature, so as to reduce their heat-conducting properties, whilst they are faced with a carborundum mixture so as to present a hard surface.

TABLE 2.—*Showing Comparison of Heating Cost Using Gas and Electricity.*

	Gas. B.Th.Us	Electricity. B.Th.Us.
Heating Metal	380,000	380,000
Latent Heat	40,000	40,000
Radiation Losses	32,000	—
Heating Pot	16,000	—
Flue Gases	265,000	—
Heating Brickwork ...	842,000	842,000
	1,575,000	1,262,000

The use of electric furnace (assuming no radiation losses) would save 213,000 B.Th.Us.

COST.

1,575,000 B.Th.Us. in gas cost 14s. (with gas at 4s. per 1,000 cub. ft.)

1,262,000 B.Th.Us. in electricity cost 370 kw. at 1½d. per kw. = 46s. 3d.

From this will be seen that on this type of furnace electrical energy must be procurable at .455d. per kw. if it is to be used as a substitute for town's gas.

Pre-heating.

Considerable economy may be effected by preheating the work, which may be carried out in a separate chamber heated by waste gases, or in a salt bath (if oxidisation is to be avoided). In some furnaces arrangements are made to pre-heat the incoming air by passing it through a previously heated passage. This system results in a gradually rising temperature, because as the air gets hotter so will the furnace temperature increase. If this arrangement is to work successfully it must be provided with some means of temperature control, and herein lies a serious

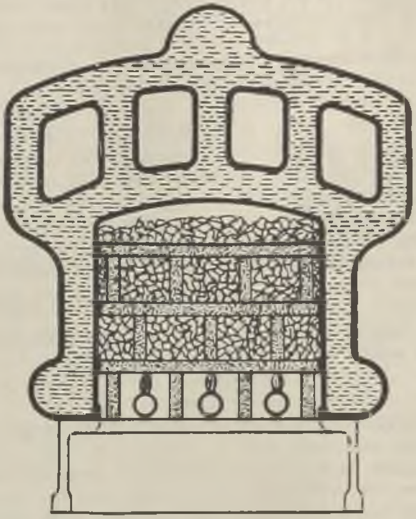


Fig. 7.—Section of a Boiler Adapted for Gaseous Firing.

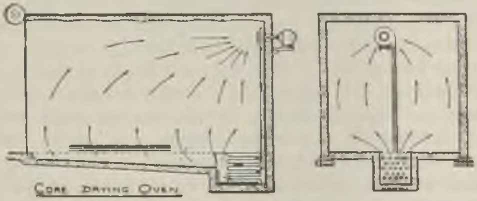


Fig. 8.—Diagram of Core Oven Heated by Gaseous Firing.

difficulty when operating with separate gas and air owing to their varying densities. Gas and air mixture can, however, be satisfactorily preheated, as thermostatic control modifies the supply of both at the same time, and, since both gas and air are delivered by the incorporator correctly proportioned, it does not matter to what temperature they are raised, providing this is below the temperature of combustion, the proportions, in all cases, remaining constant and accurate.

Fig. 7 illustrates the application of gaseous firing to an ordinary section-boiler for the heating of works and offices. It will be seen that the bed of fuel has been replaced by layers of firebrick. A series of gas burners provided with nickel gauze nozzles are placed underneath. By this system of firing the temperature can be easily regulated, and practically no labour is required.

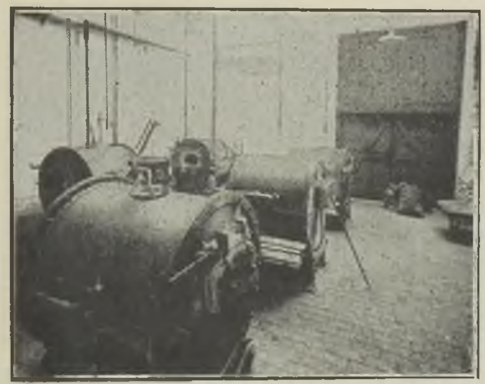


FIG. 9.—GAS-FIRED MELTING FURNACES.

Heated air is frequently used for drying purposes, the air being made to pass round a series of steam-heated tubes, after which it passes on to the work which it is required to dry. The use of steam for this purpose is most economical, owing to the condensation and other heat losses between the boiler and the apparatus. When gaseous firing is used, heat losses are practically eliminated, as not only can the heating chamber be placed inside the drying machine, but even the heat of the products of combustion can be utilised.

In engineering works during the afternoon large coke fires are made up for heating the core ovens, after which the cores are run in, and the doors sealed. The fires are usually kept in throughout the night, and the cores withdrawn the following morning. This method is both crude and wasteful. In the first place, the fuel is not burnt economically, practically no secondary air being available. Furthermore, the moisture in the cores is retained in the oven, whilst the air, instead of being in circulation, is practically stationary.

FIG. 10.—GAS-FIRED REVERBERATORY MELTING FURNACE.

Owing to lack of circulation the water vapour, generated by the heat, remains on the surface of the cores. This vapour is, however, a bad conductor of heat, thereby hindering the drying process. It is well known that wet clothes, hanging out in a good wind, will dry rapidly, even if the temperature of the atmosphere is low. In the same way, a little warm air on the move is far more effective than a large quantity of stationary air, even though the latter be at a high temperature.

Fig. 8 shows a core oven heated by gaseous firing. A motor-driven fan draws air from the oven and forces it down a vertical pipe and so through the tubes of the gas furnace. It is then re-distributed throughout the core oven by means of a central duct, and is thus kept in constant circulation. It will be seen that, apart from radiation losses, the whole of the heat put into the chamber remains inside the oven. The author recently investigated some large core ovens of the old type, and found that the thermal efficiency was under 5 per cent. The thermal efficiency of the arrangement shown in Fig. 8 is, however, within the neighbourhood of 55 per cent.

The type of furnace recommended for the melting of metals, such as nickel alloys, malleable iron, gunmetal, aluminium, and white-metal alloys, varies with the normal quantity required per heat. Thus for small weights, say 80 to 100 lbs., a crucible type of pot furnace is recommended which requires 3 to 4 cub. ft. of coal gas per 1 lb. of gunmetal melted at a cost of 5d. to 6d. per 100 lbs. When, however, the heats average about 300 lbs. and upwards, a reverberatory type is recommended which requires 2 to 2½ cub. ft. of coal gas per 1 lb. of gunmetal melted at a cost of 3d. to 4d. per 100 lbs. Figs. 9 and 10 show respectively a battery of gas-fired melting furnaces and a gas-fired reverberatory furnace. the latter being the most economical of

FIG. 11.—VIEW OF A BATTERY OF CARBURISING AND NORMALISING FURNACES.

all systems for metal melting, especially when the heating is effected by producer gas. With the former type heat units are required to heat up the pot which, unfortunately, is a poor conductor of heat. Furthermore, the average life of a pot is only about 36 heats. With the reverberatory type the flame impinges directly on to the metal, whilst radiant heat is reflected from the walls of the furnace. In addition, the reverberatory type can be bottom tapped, so that only clean metal comes out, the scum and oxide being left behind. With crucible melting there is always a certain amount of trouble with the oxide, owing to its being poured from the top.

FIG. 12.—COAL-FIRING CARBURISING FURNACES.

Fig. 11 shows a battery of carburising and normalising furnaces working on the gas- and air-mixing system.

In contrast with the above, Fig. 12 shows that for the firing of six furnaces no less than four men are seen handling the fuel.

DISCUSSION.

THE BRANCH-PRESIDENT (Mr. E. Carey Hill) said the author had compared the use of gas for metal melting in four or five different methods. Personally, he had had experience in high-pressure gas melting, and in what was more or less the approved method of gas and air mixing. He could tell them that the method of mixing the gas and air in an incorporator before passing into the furnace resulted in a saving of 7,000 to 8,000 cub. ft. per ton of aluminium melted, as compared with the high-pressure gas, in which the gas is supplied under pressure of 12 lbs. per sq. in. and injects its own air. That was a corroboration of one point. He hoped that they would have had a little more illustration of the saving of waste gases for the heating of core stoves and ovens. The lecturer had outlined a method of heating a core oven, but an efficient method of utilising the waste gas from a suction gas plant used for metal melting—for instance, for the drying of cores—would be welcome, instead of having to use the fresh suction gas for that purpose.

Tests on Morgan Furnaces.

Mr. E. Player remarked that the use of gas in the foundry was by no means new. During the war his firm had an opportunity of making some very interesting tests in metal melting. A battery of three Morgan tilting furnaces, 600 lbs. capacity, employed on melting brass swarf, were tested for a period of six months' continuous service, accurate records being taken in respect of fuel consumed, labour involved, metal losses and maintenance and repairs, linings, crucibles, etc. One of the furnaces used coke fuel and one town's gas, using the ordinary Keith type burner with air supplied at 3 lbs. per sq in. pressure. On a short run the coke-fired furnace appeared to be the most economical, this being due to the fact that only the fuel cost and the metal losses were ascertainable. Over the period of not less than a week the oil furnace appeared to be the most economical, owing to lower labour costs in running the furnace. Over a period of a month or more, however, the gas furnace proved to be easily the best, the saving occurring chiefly in the largely extended life of crucible, lining, and burners, together with very low labour costs and low metal losses, these economies counteracting the rather higher fuel bill.

It is interesting to note that it was necessary to carry out protracted observation in order to ascertain definitely the best all-round type of furnace, so far as regards total costs.

Core Ovens.

All their core ovens, continued Mr. Player, had been fired for some years with town's gas at the ordinary town pressure with a separate air supply, but that they had now changed over to a gas and air mixture supply by means of mixing the gases in correct proportions for perfect combustion at the burners.

In regard to core drying, this method had been adopted not so much on account of the cost of fuel as for the reason that very accurate temperature control is possible, a factor of the highest importance in drying such delicate cores as water-jacket cores for motor cylinders. He had yet to see a coke-fired oven where sufficiently accurate temperature control could be obtained. They had found by converting the coke-fired ovens to gas-fired that the loss in burnt or badly dried cores had been diminished to a negligible amount, owing to the fact that a few tests enabled maximum and minimum temperatures and times to be established, which figures were easily worked to by a man in charge.

Utilising Waste Heat.

He agreed that the utilising of waste heat from furnaces was a serious one, particularly when melting metal, as something like 50 per cent. of the heat generated was wasted in the form of hot gases. In this connection no doubt could possibly be entertained as to the value of accurately mixing the gas and air before supplying it to the furnace.

Before this system was adopted at their works the furnaceman dealt with the proportion of gas and air as he chose, and it was a common thing on going through the foundries to observe large flames issuing from the furnaces, representing excess gas which was going to waste, the furnaceman himself being quite unconcerned, as he did not have to pay for fuel. With the gas and air mixture the adjustment of the burner is taken out of the operator's control, as he can only open or close the cock, and consequently the only waste that can arise through carelessness on the part of the furnaceman occurs when the burners are left on after the metal has been taken out of the crucible.

Mr. Player remarked that a Belfast firm had put on the market a core-drying oven in which the hot products of combustion were circulated in a manner similar to that illustrated by Mr. Docking, with this difference, that whilst they brought the hot air from the heating furnace, together with the products of combustion, and circulated these in the stove, they also had a by-pass on the top of the stove which could be adjusted to allow of the escape of more or less of the hot gases, such escape taking off the steam or hot gases removed from the cores. This appeared to him to be necessary, as unless there is a definite out-flow from the stove, the cores are liable to be merely steamed instead of dried.

Pre-mixing is Advantageous.

Mr. F. H. Hurren, A.I.C., said he was pleased to hear the eulogy that Mr. Docking gave to the pre-mixed system, as in his works they had been using that particular system for just over seven years. From experience it could be said that it was admirable in every respect. They had used the pre-mixed system for melting aluminium, gun-metal, and core drying, and even used it for drying shanks and lighting up the cupola. It was found that this was a considerable economy over various other systems that have been tried. With regard to the burning of gas and injecting the air under pressure, it was found on a test made some years ago that the pre-mixed system gave a saving of approximately 75 per cent. on the gas consumption for the same amount of work done. The gas firing of core stoves was started about four years ago, and it was found that there was not only a great saving in fuel consumption compared with coke, but there was also a considerable saving in labour charges. The labour charges on gas-fired core stoves were practically nil. Personally he was not aware that there was any controversy at the present time as to the respective efficiencies of pit and barrel furnaces; it was quite definitely settled that the latter were the better. The crucible costs, now very low, due to the use of barrel furnaces, was previously something like £80 to £90 per month.

The Lecturer's Reply.

Mr. Docking, in his reply, observed that there was only one point to answer, that was the question raised by Mr. Carey Hill of the drying of cores by waste heat from the furnace. No doubt there was a great deal to be said in favour of this proposition, but, unfortunately, most core ovens were a long way from the furnaces, and to carry the spent products a long distance when they were at a comparatively initial low temperature would be useless, as by the time they had conveyed these waste gases along the necessary flues to the core ovens the heat would be practically absorbed. Moreover, in using waste heat for core ovens by conducting it direct into the oven would make it almost impossible for the men to work in the ovens with any degree of comfort. If the core ovens were situated near to the furnaces, he suggested running the waste gases into a tubular furnace, where the exterior of the tubes could be heated, and the air made to pass by means of a fan or natural draught through the inside of the tubes to the core ovens. By this method no spent products could enter the ovens and the cores would be dried by a warm current of air passing through the ovens, which he considered would be an ideal method, moreover by the adoption of this method perfect regulation of temperature could be assured by the use of dampers.

This undoubtedly was a good means of utilising the spent products from furnaces, but he believed the day was not far distant when furnaces would be so designed that almost every B.T.U. would be put to useful work in the furnace, that is, by using good insulating material to prevent radiation losses and using the spent gases for the pre-heating of the metal and the pre-heating of the gas and air before entering the furnace. Many furnaces were designed to do this, but he was sorry to say the design left much to be desired.

London Branch.

METAL MOULDS IN THE FOUNDRY.*

By S. A. E. Wells.†

In a general sense the casting of metals in the foundry falls under two main headings:—

(1) Methods in which sand is employed for making moulds and the moulds are unavoidably destroyed in removing the casting.

(2) Methods where metal moulds are employed and used time after time. The use of metal moulds may be divided into three classes:—

(a) That in which the metal flows into the mould solely under its own weight.

(b) Where additional externally applied pressure is used to force the metal into the mould.

(c) When the mould consists in part only of metal.

Gravity Castings.

Included in the first class are moulds which are used for the production of ingots, strips, billets, ets., for subsequent mechanical treatment in the manufacture of wrought metals and alloys.

These moulds vary considerably in size and shape and are mostly made of cast-iron, one possessing a close fine grain being preferred.

In making cast-iron moulds for producing repetition castings as bases for the manufacture of wrought material, a number of factors must be considered. The mould must be of a very convenient form, capable of being opened and closed in a minimum time with low labour charges. It must also be constructed of such a size that the abstraction of heat is regulated to produce a uniform grain ingot.

Moulds are made in sections, usually halves, and are cast in sand to the shape desired. When

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* A Lecture read before a joint meeting of the London Branch of the Institution of British Foundrymen and the Institute of Metals on December 7, 1921.

† Mr. Wells is connected with the National Physical Laboratory.

casting these sections allowance is made so that they can be readily machined to fit one another, to permit of easy parting to release the solid casting.

The inside surfaces which are in contact with the molten metal are machined also, and "worked up" by means of emery cloth, thus providing a smooth surface which will be reproduced upon the finished ingot. The sections of the mould are finally clamped together, the most common method being by means of rings and wedges, a quick and very effective method.

The influence of the mould upon the metal poured into it should be considered in order to determine some standard of relationship between them.

Molten metal poured into a small cast-iron mould is cooled very rapidly, resulting in a fine uniform grained metal suitable for successful mechanical working. However, with increasing size of ingots the problem of producing a uniform grain becomes a more difficult matter.

In a large ingot of metal cooled from the molten to the solid state, when poured rapidly into a cold metal mould, the immediate effect of contact with the walls of the mould will be to "chill off" the surface layers of the ingots, following which, solidification works inwards from the walls of the mould, the centre being the last to solidify.

The centre remaining molten considerably longer than the rest is thus called upon to feed the remainder of the ingot, until liquid contraction ceases, therefore the centre will be seen to contract in the form of a rough inverted cone. Beneath this cone further contraction has probably occurred, and a chain of cavities formed which may extend a considerable way down into the ingot.

These are known as contraction cavities, and will be revealed upon suitably splitting the ingot vertically through the centre.

If a cross section of the ingot is taken somewhere about the middle of its length, and etched with a suitable reagent to develop the macrostructure, it will be found that the grain so revealed will vary considerably.

The layers in contact with the walls of the mould having solidified rapidly will be found to consist of a fine close grain, while the remainder will gradually increase in grain size the nearer the centre of the ingot its location.

It will now be understood that the centre of the ingot consists of a more or less coarse-grained core, the object must be the elimination of this core as far as possible by controlling the various factors affecting the rate of cooling. These may be conveniently classified as follows:—

(a) The pouring temperature of the metal.
(b) The rate of pouring the metal.
(c) The abstraction of heat by the mould.

Assuming the pouring temperature of the metal to be that generally accepted as the standard for the metal concerned and pass on to consider the rate of pouring; the rate of pouring will vary with the class of metal and type of ingot being dealt with, and is best settled by experiment.

Assuming the heat abstraction factor to be already settled, a pouring rate should be ascertained, so that a minimum amount of metal only remains molten in the mould at any time during pouring.

In this way the complete horizontal section of the ingot solidifies practically simultaneously in successive but undefined layers, each layer only being required to feed the one immediately beneath it.

Thus when the mould is completely filled what liquid contraction remains to take place is small and may be readily followed up with molten metal. Piping of the ingot is therefore arrested and minimised.

The rate of pouring is best controlled by tilting the mould forward to an angle of 15 to 45 degs. to the floor, and pouring the metal in a steady continuous stream down the incline formed by the lower surface of the mould, and by employing some mechanical means of concentrating the stream in the mould.

The concentrating of the stream so that its surface is small is most necessary where very slow rates of pouring are employed, in order that the stream may retain its temperature instead of dissipating heat by straggling about the surface of the mould in a comparatively thin film.

Some types of moulds are of such a shape that one may accomplish this by utilising the particular shape of the mould to this end. Small diameter billet moulds and square section moulds are some of these types; in the latter case the angle formed by the junction of two sides is made use of.

The casting of strips is one of those cases where control of the stream is essential and difficult.

At the National Physical Laboratory, for the production of light alloy strips for rolling, a very successful method has been developed for the mechanical control of rate of pouring. It consists of the provision of a small V-shaped groove cut from top to bottom at one side of the strip mould. Fig. 1 illustrates a horizontal section through the mould with a sketch of the V-groove alongside. It must be borne in mind that the resulting V-shaped runner left on the edge of the strip is to be removed before any mechanical working. This runner would be unaffected by the early working and remain in the weak cast state, and therefore unable to accommodate itself to the extension of the strip as a whole. Serious cracking would result from omitting to remove the runner.

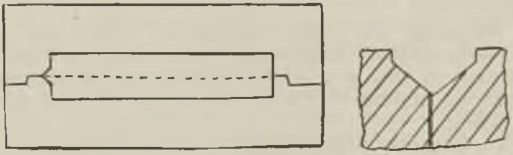

FIG. 1.—TYPE OF MOULD USED AT THE NATIONAL PHYSICAL LABORATORY.

The pourer's responsibility in employing the V-groove consists in keeping a steady stream flowing, which just keeps the groove filled to its maximum. Another most useful function of the V-groove is to assist in eliminating splashing. The size of the groove varies with the rate desired to be employed; for example, quite a small groove would be used for aluminium and its alloys, where the rate of pouring is very slow, and a considerably larger groove for brasses, where a faster rate is required. The abstraction of heat from the ingot by the mould is the next factor to consider.

The depth of chill imparted to the ingot depends upon the wall thickness of the mould and the temperature of the mould. All other factors being constant, the thicker the wall of the mould the greater will be the depth of chilling.

Two ingots of 70/30 brass were poured into hot sand moulds, the bottoms of which consisted of light and heavy chills, ½ in. and 1½ in. thick respectively. The lightly-chilled ingot developed a fairly coarse columnar grain growth, which merges into massive grains, while the heavily-chilled ingot has developed a much finer columnar grain, extending to about double the depth of that of the lightly-chilled ingot before merging into the massive grain growth at the centre. Figs. 2 and 3 show vertical sections of the two ingots, representing a total depth of 2 in. on the actual sections. The walls of the moulds were purposely constructed of sand,

Fig. 2.—Grain Growth as Influenced by Light Chill.

and made hot in order to keep down opposition grain growth.

Ingots demonstrating the effect of mould temperature were made in precisely the same manner to that for the "wall thickness" ingots, also using 70/30 brass. The ingots were cast upon 1½-in. chills, which were used cold, 300 and 500 deg. C. respectively. The effect of this temperature variation has been to diminish the depth of chill as the temperature rises. Figs. 4, 5, and 6 are vertical sections of the ingots, representing a total depth of 2 in. of the actual sections.

Fig. 3.—Grain Growth as Influenced by Heavy Chill.

Mould Temperature Variations.

The effect of mould temperature variation upon the casting of small round billets of an aluminium alloy has been determined. A temperature range extending from 150 to 500 deg. C., rising in steps of 50 deg. C., was investigated. Using a constant pouring temperature—namely, 700 deg. C.—and utilising a slow rate of pouring, employing a stream having a cross-sectional area of approximately 1-10th sq. in., a series of small billets were obtained, which, when suitably sectioned vertically and macro-etched, provided interesting results. Temperatures from 200 to 350 deg. C. appeared to give similar results, all being of a fine grain, with freedom from contraction cavities (Figs. 7 and 8). The billet produced from the mould standing at 150 deg. C. was generally coarser in grain, except for the surface layers in immediate contact with the mould, and had developed a central chain of contraction cavities extending almost to the bottom of the billet. In this case the billet appears to have cooled too rapidly on the surface, leaving a molten centre, which had to contract substantially without a reasonable chance of feeding. The higher temperature moulds, 400-500 deg. C., produced billets having a much coarser grain, increasing in size with rising mould temperature, accompanied by a certain amount of contraction,

FIG. 4.—INFLUENCE OF CHILL TEMPERATURE ON GRAIN GROWTH.

forming cavities. Observation had shown that these billets had taken a considerably longer time to solidify than those mentioned above, so that the coarser grain was anticipated. It will be seen that what thickness of wall and temperature of mould to employ is largely a matter of experiment. So many sizes of ingots and classes of metals are dealt with, each requiring treatment to suit its own special case, that to lay down a definite rule is difficult. It is, however, worth noting that metals of the heavy classes with high melting points require lighter moulds, used at higher temperatures, than those of the light alloy classes when a comparatively heavy mould at a lower temperature is employed.

FIG. 5.—INFLUENCE OF CHILL ON GRAIN GROWTH.

Mould Facings.

The facing of the mould is of the utmost importance, and should be carried out frequently. Dressings of graphite or plumbago and oil, lard oil, Russian tallow, beeswax, and ordinary domestic black-lead all have their special purposes.

Rate of Pouring.

In this class, moulds specially designed and constructed to cope with the extensive production of small parts and fittings of machines and instruments where accuracy and interchangeability are required are included. The various methods used are known as die-casting processes. A suitable die or mould is constructed of steel, and is so made that when the mould is opened the casting will either fall out or can be easily ejected. The design and construction of the dies constitute the vital factor in the successful operation of die-casting processes.

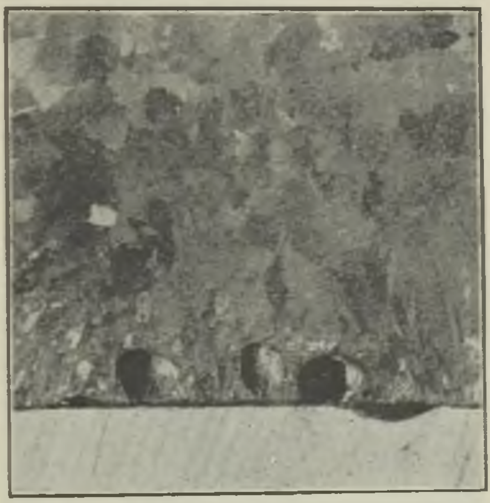

FIG. 6.—INFLUENCE OF CHILL TEMPERATURE ON GRAIN GROWTH ALMOST DESTROYED.

Choice of Dies.

Firstly, the choice of material is of utmost importance, as the number of castings that can be produced from a single set of dies varies with the properties of the steel from which the dies are made. Chrome-vanadium steel is most widely used, and 10,000 castings may be taken as a fair average yield for a properly constructed die of this material.

A die is usually a costly piece of plant to construct, which makes it essential to employ only very skilled labour for their production. A simple die may cost £20 to produce, while there is a demand for very complicated dies costing as much as £100. Dies should consist of as few partings as possible in order to avoid fins.

The chief difficulty in die design is the necessity for quickly removing the finished casting, and the designer is frequently compelled to resort to the use of loose parts and cores for the formation of projecting parts. As far as possible dies should be mechanically operated, so that the dies are opened and cores and castings removed in minimum time with lowest labour charges. Dies must be used at a constant temperature to prevent changes of dimensions being brought about through expansion of the die.

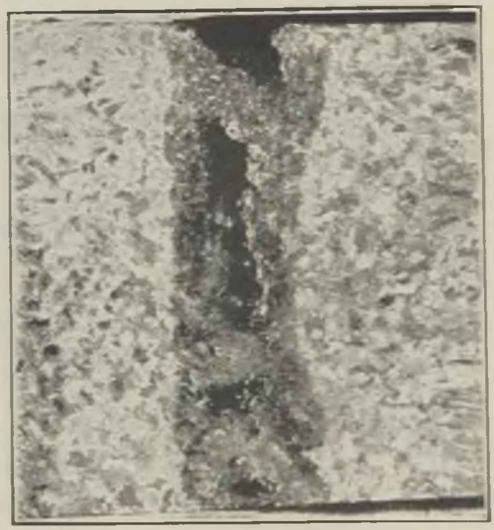

FIG. 7.—CONTRACTION CAVITIES IN CENTRE OF INGOT. VERTICAL SECTION.

Venting.

Careful allowance must be made for shrinkage, and gates and vents carefully planned and located. The gates need only be small, as the pressure employed ensures a rapid filling of the mould. The vents need only be of a very small area owing to the high pressure employed, although some arrangement of venting is essential. The spaces between the die faces, although serving to remove a portion of the trapped air, are insufficient to permit of a complete escape of all the air trapped.

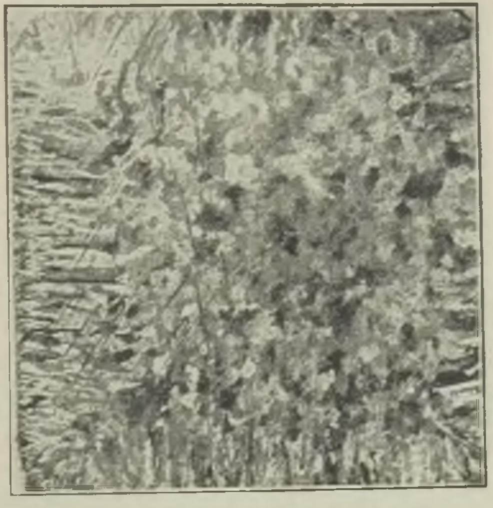

Fig. 8.—Showing Variation in Grain Size from Outside to Centre of Ingot. Vertical Section.

Pressure Castings.

Pressure is applied by a number of means—either by a pump exerting pressure directly upon the metal, by air pressure upon the top of the molten metal, or by a head of molten metal. Casting is usually carried out in a machine, the principle of which is similar in all designs. The metal is melted in a lined metal crucible fixed inside a gas- or oil-heated furnace. Passing down into the molten metal is a tube of refractory material, which is connected at its upper end with a nozzle, through which the metal is forced into the mould. A sprue-cutting device is provided, by means of which the flow of metal is controlled at the nozzle. By raising the cutter the metal is allowed to flow through the nozzle into the mould, and by lowering the cutter, when the mould is filled, the flow of metal is arrested and the casting parted from the gate.

FIG. 9.—FRACTURE OF CHILLED IRON, WHITE IRON GRADUALLY MERGING INTO GREY IRON.

The application of air-pressure upon the surface of the molten metal is found to be the most successful method of forcing the metal into the die mould. The crucible is fitted with an air-tight cover, and connected through a control valve to a source of compressed air. By opening the valve pressure is applied to the molten metal, which, when the sprue-cutter is raised, forces the molten metal through the nozzle into all the interstices of the most complicated dies.

The dies, having been assembled and fixed to the machine over the nozzle, are carefully heated by means of an ordinary Bunsen burner. The temperature of the furnace is so adjusted that the metal is kept at a temperature a little above its melting point. Immediately the mould is filled, and almost without a pause, the die should be opened and the casting removed while still hot. The dies should be cleaned out occasionally and the surfaces dressed, after two or three operations, with beeswax, Russian tallow, or lard oil mixed with plumbago. This facilitates the extraction of the casting and also protects the surface of the mould.

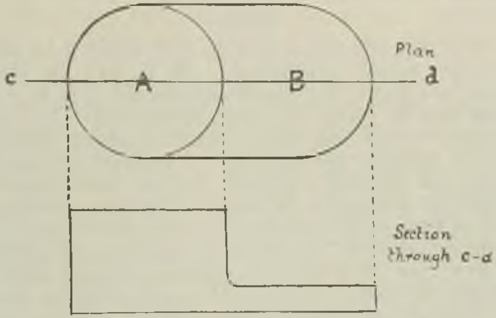

FIG. 10.—DIAGRAM OF CASTING OF UNEQUAL SECTION.

The process in which mechanical pressure is employed directly upon the metal is particularly well suited to large castings of an open character, where freedom from blowholes and other irregularities, combined with a good finish, is desired. In this case the top and bottom of the mould are constructed as two separate units, with the top half containing the cores. The lower half of the mould is preheated to a suitable temperature and just sufficient metal for the finished casting poured in. The top half is then forced down into the bottom, making a metal-tight joint and forcing the metal into the interstices of the mould. This method is applied for the manufacture of crank-cases, gear-boxes, cylinders, etc., for motor-car and aeroplane engines.

Die castings can be produced accurate to within 1-1,000 in., including holes. Threads, both external and internal, of any desired pitch above 24 to the in., may be cast. Die-casting processes applied to repetition castings work out at much lower cost than any other existing method. Alloys for die-casting must be of fine, close grain, low in shrinkage, and the melting point should not exceed 650 deg. C. Alloys of lead, tin, antimony, zinc, and aluminium are usually employed, but a commercial success has been made of aluminium-bronze containing small percentages of iron.

Chills.

There are two main reasons why chilling in sand or loam mould is practised. It is not, in these cases, the want of a permanent mould, but to produce one or other of two conditions: (*a*) The equalisation of the rate of cooling where castings are of varying section; (*b*) to produce a casting from one quality of metal having two distinct grades of properties in itself. The first condition can be applied to any metal or alloy which does not become " chilled " in the sense that certain grades of cast iron do when brought into contact with a metallic surface. Castings of unequal section tend to contract at different rates during cooling, and it follows that the portion most rapidly cooled completes its contraction first, the heavier portion, with a slower fall in temperature, continuing to contract after the lighter portion has ceased. This condition gives rise to stresses in castings, which increase as the differences in thickness of section are more pronounced.

Liquid contraction and shrinkage may be regarded as simple contraction only, and it may be reasonably assumed that castings in cooling contract towards their own centres when the casting is of equal section. A casting having a form similar to that shown in Fig. 10 obviously will have two independent centres of contraction. The light portion will cool rapidly, while the massive portion will cool slowly, so that the whole casting behaves rather like two distinct castings, the result being that the contraction is directed towards the centres

A and B respectively of the two sections, producing a plane of weakness at the junction of the two sections, the metal drawing away from the junction. To produce the ideal conditions found in a casting of equal section it is therefore necessary to hasten the cooling of the heavier portion. To bring this about, a chill is inserted when ramming up the mould to form the lower surface of the heavy section, and so rapidly abstract the heat and hasten the cooling, thus equalising the rate of cooling throughout the casting. By this means the opposing forces are neutralised, and the plane of weakness at the junction of the two sections is eliminated by the merging of the two centres of contraction into one. Cast iron is mostly used for "chills," although brass and aluminium have been employed for certain classes of work. Comparatively light chills may achieve the object of equalising the rate of cooling, and the heavier the chill employed the more rapid will be the abstraction of heat. The use of chills requires that they be provided with some means by which they may be held in position in the mould, and for this purpose rods are usually cast into the backs of chills. Chills, when used for these purposes, must be free from rust and evenly coated with plumbago. The latter may be rubbed on dry or mixed with water and painted on, the chill being dried before use. The use of chills with green-sand moulds requires that the moulds are left open until ready to cast, as moisture from the mould tends to condense on the surface of the chill. Chills are usually inserted in the mould by bedding against the pattern and ramming up with the mould. Plane surfaces require only flat pieces of metal as chills, but curved surfaces require the preparation of chills of the desired curvature.

Variations of Properties by Chilling.

The production of castings from one quality of metal, having two grades of properties in itself, is limited to grades of cast iron which possess the property of "chilling." The effect of contact with a metallic surface is to produce an extremely hard surface upon a casting having a comparatively soft centre. Fig. 9 shows the effect of chilling on the fracture. The bottom shows the typical hard white-iron fracture passing gradually into soft grey, the hardness being determined by the condition of the carbon present. The sudden cooling of the surface has prevented the separation of the graphite, and the iron is thus left white by the carbon being retained in the combined condition. The thickness of the hard white surface layer is influenced by the temperature and thickness of the metallic chill and also the temperature of the molten metal. "Chilling" cast irons must have a low phosphorus content, and the silicon should be of the order of 1 per cent. Table I. shows analyses of three samples of pig-iron suitable for chilling:—

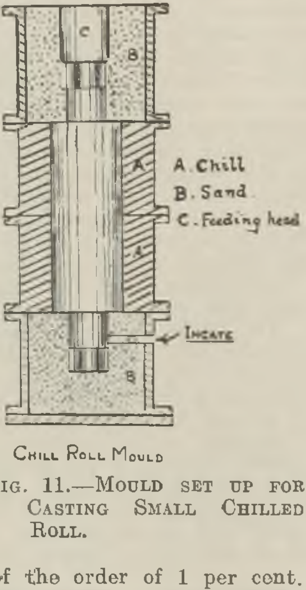

FIG. 11.—MOULD SET UP FOR CASTING SMALL CHILLED ROLL.

TABLE I.—*Typical Analyses of Chilling Irons.*

Cc.	0.84	0.50	0.60
Gr.	2.51	2.49	2.26
Si.	0.81	0.94	0.96
Mn.	0.66	0.72	0.60
P.	0.48	—	0.50

Chilled Rolls.

The chilling of cast iron is most extensively practised in the manufacture of rolls for rolling mills, which require to be externally chilled in order more successfully to resist wear by abrasion. Certain classes of car wheels are also chilled on the tread in order to provide a hard wearing surface. Fig. 11 shows a vertical section of a mould set up for casting a small roll. The mould is a composite one of sand or loam and metal, the metallic portion consisting of a cylinder or series of cylinders bored out to size, whilst the neck and coupling are moulded in sand. The roll is gated at the bottom, and the gate should be cut horizontally at a tangent in order to induce a rotary motion around the axis of the roll. By this means any sullage is concentrated in the centre, which assists in producing a clean surface to the roll. A feeder head is provided by extending the coupling. To conduct the heat away rapidly, and so give the required depth of chill, the area of the cross-section of the chills should at least equal the area of the cross-section of the hot metal in contact with them. The surface of the chills should be well coated with plumbago, and used dry and hot enough to prevent the condensation of water vapour.

Newcastle Branch.

PRESIDENTIAL ADDRESS.

By R. O. Patterson.

The Branch-President, in delivering his address, said:—

Gentlemen,—The foundry trade to-day is undoubtedly passing through the worst phase in its whole history. Never in the memory of man has business been so scarce as at present. It would appear that we were experiencing another strike, *i.e.*, the strike of the buyer who will not pay the present-day price of castings, the result being very nearly a total cessation of orders. This state of affairs has always happened in past years after wars, and is, in this case of such huge dimensions, in direct proportion to the size of the late war. The position has been seriously affected also by strikes both in our own trade and in the coal industry.

The false state of prosperity during and immediately after the war led all of us to believe that this comfortable state of affairs was going to be continued indefinitely. However, the pressing needs of the world have been satisfied, and orders irrespective of price are a thing of the past, so that the sooner we buckle to and get back to normal output and cost, the better for everyone concerned. This will be a matter of time.

One cannot expect a great world upheaval, such as the war, to go past without leaving its mark behind. Exchanges have been thrown into a state of chaos, so that the question of export is nearly an impossibility, and, with our export trade gone, we are in a very parlous state. It therefore behoves every man to put his best foot forward to try and bring things back to a reasonable state. Undoubtedly prices must be still further reduced, output per man must be increased, and every possible means must be used to endeavour to cheapen the finished article.

Improvement in Foundry Practice.

In the foundry, I think that there are many directions in which improvements can be made. One of the most important ones is in the direction of getting castings standardised, so that a serious attempt could be made to introduce machine moulding into our district. The apathy of the users of castings towards standardisation is very difficult to understand, but it is largely due to the insane cut-throat competition between founders which obtained before the war, resulting in castings being sold at considerably less than their true worth. To-day, with higher labour and material costs, these users of special castings cannot afford the price, the result being the present state of affairs.

If we take the example of street castings, such as manholes, etc. Every surveyor, whether of a large city or of a country village, has his own pet ideas as to how a manhole should be made, instead of discussing the matter in their Institution and agreeing to a standard so that the founder could quite safely spend an adequate sum in making first-class patterns and box parts, thus helping to produce the articles at a cheaper rate. Now this state of affairs obtains in a more or less degree throughout the whole of the British engineering trade, and I only hope that this part of the lesson of the present slump will be taken to heart. I am glad to see that the President of the Institution of Automobile Engineers took up this question of industrial standardisation very thoroughly in his opening address a few days ago, and I hope therefore that some progress in the right direction may be the result.

Another field in which there are large possibilities for economies is in the direction of scientific research.

The British Cast-iron Research Association.

As most of you are aware, the British Cast Iron Research Association has been formed during the past twelve months which, in my opinion, is one of the greatest advances the foundry industry has ever taken. The lists of the problems which have been handled by the Director of Research, and which appear monthly in THE FOUNDRY TRADE JOURNAL, give you some idea of the work going on. These problems have been submitted by firms who are members of the Association, and the results are only supplied to members.

Now, Gentlemen, I think that you will agree that these problems constitute a very interesting programme of vital importance to every foundryman. Yet the apathy shown generally, and particularly on the north-east coast, can only be described as appalling. Out of all the foundries in our neighbourhood only some twelve to fifteen have become members. Now the Association cannot exist without the full support of the foundry trade, and I appeal to each of you not to rest until your firm has become a member.

With regard to the programme of the B.C.I.R.A., I think that the subjects appertaining to the cupola are of great interest and offer a very large field for economies in the foundry, for even with the best-known practice there is a wide margin before anything like 100 per cent. efficiency is gained.

Apprenticeship Training.

Another subject which is indirectly connected with foundry economies is the education of foundry apprentices. This subject has been discussed by your Council and an attempt has been made to get classes instituted by the educational authorities, but I regret to say that so far we have been unable to make headway, apparently owing to our ignorance on the subject of red-tape pulling. However, we have not yet given up hope, and trust that before long we shall win some measure of success. On the other hand, it is quite possible that anything done in this direction will have to be done by ourselves. In this case it would appear that each foundry or a group of a few foundries would have to provide a fair-sized room to be used generally by the men for recreation purposes and on occasions for a lecture. The lecturers would have to be provided by this Institution, and if the subjects were arranged in some sort of order, I have great hopes that a very large amount of spade work would be accomplished. I am quite sure that foundry boys and young men have only to be started along the right path, and in a short time an immense amount of enthusiasm would be aroused.

It is very evident to me that the abominable feeling of hostility which exists to-day between employer and employee is largely due to the lack of interest taken by the men in their work and also the "up against a stone wall" feeling which is bound to exist when a man only knows the alphabet of his job. By this I mean that it must be very discouraging to an intelligent man to make castings day after day and to know no more about his business than to ram the sand around the pattern.

If that man knew enough about iron so as to form an intelligent opinion as to the cause of a faulty casting he would certainly have a greater interest in his work. As things obtain to-day, all he can say is that the metal is bad! As to how or why it is bad he knows nothing.

Another view of this hostility leads one to think that it is the return swing of the pendulum from the bad old pre-war days.

Now I think that if there was a works recreation room where employers could sit and talk to the men, smoke with them, and talk over foundry problems of everyday interest, it would be largely responsible in bringing around that feeling of confidence between both parties which is so greatly to be desired.

Now the foregoing is only an idea, and so far as I know has not yet been put into practice, and it may possibly contain some disagreeable features, but a start with this problem has got to be made, and in my opinion the sooner the better.

There is one item of interest which I should like you to know, and that is that I expect my friend Mr. David McLain, of Milwaukee, to visit this country in the near future, and I fully expect him to give a Paper on semi-steel. It will have to be a special night, but I expect to see a record attendance here in view of the absorbing interest of the subject.

East Midlands Branch.

At a meeting held on November 19 at the Technical School, Leicester, a Paper was read by Lieut. F. G. Skerritt on "The Electric Welding of Cast Iron and Steel."

The Branch-President, Mr. W. T. Evans, of Derby, was present, but he having lost his voice, Mr. S. H. Russell, of Leicester, deputised in the chair.

THE ELECTRIC WELDING OF CAST IRON.

By Lieut. E. G. Skerritt.

LIEUT. SKERRITT hoped the members would forgive any shortcomings, as it was the first time he had ventured to address such a gathering on a technical subject.

He said electric welding had been known for 40 years, but the recent intensive development can be attributed to the war. Shortage of carbide and oxygen led in many cases to the substitution of electric arc welding for oxy-acetylene welding. The improvements made resulted in its being recognised as an engineering and commercial success, and the rapid development of specialised processes is due to the wide scope of their applicability.

Oxy-acetylene and electric welding should not be regarded as replacing one another, but as supplementing each other, and both processes were used by the author. Electric welding can be placed in two distinct groups, one producing heat by the resistance of the metal being welded to the passage of the current, and the other by using the heat of the electric arc. They are known as resistance welding or sectional welding, and arc welding or surface welding. The differences rest entirely on methods and special applications. In arc welding the heat is localised through the action of the electric arc, and no pressure is applied. In resistance welding the heat is localised by the resistance to the flow of the current and pressure is applied. The contact or resistance method can be termed a proper welding process, and the other more correctly described as autogenous welding by the electric arc.

The methods of using resistance welding are butt, spot and seam welding; and of arc welding by the carbon electrode and the metallic electrode, the latter sometimes bare and sometimes covered.

Resistance Welding.

The process of resistance welding is based on the fact that a poor conductor of electric current will heat if current is forced through it, or that a good conductor will heat if enough current is passed through it. The resistance method is the simplest, and is limited almost exclusively to new work and to articles of moderate size, although later developments have made heavy steel members a practical proposition. The operation consists mainly in clamping the pieces in a machine, passing a heavy current through the area of contact until it becomes plastic and then squeezing the pieces together to form a weld.

Cast iron cannot be commercially welded by this method as it passes suddenly from crystalline to fluid state when at welding temperature. With steel or wrought iron the temperature must be kept below melting point to avoid injury to the metal. The metal must be heated quickly and pressed together with sufficient force to push out all burnt metal from the joint. High-carbon steel must be annealed after welding, but nickel steel welds readily, increasing the strength. When welding copper and brass pressure must be less than when welding iron, current is cut off the instant metal begins to soften and pressure applied.

Butt welding consists of bringing two pieces of metal in contact end to end or side to side, and then clamping the ends between two heavy copper jaws supplied with a large current at low voltage. The metallic surfaces should be of practically the same cross section. A slight burr is formed at junction, and weld is finished off by hammering. The current is generally alternating single-phase. Electric welding can be used for bars, chains, tyres, frames, wires, and the like.

Spot Welding.

Spot welding is a modification of butt welding used for joining sheet metal. Plates to be joined are placed between electrodes through which a high current is passed while pressure is applied. Intensity of current produces a rapid rise of temperature which, combined with pressure, tends to prevent oxidisation in the weld. The appearance is similar to flush-riveted welds. By replacing pointed electrodes with mechanically-driven electrodes, continuous seam welding can be carried out, and this form of continuous welding machine is becoming increasingly popular for joining metal sheets to form cases, drums, trays, etc. Heavy spot welding is in an experimental stage.

Carbon Arc Welding.

The characteristic principle of carbon arc welding is that an electric arc is held between the metals to be joined, and this forms one electrode of the circuit and a carbon rod or pencil manipulated by the welder which forms the other electrode. By placing the carbon electrode in contact with the metal, thus closing the circuit and instantly withdrawing it again, an electric arc is formed between the two electrodes, and owing to the high temperature of the arc the metal is melted. Experience has shown that the metal to be welded should be the positive electrode and the carbon the negative electrode. If this order is reversed a shorter arc is obtained, and particles of the carbon rod can enter the molten metal and cause brittleness. Cutting can be done by carbon arc, but few operators can follow a sharp line, and the arc leaves a very rough edge. Direct current is used of from 60 to 90 volts, and from 250 to 600 amperes according to thickness of metal.

Metallic Arc Welding.

Metallic-arc welding is a modification of the carbon-arc welding. The process is better for the operator, for the electrode is only 3-16 inch, and the welder has one hand free in which to hold a protecting screen.

Arc Burn.

It is very painful if the rays reach the eyes either directly or reflected; the symptoms do not show at the time, but arise about six hours later, and the inflammation remains several days.

A low voltage is required as in the carbon arc, but current is reduced to 50-175 amperes. The electrode usually supplies the filling material.

Protection for the skin as well as eyes is necessary in all arc welding. A wooden or metal screen fitted with coloured glass and large enough to protect forearm, face and neck is desirable, the right hand being gloved, while in addition a helmet is worn against reflected light.

Covered Electrodes.

Practical tests have shown that welds with bare electrodes lacked ductility and resistance to shock, but much useful work is done, and the cost of electrodes is less than half, and the time occupied as two is to three. Covered electrodes permit the electro-magnetic effect of the welding current to act upon the molten metal; it applies flux to the weld at a rate that adjusts itself perfectly to that of the melting of the electrode and imparts to the deposited metal certain desirable characteristics. The electro-magnetic action is in effect the propulsion of the molten metal from the electrode toward the molten metal in the weld, thereby thoroughly uniting the metal to be welded and the deposited metal from the electrode. There are possibilities of defects at the junction of old and new layers and also when new electrodes are inserted, but a really skilled operator can overcome these difficulties, weld perfectly vertically and overhead, and in any position bring the slag to the surface.

Welders require a great amount of training, and the idea that the operation is simple is responsible for many disappointments. No welder should regard a job as impossible, though whether it will pay is often a determining factor. A good welder must be something of a boiler smith, engineer, electrician, moulder and draughtsman. It is often necessary to know the cause of the breakage; it is not fair to a customer to weld a piece that is of too light a section.

Electric welding should be considered as supplementary to and not supplanting oxy-acetylene welding. The latter is generally more suitable and economical on repairing small jobs and electric welding for heavy work. Record advances in the use of arc welding are in application to constructional work, roof trusses being welded instead of rivetted, but many people are unwilling to risk a new method without the guarantee which time alone can give. It is suitable to fastening the steel skeleton for reinforced concrete. One very important advantage of welded joints is that for oil- and water-tight structures. As compared with a rivetted joint a welded joint is water-tight up to its breaking point. Ship and marine boiler repairs figure largely in the work done with large masses of metal, and much money has been saved. Arc welding for boiler repairs is now standard; all kinds of worn machine shafting can be reinforced and machined down to the original size. Tramways can effect more economy by using electric welding on such things as the side frames of tramway bodies, meter frames, the building up of worn bolt holes, armature shafts and on the track.

Many successful repairs to cast iron have been made with steel electrodes, no effort being made to deposit cast iron. With this method of welding the amount of heat applied at the weld has been found less than with any other method, and therefore extensive strains and contraction cracks are avoided. This is a most important point in cast-iron welding. It enables cast iron to be welded *in situ* and without pre-heating.

In conclusion, Lieut. Skerritt mentioned a number of repair jobs undertaken by his firm and, passed round samples of electrodes. An interesting job, he said, was to weld a crank-shaft with a three-fold fracture. It was in a cellar three storeys down; a 26-h.p. motor had to be carried down to drive a dynamo. This job cost £56, and had stood two years, and without this method the main shaft, weighing 5 tons, would have had to be removed.

DISCUSSION.

Asked as to cost, the lecturer said he had worked out a calculation of 5s. per cubic inch. He had worked out this on actual jobs, and found that for jobs *in situ* the basis is under the mark, for jobs in the shop it is well over the mark.

Mr. Bailey asked whether for the electric welding of cast iron the material had to be pre-heated.

Lieut. Skerritt referred Mr. Bailey to the three pieces of cast iron exhibited, which were simply cast iron deposited with a specially prepared electrode of mild steel which deposits cast iron. In welding with such an electrode it is necessary always to pre-heat in exactly the same way as it is necessary to pre-heat for oxy-acetylene welding. All the other samples shown where steel has been deposited on cast iron had been effected cold.

Mr. Barrett asked about the welding of copper and brass.

Lieut. Skerritt said he had no experience, but was advised a process would shortly be marketed. Heavy castings could be welded by the electric arc without pre-heating, using a mild steel quasi-arc or other specially prepared electrode. The carbon arc process was generally considered appropriate for filling up large blow-holes in heavy castings.

Answering further questions, Lieut. Skerritt said with reference to welding cast iron assisted by inserting steel pegs on either side of the Vee he would not guarantee a water-tight or pressure-tight job if he had to rely for the soundness of the job on steel pegs alone; he would require, in addition to that, perfect amalgamation of the deposited steel with cast iron.

A Member said he maintained they could get water-tight and pressure-tight joints without amalgamation of the metal.

Mr. Bentley, President of the Leicester Association of Engineers, proposed a vote of thanks to the lecturer. He had been experimenting with oxy-acetylene welding, and there was no doubt difficulties exist which are easily overcome by the electric process.

Mr. Clarke (Loughborough) seconded, and in reply Lieut. Skerritt said he was grateful to know he had interested them in his address on such a subject.

Scottish Branch.

MECHANICAL TESTS FOR CAST IRON.*

By F. J. Cook.

A Paper on " Mechanical Tests for Cast Iron "* was read before a meeting of the Coventry Branch on December 7 by Mr. F. J. Cook. The occasion was a joint meeting with the Coventry Engineering Society, and a good muster of members of both bodies were present. Mr. E. Carey Hill (Branch-President) was in the chair.

DISCUSSION.

THE PRESIDENT, in inviting discussion, said they had heard a very interesting lecture, and it had been an admirable demonstration of many of the scientific methods employed in measuring qualities of cast iron by mechanical tests.

Transverse or Tensile Test ?

MR. HARLEY said that the lecturer had always been ready to place the results of his investigations at the disposal of the Institution. Cast iron, of course, was a very complex substance, and the conditions which caused variations were innumerable. The problem was to find some method whereby the conditions for any particular line of work could be stabilised and kept constant from day to day. With regard to the most important physical tests—the tensile and transverse tests—a great deal had been said as to the best method of taking them. With heavier classes of work, doubtlessly it was very satisfying to an inspector to see the test-piece on the casting and then to see it broken off and tested. But with automobile work that condition was very difficult, because a majority of the castings were so small, and other factors would make this practice a nuisance. What would have to be done was the standardisation of methods of making such test

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* This paper appears in the Proceedings for 1920-1921.

bars. Every detail in regard to the method of moulding and casting test-bars should be definitely established. Whether it was actually the best method did not so much matter. What they should have was a comparison between one iron and another, and between one foundry and another. This could only be done when the same methods were universally adopted. Obviously, there still remained the problem of whether these results corresponded to the castings under examination. In his opinion, it was almost impossible to guarantee the life and capability of any castings from a test-bar, but it would give some idea, particularly if a sufficient number was taken, of the quality of the metal. However, in a mould there were other factors which operated either to make the casting a good or a bad one. The question of the ramming of the mould, of the amount of moisture therein, the condition and the kind of sand, and the method of running were amongst these factors. Additionally, there was the casting temperature. Dr. Longmuir had proved that the casting temperature had very striking results on the strength of the metal. But he would like Mr. Cook or Dr. Longmuir to tell them whether there was any exact workshop method of judging the temperature of molten cast iron. He had tried a good many methods, but had not yet found a satisfactory one of indicating some of the small differences in temperature such as were shown on the chart. With regard to the "hardness" chart, where combined carbon, sulphur and manganese were shown, some remarkable variations were obtained in hardness. He (Mr. Harley) would like some expression of opinion from Mr. Cook as to whether, if a foundryman had to choose between a transverse or a tensile test, there was anything which favoured the one more than the other, and which was the more valuable. There was a very general consensus of opinion that the transverse test was the more suitable, but against this he quoted his experience that he had never been able to obtain two transverse tests which came out similar, even though the conditions, as far as it was humanly possible to ensure them, were the same. As to how or in what measure test pieces represent a cast, or the quality of a number of castings, a great deal would still have to be left to the honesty and ability of the foundryman. With regard to the Brinell hardness test, he agreed that this test was not of much value in cast iron. But he would like to mention in connection with this test, although it had nothing to do with cast iron, that those dealing with non-ferrous alloys, particularly aluminium, would find the Brinell test very useful in indicating variations in the composition of the alloy.

Troubles Through Growth.

Mr. G. Kirby, of the Coventry Engineering Society, said, with reference to Mr. Cook's mention of iron as used for Diesel engines, he had found that iron as used for superheated steam had a tendency to grow, so that it had eventually to be replaced by steel. Could Mr. Cook tell him of any particular grade of iron which he had found particularly useful for high temperatures? It might be of interest to them as engineers. As to the hardness of cylinders, and their ability to stand wear and rubbing and present a good surface to the piston, he expected that the lecturer was aware that in certain industries there was a method of rolling these cylinders in order to give an artificial surface hardness.

Blast Pressure and Casting Temperature.

Mr. Player, being interested in the control of blast pressures and casting temperatures, asked Mr. Cook whether he considered that the pressure was a sufficiently accurate guide to the volume of air supplied during the blow to allow the foundryman to ignore entirely the rather difficult problem of recording accurately the volume of air? He had in mind that in almost every cupola variations took place in load, and it seemed possible, although their blast pressure might remain constant owing to the make of the blower and other factors, that they might be supplying different quantities of air per minute at different portions of the blow. That point had received considerable attention in foundries, and at his works they had considered putting in a volume recording meter, but they were not satisfied that the instruments on the market were really reliable, although on the Continent expensive installations were being put down. Mr. Cook had shown some interesting charts indicating variations in hardness, and particularly in tensile strength, obtained by Dr. Longmuir with varying temperatures of pouring. Later he showed similar charts of his own, giving variations in tensile and transverse strength, and also in hardness, with varying blast pressures. He would like to know whether Mr. Cook considered his own results to be due to the variations in temperature, which are almost certainly consequent on the variations in the blast pressure. If so, the lecturer's experiments would seem to follow on the lines of Dr. Longmuir's experiments, with the difference that Mr. Cook had measured blast pressure and Dr. Longmuir the temperatures of casting. It was quite easy to make a series of tests of blast pressures, and, carefully carried out, some interesting results similar to those obtained by Mr. Cook would be available and no doubt valuable. At his works they were of the opinion that such variations were only indirectly due to blast pressure, but were directly the result of the volume of air supplied. That temperature was a considerable factor they had proved over and over again. He hoped Mr. Cook would tell them how to get sound cylinder castings, which was an important industry in Coventry. They thought the question of tensile strength was rather over-laboured by many of the experts, because they found little difficulty in obtaining tensile strengths, but experienced considerable difficulty in getting 100 per cent. of good castings.

Cast Iron for Machine Tools.

MR. P. A. SHAW, Coventry Engineering Society, remarked that he was very much interested in what was said respecting the cast iron put in American machine tools, and said it was the general practice when they had broken tools of this sort to replace them by steel. He did not think that they gave the English foundries a chance of showing what they could do in the matter of good castings for machine-tool work.

The Drill Test.

MR. BROUGHALL said that Mr. Cook's drilling tests formed an old point of contention between them. Some years ago Mr. Cook convinced him (Mr. Broughall) that Mr. Cook's method was the right one for testing cast iron, and they designed and made a machine specially for this test. The results, however, had not been so good as he had hoped for, but this may have been brought about through the machine not being designed for using large drills. Mr. Broughall pointed out one particular instance of the unreliability of this test and which the lecturer had not explained. Mr. Cook illustrated the mixture containing 0.5 per cent. of combined carbon and another mixture containing 1.2 per cent. of combined carbon, and the drill-hardness test showed that the mixture containing the smaller percentage of combined carbon was the hardest. Mr. Harley had raised an interesting point in connection with transverse test-bars. The question of standard test bars had occupied the attention of the Institute for many years.

About ten years ago a committee was appointed to deal with the matter, but that committee had evidently carried out its work on the lines of a Royal Commission, because he believed that up till now they had announced no result. His opinion, based on many years' experience, was that the transverse test-bars properly made and properly tested told them perhaps all they wanted to know.

Necessity for Several Standards.

Of course, for different classes of iron different standards would have to be adopted; for instance, a different deflection would have to be fixed for a soft iron from that of the harder iron. Their method of using a transverse bar was to cast these bars 1¼ in. square and machine them accurately to 1 in. square, and then carefully test, particularly noting the deflection. Mr. Harley had stated that if there was a variation of 1-32 in. in a transverse test-bar the result obtained would be totally different. To use test-bars made under these conditions was altogether unreliable.

Mr. Cook had mentioned Dr. Longmuir's Carnegie Research work, but he must confess that he had always entertained a certain amount of doubt about the value of this research, so far as had applied to casting temperatures. Dr. Longmuir claimed to have measured temperatures of 1,400 deg. C. during his research work, but he had never been able to find out what pyrometer was used in that research, nor did he believe there was, at that time, any pyrometer existing which would measure such a degree of temperature accurately.

Brinell Testing.

Mr. Cook had mentioned the small ball Brinell testing-machine made by Messrs. Alfred Herbert, Limited. Although very little reliance could be placed on the Brinell test of cast iron, using a 10 m/m. ball it had been found that most reliable results could be obtained on close-grained cast iron when using this special machine, which carried a ball 1 m/m. in diameter. In a recent investigation on cast-iron piston-rings for motor-car engines they were able to find three different hardnesses in the width of the piston ring. Mr. Broughall exhibited a micrograph showing this small ball impression on a piston ring which clearly demonstrated that the tiny impression of the ball covered no less than 400 graphite flakes.

Alluding to the test which the lecturer associated with the name of Mr. Owbridge, of the British Piston Ring Company, Mr. Broughall said that this particular test had been dropped quite a long time as unreliable.

THE LECTURER'S REPLY.

The Lecturer (Mr. F. J. Cook), in replying to the points raised, said a number of things had been touched upon which might be usefully known regarding tensile and transverse tests. From his experience he thought that the method of making test-bars and their size was one which would not be settled by any one specification. In reference to the casting of test-bars for a 2- to 3-ton cylinder, and also in regard to small work generally, he agreed with Mr. Harley that different methods would have to be adopted. As to the question of test-bars being cast separately, he remarked that the old fundamental principle underlying these matters was to ensure as far as possible that the conditions for these tests should be the same.

Tensile Test Preferable.

Whether the test should be that of a tensile bar or a transverse bar depended on the importance of the work. On the other hand, he thought that the best results or *the most information* had been obtained for large cylinders from machined tensile bars. The question of arriving at a specification which would give comparisons for the same class of work in different foundries was not an easy one, but it should be borne in mind that no bar would supply the actual results of the castings. Obviously, it was no indication that the casting was a good one. However, if for a long period they found that the metal on a standardised test-bar cast in a definite manner gave results on the bar which closely approximated, it was safe to assume that the castings are to specification. Some people, it was true, declared that test-bars were of no use, but the only alternative they gave was the impracticable one of breaking every casting and testing it for fracture. Concerning the size of graphite plates, he had invariably found, as the results exceeded 18 tons tensile and approached 19.4, so the flakes of the graphite became larger; they were longer and very often rather wider. It was a curious coincidence, and he was dealing with the subject in a Paper which he had been asked to present on behalf of the Institution in America. Speaking of the American specification, which was taken on 1¼-in. round bar as cast, the Lecturer said he did not think this was quite satisfactory. He had only had one American bar submitted to him, and he had found it nearly one-eighth of an inch oval, which would give a different result had it been round, and so far as he knew no formulæ were available to correct irregular circular test-bars. Mr. Harley had spoken of the difference in the depth of bars and the variations in size, but it was obvious that by engineering formulæ the difference was as the square of the depth, and it would be necessary to square the difference in depth to get the proper result. All the results he had obtained were from tests made by getting away from the skin area and under the same conditions every time. The Brinell test was undoubtedly a very good one for aluminium, and he hoped they did not conclude from what he had said that he was condemning the Brinell test for every kind of work. What he stated was that it was not good for cast iron. But it was an excellent test for many things; for surface hardness, such as in case-hardened pins and articles of that sort. As to rolling surfaces of cylinder, this had been used with regard to Diesel engine liners. The question of surface on Diesel engine liners was a very important one; they required to have a perfectly round bore, because it was necessary to get an accurately fitting piston-ring to keep the cylinder case tight. Rolling, to give good results, had to be very carefully done. It also needed good metal, otherwise it became very uneven. They heard comparisons made about the engines made to-day and those of years ago, and although cold-blast iron was better than hot-blast iron, there was another factor which was often forgotten. In the old times it was not unusual when installing an engine to run it for weeks with a view to getting that high polish which produced the good-wearing properties, but to-day they had high-speed engines which were put on load almost at once. As to blast pressure and the volume of air supplied, the subject was one which required a whole evening to discuss. Extensive research was carried out in this particular field some years ago, and was available for those interested. It was generally laid down that there were two functions, one of pressure and the other of volume of air. Air volume gave efficiency or output, and theoretically the pressure required for actual working was just sufficient to keep the air in the centre of the cupola. Air would take the least line of resistance, which in the cupola was at the sides. If they did not get sufficient pressure the result might be that melting was taking place in a small area only. Sufficient pressure to keep the necessary volume of air in the centre of the cupola in order to provide the required heat for proper melting throughout the area was essential. Therefore, theoretically, all that was required was sufficient pressure to ensure that the air was well distributed, and with that the highest efficiency of the cupola was secured. By altering the pressure and carrying the idea further and getting the required ratio of volume, different results of hardness and tensile strength could be obtained. The formula was given by which the highest efficiency of the cupola could be obtained. But beyond this oxidation was caused, and output fell, while the quality of the iron materially decreased. He did not think the results obtained were altogether due to temperature, but partly to pressure, The test which he had dealt with was sufficient to give a sound "K," and he had tested from 2 ozs. to 24 ozs. The temperature was good, and the slowness with which the melt was made was effected by the volume of air. Mr. Shaw had spoken of the metal put into American tools, but he would like to emphasise that he had not said the metal generally was bad; he only referred to the metal in this particular American bar which was referred to him. However, he believed that American cast iron was inferior to English, and this was a matter which he was dealing with in his Paper.

Drill Test Useful.

Regarding Mr. Broughall's point that his reference to the Owbridge test being somewhat out of date, as it had been dropped, he mentioned it as being one way of getting over the difficulty of the different sizes of indent and their measurement. Up to date he had a record of 48,000 holes drilled, and he had no diffidence in saying that he had pinned his faith on the hardness test if it was properly carried out. There were also many thousands of tests not recorded. Mr. Broughall's machine was a very good one, especially so for softer metals, but it did not appear to be sufficiently strong to work a large drill. The difficulty was that anything which had a tendency to whip, as is experienced with a small drill when testing strong irons (which was the fault of the "Keep" machine) reduced its efficiency. The resistance was too great for the type and power of the machine. With similar drills he had found the same inconsistencies, but with other drills and power he had been able to get consistent results, and also to get very close figures with regard to the ratio of hardness over long periods, and to cut out quite a lot of difficulties with cylinder work by that and other tests. The great trouble with transverse testing was that they had very few people who were able to diagnose their results.

Mr. Broughall, in proposing a vote of thanks to the Lecturer, alluded to Mr. Cook's many activities for the good of the foundry trade. Mr. Broughall referred to the important research which Mr. Cook and the late Mr. George Hailstone carried out in connection with the structure of cast iron and another important Paper on blast-volume and pressure.

Mr. Elgie seconded, and the vote, which was carried by acclamation, was suitably replied to by the Lecturer.

Birmingham Branch.

At a meeting of the Birmingham Branch on December 10, held at the Birmingham Municipal Technical School, Mr. J. Shaw read his well-known Paper on " Some Perplexing Foundry Problems."

A DISCUSSION ON SOME PERPLEXING FOUNDRY PROBLEMS

The Chairman (Mr. W. J. Flavell) reminded the members of the interest taken in the Branch by Mr. Shaw when he was a member. Since then Mr. Shaw had been connected with one of the Government Departments, and was now at Sheffield with Messrs. The Brightside Foundry Company. When the conference was held at Blackpool Mr. Shaw gave this Paper, and it was followed by a most interesting discussion. The Council of the Birmingham Branch thought it would be very useful and interesting to the Birmingham Branch if they could get it repeated so that they could have a further discussion on it.

Co-operation with the B.E.S.A. Essential.

Mr. H. L. Reason, in proposing a vote of thanks to Mr. Shaw for his Paper, said a very great honour was conferred upon Mr. Shaw during the war when he was engaged as an expert on cast iron at the Ministry. Mr. Shaw came in close contact with the troubles in the various foundries that were called upon to meet very high tests required in connection with munitions, and this, coupled with his previous experience in connection with test bars and the study he had given the question since the war, had led him to induce the Institution to give the question serious consideration. He agreed with Mr. Shaw that the Institution should advise authorities empowered to lay down specifications for cast-iron test-bars. He (the speaker) had had quite ten years' experience with the British Engineering Standards Association, and his experience of them and their management was that they never put a specification into force until they had consulted both the manufacturers and users. It was their duty as an Institution to pursue this question and to ascertain where they could assist the B.E.S.A. to prepare specifications which could be worked in such a manner that they were not at the mercy of the whims of an Inspector, and so that they could produce their test-bars with a regularity that was not going to bring forth trouble. The Institution could pursue their work up to a certain point, but when they wanted research which was going to cost much money they had to stop. They were now in the very happy position of having the B.C.I.R.A. constituted for this purpose.

Square and Round Test-bars.

Mr. Frank Holberry, in seconding the motion, said, with regard to test-bars, he agreed with Mr. Shaw that there ought to be standardised test-bars if they were to obtain correct readings or any satisfactory results. He would like to ask what Mr. Shaw thought would be the difference in a tensile-bar cast square and turned round and a bar which was cast round.

The vote of thanks was heartily accorded to Mr. Shaw.

Difficulty of Producing Pig-irons to Analysis.

Mr. J. E. Fletcher. Director of Research, B.C.I.R.A., said Mr. Shaw had practically introduced two definite topics. The first was a very tempting one, and one of vital importance. There was some reason why two irons of similar chemical composition should give physically different results, and Mr. Shaw had hinted at one thing that might possibly account for it. Those who had had any experience with blast-furnace work, with hot- and cold-blast irons, knew that there was a difference between two such irons although they might be made practically from the same materials. The difference in the temperature of the working in the furnace was, at any rate to his mind, the chief reason for the difference. There were several things that seemed to fix the physical conditions of cast iron, and the first in importance, as in the case of steel, was carbon. Whether carbon was relatively high or relatively low had a great deal to do with the physical condition of the material. If it was high it would, if cast hot and chilled rapidly, give a certain result. If it was high in carbon, cast hot and cooled very slowly, it would give another result, and the result Mr. Shaw mentioned as a kind of freak was not altogether a freak. He had seen it many times, and it was due largely to certain furnace operations that had caused the iron in the well of the furnace to become desiliconised. Especially in the older type of slow-running furnaces this sort of iron was not at all unusual. He had seen it sometimes when a furnace had had a "hard tap," and instead of being tapped at the usual, say, 12 o'clock, it was tapped at 6 o'clock next morning. He thought as foundrymen they ought to recognise the great difficulties of the blast-furnacemen. Too much was said, as if the blast-furnaceman, with his unwieldy, gigantic furnace, could operate it as though he were operating a Siemens-Martin furnace. It was impossible to do anything of the kind. He was hampered to-day, and he would apparently be increasingly hampered in future with ores that were physically finer, more siliceous and more difficult to deal with, and he also had his fuel problem. It was certainly getting a little better now, but when the chemist tried to take out of the coke what some considered was the best part of it and gave the remaining coke to the blast-furnaceman to do what he could with it there was something resulting from that difficulty which perplexed the foundryman from day to day. During the war they had coke, occasionally, which contained 10 to 15 per cent. of moisture and which contained over 15 per cent. of ash. That was the sort of coke with which foundry metal had to be made during the war to give some of the results that engineers expected. There was no wondering at the variable results that had been obtained. The blast furnaceman went to his pyrometer and expected to find his 1,100 or 1,200 deg. and found instead 750, and he had burdened his furnace for a certain expected stove-temperature. He had burdened it with his limestone, and it took a temperature of 1,000 deg. before it melted the slag, probably, and under these conditions the blast-furnaceman had to work. It was a most difficult problem. He saw practically from day to day the difficulties that blast-furnacemen had, and though they were grappling with them as well as they possibly could, the product varied. When they went to the modern blast-furnace, with its big hearth and high rate of driving, and took analyses at various parts of the bed and found considerable variations, then what was the blast-furnaceman to do? How could he deal with it? The result was that the iron had to be graded according largely to fracture. Theoretically, it should be graded largely according to analysis, but when they had a dozen different varieties of iron in the one bed how could it be graded by analysis? Of course, it was largely a carbon question, but there was also the variation in manganese and silicon. The differences were largely due to temperature control in the blast-furnace. So far as irons were concerned having the same analysis and giving different physical results, a great deal depended then, of course, upon the rate at which the pig-iron had been cooled and the later cupola metal. He had records year by year of irons made in the same furnaces in the winter and in the summer with the same burdens. During the winter time the iron was of a different nature from that in the summer, and these were very difficult matters for the foundryman to understand when he got pigs that analysed the same or very nearly the same. There was a very serious and important ratio between the combined carbon and the graphitic carbon in iron. That ratio had to do really with the rate of iron cooling. If they took the iron and quenched it right out in iced brine they would get from the same iron nothing but practically combined carbon and little or no graphite at all. The question of cooling had a very great deal to do with the difficulties that Mr. Shaw had mentioned.

Test-bars.

With respect to the test, he entirely agreed with Mr. Shaw that if any sort of representative test was to be made, a tensile or a transverse test, it should have some relation to the rate of cooling and some ratio to the thickness of the casting that the bar was to represent, and it would be a matter of experiment and judgment along those lines. They were suffering from having tests prepared for them, made to fit almost every condition without considering that one casting cooled quickly and another slowly. He thought the tensile test-bar should be made from a round bar, cast dry-sand, and cast carefully as the Americans had suggested. The question had not been tackled as it ought to have been in this country, and it was a matter for the I.B.F., in conjunction with the B.C.I.R.A., as well as for those who made the material. They would welcome a committee or a council of advice and arbitration when it came to really seriously considering what should be the British standard test-bar for cast iron. He thought, too, that the transverse test ought to be on the same lines as the tensile test, if it could be. An 18-in. transverse test would be very much better than a 12-in., and if a round test machined flat on two sides could be made for that purpose it would be very much better.

Mercury in Pig-iron.

Mr. R. Buchanan thought it was probably right to say that oxides had a marked influence on molten grey iron. Pig-iron was such a complex body that they knew very little about it, and he mentioned that somewhere in the Technical School was a bottle containing liquid mercury which he obtained from solid pigs. He agreed that pigs did differ, although the analyses were similar. He was quite in accord with what Mr. Shaw had said as regarded the difficulty of getting a test-bar which would indicate the strength of the casting which it was supposed to represent. He recalled that he wrote a Paper fourteen or sixteen years ago which he called "The False Witness of the Test-Bar," the idea of which was to show that although test-bars were honestly made and cast from the same metal as what was going into the casting, they did not represent the casting as regarded the strength which the casting would be. He suggested that where it was possible that the casting should be tested to destruction. He agreed that it was desirable test-bars should be more related to the thickness of the casting which they represented. As regarded a circular test-bar being better than a 36 in. × 2 in. × 1 in., he confessed that he never met difficulties with the latter bar. In his opinion, the deflection of a transverse test-bar was more instructive than the breaking stress of a tensile-bar.

Test-bars should represent the Metal.

Mr. D. Wilkinson said that after a long experience in test-bars of steel, cast iron and non-ferrous metals he had come to the conclusion that the test-bar should not represent the casting, but only the metal put into that casting. It had seemed to him for some time that as regarded cast iron the whole question wanted handling carefully and revising. It was comparatively well known now what quality of iron was required to make a heavy, a medium and a light casting. What was to prevent careful research being carried out for a period by various manufacturers who were making satisfactory castings of various descriptions on one standard test-bar made in a certain definite manner and tabulating all the results they obtained? Then, after a lengthy period, if all these various results were compared, they ought then to obtain a definite standard of strength, both tensile and transverse, which would give fairly accurately the character of the metal required for various castings. As regarded the shape of the test-bars, that was a very wide question. A circular test-bar in steel cast vertically was useless. It was all a question of crystallisation. The centre of a round steel test-bar was always open and weak. Similar conditions occurred with brass. Concerning the variation in analyses and properties, he said they had all known for a long time that analyses, no matter how carefully carried out, were not the last word. It must be some property of the metal itself.

Mr. A. Parsons inquired whether the metallurgist and chemist were justified in taking it for granted that the pure metallic content for cast iron was constant. With regard to test-bars, from the experience he had had of the chemical compositions of iron, there certainly seemed to be a wide range of chill for identical compositions. He was not going to lay all the blame on the composition, because they were up against the human element.

The Lecturer's Reply.

Mr. Shaw, replying upon the discussion, stated that he was pleased the various speakers were in agreement that the Institution should put forward some definite proposals for specifications and tests for cast iron. Their position on this matter would then be quite clear. Mr. Fletcher and others had endorsed his (the speaker's) view, that the size of the test-bar should bear some relation to the thickness of the casting it represented. To have three sizes of bar might be cumbersome, but this was infinitely superior to the American specification with varying test results on the same size bar. It was often stated that the test-bar result was no criterion that the casting would give the same result, due to difference in the rate of cooling, etc. Whilst this was true, the bar at least gave the customer some idea of the quality of the metal used, and he could make comparative figures. If it be taken for granted that the test-bar does not necessarily represent the strength of the casting, there can be no objection to having a round test-bar, cast vertically in dry sand. This would eliminate a number of variables, such as chilled corners, wet sand, etc. In short, conditions would be more stable and results more comparable. Whilst agreeing with all Mr. Fletcher had said as to the effects of quicker or slower cooling of metal on the physical test results, he knew he also agreed that these results are also altered by time and temperature effects in the furnace itself, even when showing the same ultimate analysis. He also endorsed all he said with regard to the difficulties of the blast-furnace manager. His quarrel with the latter was that they should put "off" iron through the furnace again, or warn his customer. for it is often sent out to find its level and cause trouble. After thanking Mr. Wilkinson for the list of irons that bore out his contention, he referred to oxides, and said no definite conclusion could be drawn until some fairly accurate method of their determination had been found. This is a function of the B.C.I.R.A., who will no doubt, if it is at all possible, some day clear up this matter. With regard to Mr. Parsons' question, it must be taken for granted that pure iron is always the same, and that it is the effects of the other elements that gives the variation in strengths and other properties.

Sheffield Branch.

THE FLUIDITY OF MOLTEN METALS.

By C. H. Desch, D.Sc., Ph.D.

At a meeting of the Sheffield Branch of the Institute of British Foundrymen held on December 3, Dr. C. H. Desch, D.Sc., Ph.D., of Sheffield University, gave an interesting lecture on the above subject. In the course of his remarks, Dr. Desch said when the subject of the fluidity of molten metals was looked into it was very striking that on this, as on many other foundry problems, so very little information existed in a published form. Fluidity was a thing of very great importance to every foundryman, who had, of course, a very clear notion of what it meant, and how it was controlled, but very little scientific, organised knowledge of fluidity existed. By fluidity they understood the property that metals had of flowing freely, and so of filling readily the cavity of a mould. Anything which diminished the fluidity of a metal made it more difficult to fill a mould completely. The sharpness of castings depended on other factors as well as fluidity—the amount of expansion that took place at the moment of setting, for example, affected the sharpness very greatly, but fluidity was one of the factors governing that result. The net effect, which the foundryman called the fluidity of his metal, was really the resultant of a number of different factors. To make a test of fluidity in the foundry, the method adopted was a simple, empirical one. They simply made a mould, of such a form that it would reveal differences in fluidity between different metals, and that was most easily done by using as the mould a cavity made by embedding a long, narrow pattern. If a wooden rod a foot long and of small section was taken, a sand mould made with the aid of that pattern, and provided with a pouring gate and riser, then, on pouring metal into the mould, a fluid metal might fill it completely; a metal which was less fluid would fill it to a smaller extent, and a metal which was very little fluid would give only quite a short casting. That was, of course, an empirical test, which measured what the foundryman wanted to know—the power that the metal had of filling the mould. But that was not a simple property in itself. Mr. Riddel, a former president of the Institution, was in the habit of using, in Glasgow, a wedge-shaped mould, starting with a fairly thick mass and gradually tapering away to a knife edge. He used that in the course of work on semi-steel to determine the fluidity of various semi-steel mixtures, and he was kind enough to give some of the results to the Royal Technical College, Glasgow, while the lecturer was there, and they were in use in the foundry teaching. Undoubtedly, foundry teaching in Glasgow owed much to the work of Mr. Riddel, who had built up in the Technical College excellent foundry classes, and was always ready to give help when required to all those who were concerned in the foundry industry.

Some Japanese Experiments.

The amount of work that had been done on fluidity from a quantitative point of view—that was, work directed towards getting values for fluidity which could be expressed in figures—was very small. One piece of work was simply an extension of the simple empirical foundry method of which he had spoken. Some two years ago two Japanese workers at the University of Kyoto undertook a research on the fluidity of metals. Instead of using a simple, straight rod as pattern for making the mould, they used a spiral of the type shown in plan and section, Figs. 1 and 2 respectively, in order to show up in a still more striking way the differences in fluidity between samples of different metals. The mould was provided with a pouring gate, and a riser at the centre. The pattern was embedded in sand, so as to make a mould into which the metal could run. A very fluid metal would be able to fill the whole of the narrow channel, right as far as the riser at the centre; a metal which had very little fluidity would only be able to fill part perhaps of the outer turn of the spiral, and intermediate metals would fill an intermediate length. These workers purposely chose a very long pattern in order to be able to reveal great differences in fluidity. As a matter of fact, none of their metals ever filled more than three turns. The mould was made of fine sand, very carefully dried and then brought to a certain definite temperature, the same in all the experiments. The melted metal was poured into the receiver, and when the receiver was full an iron stopper was raised and the metal allowed to flow downwards and to fill as much of the mould as it could. The quantity used was large in comparison with the capacity of the mould, so that there was always a large excess of metal and a relatively constant head. The investigators found great differences between different metals. The results were shown by photographing the castings

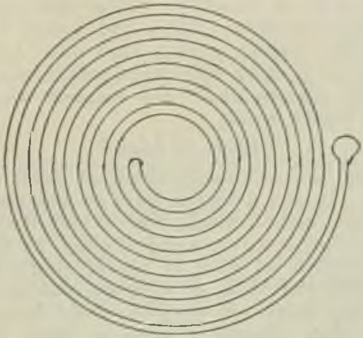

Fig. 1.—Plan of the Mould for the Japanese Experiments.

that were taken out and measuring their length, and, of course, the length of the castings was an indication of the fluidity of the metal. In every case the temperature of the metal at the moment of casting was taken—*i.e.*, the temperature when it was in the receiver and the feeding head—and the degree of superheat (the excess of temperature above the melting point of the metal) was recorded. They therefore had three factors: the degree of superheat, the temperature of the mould (which was kept as constant as possible), and the length of the casting; and so one obtained an indication of the fluidity of the metal.

Viscosity.

Now actually such a method as that measured what the foundryman wanted to know: the capacity for filling the mould; but that was not a single property, but was the resultant of several different properties. There was a property which was known scientifically as fluidity. If they compared together different substances which were not metals, they soon noticed the difference in fluidity, the difference in the ease with which they flowed. Ether, for example, flowed more readily than water; water flowed more readily than glycerine, and glycerine more readily than treacle. And so they spoke of the order of fluidity of the metals, or very often they spoke, instead, of the order of viscosity, which was opposed to the order of fluidity. Ether had a very low viscosity indeed, treacle a very high one; and so one might go on to other substances which became more and more viscous until one scarcely thought of them as liquid at all.

Pitch—A Liquid.

One did not ordinarily think of pitch as being a liquid. It was a liquid, only an extraordinarily viscous one, and it would flow if only they gave it time. If they hung up a rod of pitch by the upper end. in course of time it would flow; it would gather into the form of a drop, and at last the drop would break off, just as would happen with water if they allowed a drop to hang from the ceiling. But the order of viscosity was altogether different. The flow which took place in a fraction of a second in water might require several months in the case of pitch.

Testing of Viscosity.

The opposite of viscosity—usually expressed as the reciprocal of viscosity—was fluidity. Viscosity was a very important property of many substances, and they often had to test it in the laboratory. For example, if they were testing lubricating oil, they would want to know its viscosity in the course of routine laboratory tests, and the easiest method of determining it was by allowing the liquid to flow through a narrow opening. Suppose they had a vessel containing liquid and in the lower part of this vessel they fixed a narrow tube of known diameter, then they opened the end of the tube and allowed the liquid to flow through it, and noted with a stop watch the time that was required for a definite volume of the liquid to flow through. That was very easily done with apparatus which was sold for the purpose, usually called a viscosimeter. The more viscous the liquid, the longer was the time taken for a given volume to flow through. That was an accurate method. If they knew the diameter of the narrow tube, and knew the density of the liquid, they could then calculate its viscosity quantitatively.

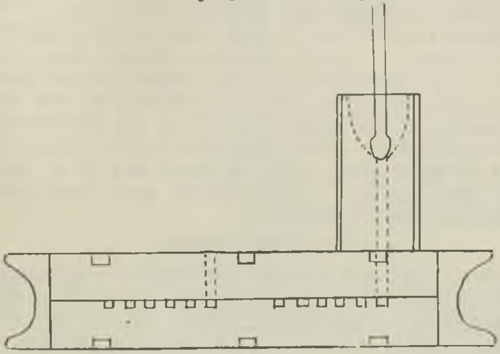

FIG. 2.—SECTION OF THE MOULD SHOWN IN FIG. 1.

Dr. Arpi's Method.

It was not a very easy matter to apply that method to metals, and, in fact, it had not been found practicable yet to apply it to cast iron or steel; but to metals which had relatively low melting points it could be applied, and that work was done with great accuracy a few years ago in Sweden by Dr. Arpi. The apparatus shown in Fig. 3 was rather a delicate one, but the essential part was a small receiver at the top, made of graphite, and connected with it was a long tube of fused silica which had bulbs blown on to it and ended in a very narrow tube, dipping into a little crucible made of graphite. This portion of the apparatus was enclosed in an electric furnace, which could be kept at any required constant temperature. There was an arrangement by which gases could be admitted. The great difficulty with metals was their oxidation, and in order to prevent this one had to keep an atmosphere of hydrogen or something similar in the vessel; and, in fact, in the actual experiments, hydrogen saturated with a vapour of methyl alcohol was used. The best method of carrying out the test was to place the molten metal in the little graphite crucible, and then, instead of allowing the liquid to run down by gravity, to draw it up by suction, and to find the time that was required for the liquid to rise from a certain mark to another mark. The time was noted, and that gave an accurate measure of viscosity. This apparatus having been very carefully constructed, it was possible to get quite accurate values for the true fluidity or the true viscosity of the metal, free from all interference by oxide films. The temperature, of course, was too high for glass, and the vessel had to be made of fused quartz. The method gave some very accurate results indeed.

Coil of Wire Method.

There was also another method for determining the viscosity of metals. Suppose they had a wire hung from a support and to the end of that wire they attached a weight in the form of a flat disc—a heavy weight, so that it would stretch the wire—and then they turned the disc through a considerable angle (perhaps through several turns) and released it. Of course, the wire untwisted, and the disc spun round. It overshot the mark and turned back again, and went on oscillating in that manner. If they carried that experiment out in air they found that it took a certain time to come to rest. If they turned it through the same angle, but with the disc in a vessel of water, they found that it came to rest sooner because the water offered a certain resistance or friction. If they carried out the same experiment in glycerine of course it came to rest sooner, and in that way they could measure the viscosity of the liquid. It was an accurate method, once one or two little sources of error had been eliminated, and it was a very convenient one. That also had been applied to metals. Dr. Fawsitt, in Glasgow, some years ago, made experiments of that kind, using a cast-iron disc for metals of low melting-point and a disc made of plumbago for higher temperatures. Obviously in the case of the plumbago there had to be a weight hung on the wire as well, to make the plumbago sink in the metal.

Results Obtained.

The results of the Japanese experiments were expressed in length of casting obtained in the spiral mould. Tin proved to be the most fluid of the metals; lead gave a casting very nearly as long, and zinc something very near to it. Then there was a series of bronzes, one containing 20 per cent. of tin and 1 per cent. of zinc, and another 10 per cent. of tin and 2 per cent. of zinc. The percentage of tin being so much lower in the latter, the fluidity was very much reduced. Aluminium gave a very short casting, the fluidity of that metal being very low. Then there were

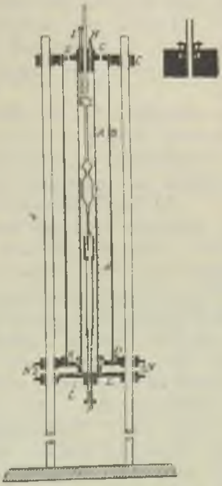

FIG. 3.—DR. ARPI'S METHOD OF DETERMINING THE VISCOSITY OF METALS.

some cast irons. Two grey irons were used—a Cleveland iron, which gave a longer casting than even tin. It was true that it had 140 deg. C. of superheat, but it gave a casting 3,250 mm. long —over 10 ft. A Chinese iron gave 2,822 mm. White iron gave the shortest casting of all—433 mm., only half as much as was obtained even with aluminium. Then a crucible steel was taken of a 0.4 per cent. carbon with 200 deg. C. superheat, and it gave 1,100 mm. This method, therefore, was found to be practicable for metals even of high melting-point. It did not measure fluidity in the scientific sense, but it measured what the foundryman wanted to know—the capacity for filling a mould.

The results obtained by Dr. Fawsitt's method of spinning a heavy disc were expressed in a figure known as the coefficient of viscosity. The measurements were taken at temperatures from 65 up to 215 deg. C. As the temperature rose, so the coefficient of viscosity became less, *i.e.*, the metal was more fluid. The higher the temperature the more fluid was the metal—that was the case for all liquids, with a few exceptions in the cases of abnormal substances, such as sulphur. Tin, at a temperature of 234 deg. C., which was only two degrees above its melting-point, had a viscosity about twice that of mercury, which was liquid at the ordinary temperature. At a higher temperature for the tin, that value had fallen. Lead, just above its melting point, was more viscous than tin; it also fell at a higher temperature. Bismuth had a low viscosity. That point was interesting. It was sometimes thought that metals were rather sluggish—watching a molten metal flowing, it seemed to be rather sluggish; but, when it came to measuring the true viscosity, it was found that most metals were only from two to three times as viscous as water. That was a rather unexpected result, but there seemed to be no doubt about it. Of course, that did not mean that they would fill a mould as readily as water.

Viscosity and Superheat.

If they compared together the different metals, they found that at any given temperature the order of viscosity was roughly the same as the order of the melting point. The higher the melting point of a metal the more viscous it was at a given temperature. In other words—and this was the point that interested the foundryman—the greater the amount of superheat the greater was the fluidity. Taking a metal melting at 200 deg. and testing it at a temperature of 500 deg., which was 300 deg. of superheat, then, at the same temperature of 500 deg., testing a metal which melted at 400 deg., and which had therefore only 100 deg. of superheat, it would naturally be expected that the latter would be more viscous or less fluid than the other.

Curves obtained for the more fusible metals by

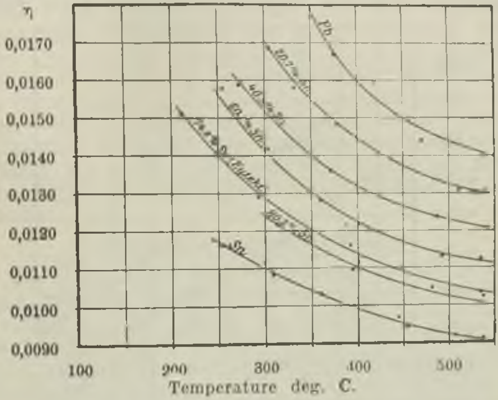

FIG. 4.—VISCOSITY OF LEAD-TIN ALLOYS AS MEASURED BY DR. ARPI'S METHOD.

Arpi's method were free from error. Different temperatures from 100 deg. C. to 500 deg. C. were plotted along the diagram, while vertically was plotted the coefficient of viscosity. Lead, which had a certain coefficient of viscosity, just above its melting point, 327 deg. C., fell pretty regularly with increasing temperature. The viscosity of tin was much lower, but that viscosity also fell with the temperature. If alloys of lead and tin were taken (the ordinary solders) and similar experiments made with them, it was found that in every case the viscosity fell with rising temperature along a curve very similar to the curves for lead and iron, and those curves for the alloys of lead and tin all fell pretty regularly between the curves for lead and for tin (Fig. 4). Solder containing three parts of tin to one of lead had the lowest melting point of all the solders. In Fig. 5 the results for the alloys were plotted in a different way and showed that the alloy which was mostly lead and contained only a little tin has a certain viscosity, and the alloys containing more tin had successively lower and lower viscosities. So that there was complete regularity in alloys of this kind, and everything seemed to show that if two metals were alloyed together, provided that they did not form compounds with one another, then the fluidity of the alloy would come between the fluidities of the two metals.

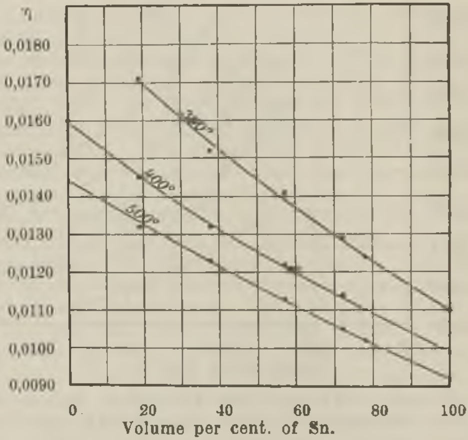

Fig. 5.—Viscosity-Temperature Curve of Tin-Lead Alloys.

The Complexity of Fluidity.

Fluidity, as understood by the foundryman, was not quite a simple thing. There were certain other factors that entered into it. Evidently one important factor was the true fluidity or the viscosity which he had been showing was measured in those different ways. But that was not the only one. If it were, then a metal like molten bismuth, which had a fluidity very little greater than water, ought to fill a mould with very great ease. But, of course, they had other properties to consider. In the first place, as the metal was going into the mould it was cooling. It was giving up its heat, and in time it would reach the freezing point, and when it reached the freezing point it ceased to flow into the mould. Evidently, therefore, the rate at which the metal gave up its heat would be an important factor. The specific heat of the metal came into consideration—that was a factor that affected the mould-filling properties. Then still more important was the degree of superheat. The hotter the metal was—that was, the higher the temperature above its melting point—the further it could go before it cooled down to the freezing point; so that, naturally, if they had to fill a complex mould having a large number of narrow portions, they required the metal sufficiently hot so that it should not freeze too soon. The degree of superheat was of immense importance.

Strength of Aluminium Oxide.

And then there was, with many metals, a certain apparent or false viscosity which was very striking. One would be inclined to say that aluminium was a particularly viscous metal. It gave, as they had seen from the Japanese results, quite short castings. The danger of getting a cold shut in a casting was great with such a metal as aluminium, and on watching aluminium being poured one would naturally get the impression that it was a viscous metal with very low fluidity. Now that was not actually true. Everything seemed to show that the metal aluminium was not really more viscous or not much more viscous than other metals. But, of course, aluminium had a remarkable property of oxidising readily, and, unlike most metals, the film of oxide that was formed on the outside had most remarkable strength. There was a very striking experiment which was sometimes shown. If an electric current was passed through a wire or a thin rod of aluminium and increased until the metal melted, the metal would not break through. It was possible to take one end of that wire and twist it through 100 revolutions or more without breaking it, although the wire of aluminium was actually liquid. This was because it was coated on the outside with a thin skin of oxide of aluminium, and that skin was so strong that it formed a bag which would suspend the metal. It was quite remarkable to take a little mass of aluminium and heat it up to a temperature which would not only melt it but would be hot enough to set it on fire, and yet as long as this bag of oxide on the outside remained unbroken the liquid metal would not escape, and would not catch fire. The apparent viscosity of aluminium was due to this skin. As the metal was being poured in a stream through the air that stream became enclosed in a thin tube of oxide which had the effect of viscosity, just as some liquids when they were in thin films had all the properties of being viscous. It was really only a thin skin that was concerned. That, he thought, was the main reason why aluminium tended to give these very short castings. The same thing, of course, was seen in other metals, although probably in no metal was it so striking as in aluminium or in magnesium.

Naturally, the chemical composition of an alloy played a great part in the result. The chemical composition might affect the fluidity of an alloy in several ways. In the first place, the presence of an impurity might alter the true fluidity, but that influence was not usually very great. The metals did not vary much in fluidity. The co-efficient of viscosity ranged from that of water, which was only just over 0.01, and that of the metals was not above 0.03, at most, so that mixing together different metals did not make a very great difference in the true fluidity. But it did make a very great difference in the apparent fluidity in this way.

Berlin Castings.

Suppose that an iron casting was required to fill a very intricate pattern.

Some years ago (he did not think it was the case now) certain firms in Berlin used to make some fancy iron-castings—which were very much sought after—such articles as fruit stands for table centres and so on. They were almost as delicate as silver filigree work, but were made by using only cast iron. They were known as Berlin castings. In order to get the very great degree of fluidity that was required for those elaborate castings, very high-phosphorus iron was used. From 2 to 5 per cent. of phosphorus was present in some of those castings. Brittleness, of course, did not matter, as they were not meant to stand any shock; all that was required was a perfectly clean casting in a very intricate mould.

Indirect Action of Elements.

Phosphorus might possibly increase the true fluidity, though this was by no means quite certain. it was possible—but it did very much lower the melting point of the iron, so that iron, being poured at given temperature, had a much greater range of temperature before it became completely solid when working with a high-phosphorus iron than when using a low-phosphorus material. The fluidity was increased in that way. Then, taking again the example of cast iron, it was common knowledge that silicon had a great influence on the fluidity of the iron, a high silicon iron producing more fluid iron. There, again, the effect was probably an indirect one. Supposing that a white iron with very low silicon was taken, with all the carbon in a combined state, one knew that it would be very difficult to get an intricate casting in that metal. In order to get the casting, the metal would have to be made exceptionally hot. In casting from a crucible, the requisite amount of superheat could be obtained, but in casting from a cupola one could not get the same degree of superheat, for reasons explained below. Differences would therefore be found between different grey irons. Taking three materials, a Swedish white iron, with all the carbon in a combined state; secondly, a grey iron, having relatively large graphite plates, and the carbon in the free state, with some areas that were free from graphite; and a third, where the graphite was in small particles distributed much more closely throughout the metal, so that there was no portion of the metal which was at a considerable distance from the graphite. Mr. Riddel read a Paper some time ago on the fluidity of cast iron, and he suggested that the great difference between cast irons in the cupola was that, if a cast iron, having large graphite plates, was examined, the greater part of the carbon would be in free condition—it was as graphite—the matrix in which the graphite was embedded would be practically a low carbon steel. In the cupola, the temperature that was reached was not much above the melting point of the metal, in the case of white iron. In a white iron casting the iron and the iron-carbide were very closely intermixed; they had a definite melting point. As soon as that melting point was reached, the metal melted, ran down through the coke bed, and collected in whatever receiver might be used there. The metal was obtained practically at its melting point; there was no chance of much superheat. As soon as the metal was liquid it ran down, and as the hottest part of the cupola was the point just where it was being melted it ran down practically at the melting point; it collected in the receiver with very little superheat, and this metal had to be used for casting at a temperature only just above its melting point. With a grey iron, this was not the case. The larger the graphite plates were the longer it took for the carbon to be absorbed by the matrix of the metal.

Why High Silicon Irons Carry Superheat.

Where they had very small graphite plates, there the absorption was more rapid. Other things being equal, high-silicon tended to favour these larger graphite plates, and a relatively low, combined-carbon matrix. Therefore the high silicon irons did not melt until a considerable degree of superheat had been obtained. The low-silicon irons melted almost at their theoretical melting point. That seemed to account very largely for the influence of silicon. It was probably not a direct influence on the fluidity, but rather an indirect influence, by determining the ease with which the carbon was taken up by the low-carbon matrix of the iron. The matrix of a grey cast iron, containing phosphide, was practically a 0.9 per cent. carbon steel. The phosphide tended to bring down the melting point very much, and to make the mass flow more readily, but liquid cast iron was not obtained until the graphite had been absorbed. The graphite was shown by large black masses, at considerable distances from some points in the metal, and a large superheat was required before these were completely dissolved, so that the fully carburised liquid iron was not obtained until a quite considerable degree of superheat had been obtained; hence more fluid metal resulted.

Evidently, then, the chemical composition was most important in its indirect effect—not in its effect on the actual fluidity, as measured by means of a viscosimeter, but in its indirect effect in altering the degree of superheat; and this was more marked in cupola practice than in crucible melting. Obviously, with a crucible or with an air furnace, any degree of superheat required could be obtained, but in the cupola they were limited by the temperature at which the metal melted and came down, and if the constituents were in such a form that they reacted readily with one another, as in a white iron, then it was impossible to get any great degree of superheat in a cupola without alteration of conditions. On the other hand, if the constituents were such that they reacted only sluggishly, then they did not get complete melting until there was a considerable degree of superheat, and consequently a hotter metal which ran more readily in the mould was obtained. That seemed to be the main influence of chemical composition.

Effect of Oxygen on Fluidity.

It would be very interesting to know whether there was a direct influence as well. In the case of steel it was known, of course, that the presence of oxygen affected the fluidity very greatly. In the presence of oxygen, one had a relatively sluggish metal, which did not run so freely. The dissolved oxide undoubtedly had a bad effect. The influence of other elements was comparatively little known, and there was one point on which the author would welcome discussion, and that was:—What was the influence of very high silicon? In Sheffield it was the practice to make steel containing a high proportion of silicon—4 per cent. or thereabouts—for electrical purposes, and he had never been able to get a quite definite opinion on the point whether that metal was more or less fluid than a steel of the same carbon content with only the ordinary proportion of silicon. As to the influence of other alloying metals, very little information seemed to exist. There must be differences in fluidity, but they were so complicated by other factors that it was not easy to say what was the actual influence of added metals on the fluidity of such an alloy as steel. Apparently that was a point on which much more definite information was required, and probably it would be wise, when a programme of foundry research was being planned, to include actual quantitative experiments on the influence of various metals on the fluidity of steel and of cast iron. There was also, in cast iron, the question of the possible presence of oxygen, which was raised by Mr. Shaw at the Annual Conference of the Institution. This was a very puzzling question, which could by no means be answered offhand, but in discussing that question of the possible influence of oxygen on cast iron it would be interesting to consider, among other things, the influence of the oxygen on fluidity. He hoped it might be possible to attract the attention of some more scientific men to the problems of the foundry. This had been a curiously neglected field of metallurgy. When it was considered all that had been done on the processes of the manufacture of steel, on the mechanical treatment of steel, heat treatment of steel, and so on, it was surprising how little had been done on the properties which were all important in the foundry. It was a matter on which accurate data was needed, and it would be well if the foundrymen, in their own organisations, could call the attention of the scientific world to the real need that there was for accurate information on this among other points affecting their industry.

DISCUSSION.

Dr. W. H. Hatfield, in opening the discussion, said he thought the lecture was typical of that real assistance which they as an Institution could expect from the University. Dr. Desch had dealt with a problem of the greatest practical importance in a delightful and scientific manner. Of course, as he had pointed out, they in Sheffield were essentially interested either in the fluidity of steel or in the fluidity of cast irons, and those metals lent themselves somewhat indifferently to the quantitative methods of investigation as described by Dr. Desch. The Japanese method was a very interesting one, but of a distinctly practical nature. The other method, with certain very considerable refinements, might be made applicable to cast metals. But turning from that side, he suggested that there was, amongst observant foundry people, more information concerning the true viscosity or mobility of molten iron and the influence of the varying elements on iron than had been available to the Professor. The published quantitative data bearing on this subject really was very scanty. We lived in an age of applied science, but the viscosity of liquid metals was only one of those regions where quantitative evidence was strangely lacking. There was not a single physical constant of the metals which had really been put on to a satisfactory basis by intensive research in the way that it should be, particularly now, when so much money was being spent on research. It could only be hoped that those vast sums were being diverted into channels where they would be of real use—which he very much questioned.

Cupola Capable of Superheating.

Viscosity, temperature and composition were the essential factors in steel and iron works, and he should like to assure the lecturer that he personally, and a number of his friends, did not feel that absence of real knowledge on this subject which would be apparent from what they had heard that evening. He was not in any sense deprecating what the lecturer had said, but, to take cupola practice, he was afraid the lecturer had rather left in the minds of his hearers the feeling that the cupola was somewhat ineffective in providing the superheat required for the running of castings. Now such was not the case. It was within his experience, and the experience of a number of practical foundrymen, that they might melt white iron in the cupola and get all the required degree of superheat. Similar conditions exist for grey, hematite, and phosphoric irons. The only point on which he was in real disagreement with the lecturer was that he could not follow him with his equilibrium diagram in his explanation of the variable behaviour of grey iron as against white iron in the cupola. When they heated an iron to a certain temperature it rapidly attained equilibrium for that temperature. It was within the experience of many of those who were interested in the case-hardening process—the cementation process, that if they heated wrought iron up to 1,137 deg. C., which was the eutectic point, it rapidly attained equilibrium as regarded composition in contact with the carbon, and very soon attained 4.3 per cent. of carbon, which was the eutectic, and melted. He suggested to the Professor that in a cupola the grey iron very rapidly indeed melted, owing to the fact that the response to the conditions of temperature and composition were such that equilibrium for that temperature was immediately reached—reached at the velocity of other chemical and physical reactions, with which they were familiar. Therefore that disability was removed. It was quite clear, then, that the explanation, which he understood was Mr. Riddel's, was an unsound one, and was untenable.

The Effect of Silicon on Viscosity.

The lecturer had outlined the influence of silicon, and asked whether there might not be a direct influence in decreasing the viscosity of the metal. He could assure Dr. Desch that the effect of silicon was to increase the viscosity. If the very valuable work done by Wüst and Petersen* was studied, it would be found that the increase of silicon to the iron-carbon system decreased the solubility of carbon in iron. To take a foundry iron containing 3 per cent. of silicon, the eutectic for that series contained something like 3.5 per cent. of carbon, as against 4.3 per cent. for the simple iron-carbon eutectic, and therefore in practice it would be found that silicon decreased the viscosity by reducing the carbon content of the eutectic, and incidentally increasing its freezing point from 1,138 to 1,185 deg. C. It was a somewhat subtle point, but what he was saying was completely established by the fact, well known to many foundry people, that if they wished to make the finest castings they purchased the Swedish white iron which had the eutectic of the iron-carbon series, containing something like 4.2 per cent. of carbon, and it was owing to that very

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* Metallurgie, Vol. iii., pp. 811–820.

high carbon content of the Swedish white iron that such things as belt fasteners were cast with the greatest ease. In foundry irons one went up to 2.25, and even 3 per cent. of silicon, and those foundry irons had really a higher melting point than the Swedish white irons. Turning to the white iron series, it was clear to all of them that if they used too much scrap in the cupola they got a sluggish iron. The explanation was quite simple, on the hypothesis put forward by Professor Desch. It was a reduction in the carbon content, and instead of taking the eutectic alloy they were dealing with an alloy which was nearer to the steels. It was quite clear to him that if they had a sufficient degree of superheat, and if their composition was suitably controlled, as regarded cast iron they need have no worry concerning its fluidity, and he ventured to suggest that it was worth the while of the foundry industry to look into the matter from this point of view. There was much data and much knowledge available in the foundries, and if they would go forward and place in the lecturer's hands that large mass of practical experience which they possessed, he was quite sure Dr. Desch would correlate it with known physical laws, and so build up a fund of knowledge which would be invaluable to all of them in their foundry practice.

Oxides in Steel Castings.

As regarded steel castings, viscosity was purely a function of temperature and composition. They all knew, if the carbon was slightly increased in the steel, what a great difference it made to the running of the material. In passing, Dr. Desch had referred to the dissolved oxide. He (the speaker) must lay it down, as a result of long experience and much investigation, that in a Sheffield steel foundry, at any rate, *oxide of iron should not occur*. Oxide of silicon might, oxide of aluminium might, but oxide of iron did not remain in a properly made steel casting.

Fluidity of Electric Steels.

Mr. F. Darley asked whether Professor Desch could give any information with regard to the fluidity of steel from the electric furnace. Recently, he had experienced some trouble with "blobs" on the bottom side of the castings, furthest away from the runner, which gave him the idea that it was on account of the steel not being fluid. The steel of which he was speaking was about 0.2 carbon, 0.17 silicon, 0.015 phosphorus and 0.4 per cent. manganese. If they increased the silicon, say, to 0.3 or 0.4 per cent., the manganese to about 0.7 to 0.8 per cent., and the phosphorus to not exceeding 0.06 per cent., would that have any effect on the fluidity of the steel? Would that have a tendency to overcome some of the difficulties of which he had spoken? He was speaking of steel from the electric furnace. They did not experience any trouble of that kind when they used the Stock furnace.

MR. J. SHAW said he was quite in accord with Dr. Hatfield with regard to cupola melting. He thought it was quite clear that they obtained fairly fluid metal from white iron, for malleable purposes at all events, but its "life" did not last very long. The metal set very much more quickly than grey iron, probably due to high phosphorus, but not necessarily so, because hematite could act similarly. As regarded actual data for fluidity, Dr. Desch had thrown out several hints to them, but personally he knew of no method except one similar to the long tapering strip that had been described. He thought that was fairly universal, both in this country and in America.

Divergent Views on the Presence of Oxides.

With regard to oxidation, he thought Dr. Hatfield was wrong. They had the positive opinions of equally prominent men, who were quite certain that there was oxide in steel.

DR. HATFIELD: What is the evidence?

MR. SHAW said the evidence was this, that in certain definite laboratories that were set up for the purpose, oxide had been found. Pickard, in his Carnegie research, found oxidation in what he called a white iron, which was a perfectly grey iron.

DR. HATFIELD: There is not any evidence in existence to-day to show that there is oxygen combined with iron in cast iron.

MR. SHAW: What about Pickard's research? Can you prove that it is not so? Are there any methods existing whereby it can be proved that there is not? I beg to differ with you. The two American papers that were published recently state definitely that one cannot by any known method make a true determination of oxygen in iron.

Dr. Hatfield: This is a subject open to direct research, research which we have conducted, and I suggest other people should conduct it. Then, instead of talking about it, we should have evidence. I have evidence, and am quite satisfied.

Mr. Shaw: I can only repeat that the bulk of evidence given by those who are equally qualified and who have conducted research work is against you.

The Importance of Specific Gravity.

Mr. J. R. Hyde said there was much that they all wished to know about fluidity. They were trying to find the basic trouble. Some said it was oxygen; others ascribed it to absence of silicon or phosphorus. After the able case that had been put for both sides, they still felt that they wanted some accurate research. Dr. Hatfield had referred in a theoretical way to the fact that the difference in the specific gravity of the metals, as tested by the Japanese research, would have some influence on the running capabilities. For instance, most of the metals had specific gravities of about 7½ to 9, and it was obvious that 12 in. of head for a metal of that gravity would give distinctly bigger pressure at the bottom than would be the case with aluminium, which was only about 2.6. He would like to ask whether the Japanese workers had made any research in which they had controlled that definite pressure at the bottom. Did they make any attempt to balance it? Every practical moulder knew that he must always take into consideration the amount of head in casting anything.

Moulders Relieved from Responsibilities.

Engineer Captain Moorshead said he had had experience of a large number of inquiries on defective castings. Prior to the war, naval construction was to a great extent held up by faulty castings. The whole of the steam run of the "Iron Duke," the ship he was building, was kept back for three or more months because of the non-delivery of the steel castings, of which many were failures. He hoped that, with the experience of the war, this difficulty had been overcome. From his point of view, all these inquiries always turned on the pattern-maker, the foundryman, and the steel maker. Dr. Desch had been a good friend to the foundryman, because he had definitely established that it had nothing to do with them, but was purely a question of the steel maker. If the latter maintained the proper superheat, then they would get the proper steel and the proper casting. He foresaw that in all future inquiries the foundrymen would say, "We are all right, we have done our job; it is the steel maker who is wrong, and if you don't set him right, and go in for research, and show him how to run the material and get the proper temperature there, until then we cannot do any better." He thought that from that point of view the lecturer had relieved the foundryman of a very great responsibility.

Lead in Admiralty Brasses.

The Japanese experiments were very interesting from a certain point of view, but it was a pity they were not elaborated, and that the workers did not carry out a series of experiments with varying degrees of superheat, so as to see what effect that had on viscosity and to arrive at something definite with regard to that. He noticed that in the bronzes viscosity was very much reduced when lead took part in the composition. Well, that had always been rather a sore point with the foundry with regard to Admiralty practice, and he thought the point arose in a Paper read before the Institute of Metals this year, in which the lecturer took exception to the conservative view of the engineering branch of the Admiralty, that they would not have any lead in brasses. He (the speaker) thought that the Engineer-in-Chief, who was in the chair, took the proper view when he said that they in the Service did not consider themselves specialists in that way, and they had such a broad field to enter that, when it came to a case of that sort, they had at their back the scientific world and many scientific advisers, and it was on scientific advice that no lead was allowed in Admiralty bronzes or brasses. Perhaps Professor Desch might throw some light on the great objection to lead. He had met with many failures, and he supposed that the high-strength bronze which was required in the Service for the high pressures of hydraulic work and for torpedo work resulted in many failures, and the suggestion that had always been put forward was that if a certain amount of lead was allowed then all would be well. Of course, those who put that suggestion forward knew that they were not allowed lead, so that that was one way of "dodging" the subject. He thought that if Professor Desch would give some definite lines on which research might be made, bearing in mind the practice that foundrymen had always in front of them, they might get some tangible result with regard to production.

Mr. T. Brown said he had repeatedly complained that the metals which they were getting at the present time from certain furnaces were not fluid enough. He had made experiments to see how far metals would run, but the Japanese method, which had been explained that night, had given him an idea for a better experiment than he had made himself. He was afraid that if they did they would find a very defective piece of steel where it had solidified and frozen at that particular angle. They might get a good piece at the end where it had been run in, but not where it stopped running. His experience was that, within a distance of 2 ft. to 2 ft. 6 in. of where a casting was run there was sound casting, but beyond that distance it was full of small holes. The casting itself was perfect, but the holes were revealed on machining. He contended that this was owing to the steel not being sufficiently fluid or the temperature not sufficiently high to travel that steel to its destination.

The Lecturer's Reply.

Dr. Desch, in reply, said he was naturally very much interested in Dr. Hatfield's remarks, and in fact he was particularly anxious, in giving the Paper, to get some expressions of opinion from those who had practical foundry experience, his own being mainly in non-ferrous practice. He quite agreed with Dr. Hatfield that there did exist amongst foundrymen a great deal of practical knowledge on this subject, but it had not found its way into print. He had searched through the volumes of the Proceedings of the Institution, and found very little indeed. The text-books and other publications, contained scarcely anything, and it would be a very good thing if foundrymen could put together some of the knowledge which they undoubtedly possessed on the practical difference between metals in regard to their fluidity. For his own part, he should be very grateful to receive any practical information of that kind, which one could make use of in a discussion of the subject. He had had to go on a very small amount of data. Dr. Hatfield expressed the hope that Universities would be able to undertake work of that kind, and referred to the possibly unlimited funds for research. He (the speaker) was sorry to say that those funds were very strictly limited. The Universities just now were in a most difficult position. They were having the greatest possible difficulty in meeting their ordinary expenses, and every British University this year had a heavy deficit. An appeal was made by the Universities to the Government for additional help, and the Government had replied by cutting down the University grant for next year by £300,000.

Head Pressure Constant.

Reference had been made by Mr. Hyde to a source of error in the Japanese experiments owing to the varying amount of pressure in the head. He should say that although that was not thoroughly provided against, it was very nearly. The Japanese did not use equal volumes of the different metals, but equal weights—40 kilogrammes—which would give a practically constant head in each case. It was a huge head, very much larger than the amount of casting, so that, having equal weights, that meant that for aluminium there was a much bigger volume of metal in the head than there was for the iron, or the lead or tin.

Cupola Super-heating.

He was very interested to hear Dr. Hatfield's remarks about the cupola, and he (the speaker) might quite possibly be wrong in that. He had derived most of his information from Mr. Riddell's experiments, had talked the matter over frequently with him, had seen his results, and examined the products of casting in different ways, and it seemed to him that the explanation was on the whole fairly correct. He did not think, somehow, that equilibrium was reached quite as quickly as Dr. Hatfield suggested. But he was very interested to hear that it was possible to melt white iron in the cupola with a considerable amount of superheating. He should like to ask Dr. Hatfield whether that was in a cupola in which there was more than one row of tuyeres.

Dr. Hatfield: No, just the one row.

Dr. Desch: Then how do you get your superheat, because one would think that the whole of the metal was melted above the tuyere level?

Dr. Hatfield: No, it is everyday experience in all malleable foundries. Of course, in melting a white iron one might run with a fuel consumption of 3.5 cwts. per ton of iron melted, but where one is melting grey iron one may run on a fuel consumption of 1.75, that is half the fuel, and therefore there is a complete substantiation there of the argument which I placed before the Professor. These facts are well known to anyone in foundry practice, and may be confirmed.

Dr. Desch: I think that is the explanation—that when you are getting this white iron casting for your malleable purposes you use a high fuel consumption, and you therefore force it up to a higher temperature. That is the fact which I had overlooked. The superheat is obtained in that case, certainly. That does undoubtedly explain my difficulty. I was speaking of casting under ordinary conditions, and of foundries where no malleable iron is produced. The experience there is that if it is tried to run a white iron under the same conditions at which grey iron is cast it runs cold. But the two things are quite consistent, because Dr. Hatfield has now supplied the information which I did not possess. I am very interested, also, to hear his account of the influence of silicon in its actually increasing the viscosity, but I did not get an answer to the simple question of the case of steel, as to whether that 4 per cent. silicon steel is more or less fluid than a steel of the same carbon content. (Dr. Hatfield: Yes, it is more fluid.*)

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* See Guertler and Tammann Zeitschrift für anorg Chemie, vol. xlvii., p. 163.

More Opinions on Oxides in Steel and Iron.

Dr. Desch went on to say that when they came to the question of oxide in steel, then he must frankly say that he did not agree with Dr. Hatfield, and he had told him so before. He had on his side other authorities, such as Dr. McCance. He could not explain the behaviour of steel otherwise than by assuming a marked solubility for the oxide in the liquid steel. As to its being present in cast iron, that was still an open question, but he thought there was some evidence. There was in Greenland a mass of native iron of enormous size. It was formed below the surface of the earth by the reduction of a basalt containing large quantities of iron oxide by carbon. It was a mass of native cast steel, practically. In that steel there was a very remarkable eutectic. It was the eutectic of iron carbide and iron oxide—a very beautifully formed carbide-oxide eutectic. Undoubtedly this was due to the fact that it was produced below the surface of the earth and under pressure, so that the gases were not able to escape freely, and the equilibrium between oxide of iron and the two oxides of carbon was upset. But since a very large solubility was obtained—because this eutectic had been formed from liquid—under that pressure it seemed to him all the more likely that under atmospheric pressure they had a decided solubility.

Lack of Fluidity in Electric Steel Explained.

That also had a bearing on the question of Mr. Darley, who referred to the difference in fluidity between two steels of the same composition, one coming from the electric furnace and one from the Stock converter. Now he had been repeatedly told in foundries that this difference was regularly found when finding the temperatures of two steels with the optical pyrometer to be equal, taking one steel from the electric furnace and the other from a Tropenas converter. It was said that the converter steel maintained its "life" in the ladle longer than the electric steel. Supposing that to be the case—and he had been told by several experts that it was so—then his explanation was this: that the metal from a converter was not dead, that the reactions were not finished, that it contained dissolved oxide which was reacting with the dissolved silicon and manganese, and heat was continually being evolved; whilst the electric steel, on the other hand, was dead, and its reactions had finished. There was an internal source of heat in the converter steel, which was not present in the electric steel. That was the explanation he put forward. It was purely hypothetical. As he had said, they had not the data for the direct influence of these elements on the fluidity. So far as altering the melting point by bringing it down, of course there was an effect, but the relatively small changes suggested would not alter that very greatly.

The Lead in Brass Query.

Captain Moorshead had asked a question about the effect of lead on bronzes and brasses. Since he knew that in Sheffield the non-ferrous foundry industry was a comparatively small one, he made very little reference to bronze or brass casting, but of course it was well known that the fluidity of bronze or brass was very greatly increased by the presence of lead. The Japanese artistic bronzes always contained a very high percentage of lead. The statuary bronzes made by European firms contained zinc and lead in addition to tin, so as to increase the fluidity. This gave a metal which flowed readily into the mould, and took a quite sharp impression. For artistic work, they undoubtedly wanted a high percentage of lead. But it did not follow that they wanted lead in Admiralty bronze, and he must say that, having gone into that question a good deal, he was of opinion that the Admiralty was quite right in maintaining its limit to the lead-content in bronze. The experiments which had been published lately certainly showed that an inferior tin-bronze was improved by the addition of lead, by which they could get sounder castings, and could send up the tensile strength quite considerably. But they would not increase the tensile strength that they could get in a good tin-bronze, and a few of the firms that made Admiralty gun-metal, and took care that it was not overheated or oxidised, and also took great care about the scrap that they put in, got much better results than any of those firms that added lead. All that the lead did was to improve the soundness and remove oxide from an inferior bronze, but as soon as they had a good Admiralty gun-metal the quality was lowered at once by any addition of lead. Of course, for certain purposes, they wanted lead there for ease of machining, but the Admiralty put up with the greater difficulty of machining for the sake of higher quality of metal.

Blowholes.

The question that was asked in regard to the presence of the little blowholes was a little difficult to answer without looking carefully into the castings. The blowholes might be due to excess of dissolved gases or to imperfect fluidity, both of which were factors contributing to the porosity of castings. He had not made any reference to the influence of dissolved gases, which he thought was a question that needed a good deal of attention. The fluidity of a liquid was quite considerably altered by the presence of dissolved gases, and to what extent it was altered, or in which direction, was a matter for research in each case. They could not predict it: it required a definite amount of research to find how far the fluidity of a metal was influenced by these dissolved gases. It was quite possible that some of the differences which had been observed between electric steels and crucible steels, for example, might depend on differences in the quantity of dissolved gas, but at present the amount of research that had been done on this subject was altogether inadequate.

The Branch-President, in expressing the hearty thanks of the meeting to Dr. Desch, emphasised what had already been said on the importance of collecting the practical information on these subjects that was in the possession of foundrymen, and bringing it forward.

Lancashire Branch.

AN IDEAL FOUNDRY.

By W. H. Cook, M.I.M.E.

At a meeting of the Burnley section, held on December 6, Mr. J. Hogg presiding, Mr. W. H. Cook, M.I.Mech.E., delivered a lecture on "An Ideal Foundry," in which he considered the matters which would come up for decision in erecting and equipping a foundry suitable for producing repetition work in fairly large quantities of medium weight castings.

Ventilation.

Dealing with the building itself he said that in the past the moulder had had to work under bad conditions, and even in modern foundries the conditions were far from ideal. Some were outwardly very pleasing to the eye, built of pressed brick with close joints neatly pointed, and with pillars and recesses of decorative design; but inside there were rough ordinary bricks and wide, unpointed joints, which provided resting places for dirt and dust, and made it impossible to sweep properly the walls or to whitewash. If pressed bricks could not be afforded both inside and outside, he would put the common bricks outside, and use the smooth pressed bricks internally. To facilitate cleaning and prevent the accumulation of dust, all the corners should be rounded, not square. He did not believe in lofty walls. If it were not intended to instal a travelling crane he would not exceed a height of 14 ft. to the eaves. In the construction of the roof he would depart entirely from the present-day practice, and follow the methods adopted in the latest weaving-shed designs of carrying the roof upon beams placed outside, and making the inside as smooth as possible. It should all be painted or whitewashed. To ensure light and brightness there should be as much glass as possible.

If it was necessary to have a travelling crane and the roof was high there should not be a depressing blank wall but a side light should be incorporated. Often a foundry was darkened by the rising steam and fumes. To overcome that trouble a ventilation expert should be called in, the conditions pointed out, and he should be instructed to devise the best possible scheme to carry away such fumes and dust and pass them into closed vessels of water in order to prevent their being deposited upon the windows or scattered through the neighbourhood. Were it possible every foundry should be compelled to put in mechanical ventilation, which would ensure proper air circulation even on the damp, muggy and foggy days. In the lecturer's foundry there was a signal proof of the advantages of mechanical ventilation. During the war this foundry was called upon to make large quantities of a 40 per cent. zinc mixture, and there were five or six men pouring throughout the whole of the day. This mixture gave off a white cloud of zinc oxide, which had a bad effect, even if only one was pouring. With six it was unendurable. A ventilation expert was sent for, and he so arranged the ventilation that no matter how many were casting or how much fumes arose, the atmosphere was cleared and made fresh in less than half a minute. The brass foundry was now the healthiest part of the shop. It suffered very little when influenza was raging.

Cupola Equipment.

It was very difficult to advise about the type, but on two points he had no hesitation: he would not have two heights of tuyeres, nor would he have the blast from only one side. The most successful cupola they had at work was 30 years old; there was no belt; the blast passed in at two tuyeres opposite to each other. The results were very satisfactory: hot soft iron, reasonable coke consumption (2½ cwt. to the ton); a good average life to the lining. They had none of the troubles due to fusing of the lining. This he attributed to the fact that the air inlets were of large area, about one-seventh of the area of the cupola. A Keith-Blackman combined electrically-driven fan was particularly efficient and economical. The full blast pressure was 10 ozs. These results were not often surpassed, and the simplicity of operation was very pleasing.

Some years ago he was told of some marvellous melting results, using 1¾ to 2 cwt. of coke per ton of metal all in, at a foundry which turned out in jobbing castings about 30 tons per week. He was surprised to find the cupola was a home-made affair adapted from a boiler casing with two side pipes, no belt, and ample air inlets. When he tested he found the reports were justified. After such experiences why should one instal a complicated arrangement?

The Lay-out of the Cupola.

The position of the cupola was a matter of importance. As generally fixed the spout projected into the foundry, taking up much space and making the appearance untidy. He suggested that it should be put farther back, with a wide and high archway for approach, a large, covered-in stage to allow of good storing, with a self-registering weighing-machine sunk level with the floor, ensuring the charges being as desired from day to day. Another suggestion was to put a light roofed building over the pig-iron, coke and scrap stores. The cost would be more than repaid by the saving of fuel and labour in the wet winter months.

Plate Moulding.

The best system of plate moulding that could be found should be installed, and the plates should be finished as smoothly as possible, because the moulder could only give castings which were replicas of the pattern. A principle which he strongly recommended was that the patterns should all be made to part across a dividing line. In the case of a symmetrical pattern the line would be through the centre, in the case of irregular patterns the most prominent point would be chosen.

In every pattern there was some suitable point. Even if the patterns were being used loose there was a decided advantage, as one part could be rammed on a flat board, then turned over, and the other part put into position for ramming in top part. This would save trouble for odd sides, jointing, and loose sand, which caused so many dirty castings in loose pattern moulding.

Plate-moulding Boxes.

The next point to decide was the sizes of standard boxes. There were many different opinions, but experience showed that a man would give a bigger production on boxes which were not too heavy; 18 in. × 14 in. was his maximum for one man to handle, and he preferred 16 in. × 12 in. or even 14 in. × 12 in.

Using the Plates.

Difference of opinion existed as to the method of using the plates, whether on the bench, on the floor, or in a machine. His experience was that with the hand-rammed, self-drawn machine the production was 10 per cent. greater than with the other methods, with less fatigue to the worker. Any intelligent person could be taught to ram and work the machine, and he should become quite efficient in one month. Only four thousandths of an inch play was required between the hole and the pin, thus avoiding twisted castings, and they could draw deep patterns without turning over.

Space Requirements,

The average space for each man should be 30 sq. yds. An area of 6 yds. × 5 yds. was sufficient with the ordinary small castings, but for large ones 40 sq. yds. was required. The man could produce, if he willed, at least 80 boxes per day; probably he could do more.

Jar Ramming

The question might be asked: " Why not install jar ramming machines? " He had studied that matter for some time, and had visited other foundries to see what they were doing, and he had not yet seen a machine suitable for the shallow boxes his firm used; there was not sufficient weight of sand to give ramming pressure. Perhaps this difficulty might be overcome in the future, if so they would go farther into the matter, but so far as their inquiries had gone jar-ramming, with its overhead charges for upkeep, did not show any great saving. In fact, it was a long way behind the Lancashire plate moulder. He knew that in the Burnley district press machines were common, and did satisfactory work. It was a question of custom.

Overcoming Sand Troubles.

He came now to what, in his opinion, was one of the most important points in relation to the production of clean, smooth and sound castings. That was a question of sand. By far the greater proportion of blown and dirty castings were due to the sand; they were seldom produced by the plate moulder, but arose usually from the loosening of the sand when rapping in loose pattern moulding. Many years ago he instituted a system under which on a particular day each week the bad castings were laid out and a clerk made a report, in conjunction with the foreman moulder, as to the faults, the cause of them, and the financial loss which arose from them. This procedure had very satisfactory results, the percentage of bad castings being reduced from about 6 to 2½ per cent. upon an output round about 120 tons per week. They found out how the losses arose. One moulder after casting up and knocking out his boxes would turn his sand over, water it, turn over again and leave it in a neat heap until the next morning. This allowed the moisture to permeate the mass. Another moulder would knock out his boxes and then leave everything. The next morning he would throw water over his sand, and cause some of it to resemble slush. Hard and blown castings were the result. Experience of this led him to insist upon every moulder following the former course, and ever since he had had in his mind the necessity, in an ideal foundry, of a system by which every moulder would be supplied each day with properly tempered sand. Up to the present he had not seen one which was quite satisfactory, but if he were erecting a foundry he would install the best one he could find. This, combined with the use of the proper quality of blacking and coal dust, would remove many difficulties.

Shanking Metal.

With regard to the carrying of the metal he had always considered that to carry it from the furnace in the shank was both dangerous and laborious, but it could only be replaced by the trolley ladle, and unless everything was systematically carried out the metal might become too stiff before pouring. To remove the possibility of delay as much as possible he recommended making the trolley axles dust proof, and using ball- or roller-bearings and cast-iron plated runways kept clean and free from obstruction.

A full supply of the necessary small tools, such as brushes, riddles, etc., should be kept.

Core Shop Suggestions.

He could say nothing very special about the cores except that he would certainly have that department isolated from the general foundry, with ample drying stoves and storage space. Every core should be numbered, and a certain number always ready in a place from which they could be given out to the moulder without his going into the core shop.

He was a great advocate of employing women in making small cores, on account of the greater neatness of their work. There were so many stoves to choose from for small cores, each satisfactory to a point, that no definite advice was necessary except to see that an outlet of large area was provided for the steam, etc. Cores did not require a great heat, but the moisture should be got away as freely as possible.

Trimming Shop Notions.

Great attention should be paid to the dressing or fettling department. It ought to be as pleasant to work in as any other, but that was not the case at present. The first step he would take was the provision of a system of runways to carry the castings from the foundry to the rattlers in tilting skips. The barrels should be constructed with the shaft running in roller bearings, the shaft not to go inside the barrel. The gearing should be at one end only, and there should be no strap to the framing underneath. This would remove any danger of accident, and allow of the castings being easily dealt with when the barrel was emptied. Finally, the whole machine should be enclosed by a sliding cover, with dust pipes attached and connected to a fan, thus carrying away practically all the dust into a water tank. There it would settle and could be periodically removed. He would provide ample emery grinders, all connected to the same fan. Finally he would have runways to carry the castings to the weighing-machine and the stores.

Ample storage boxes were needed, and also space for the examination of the castings before putting them into the boxes, so that any unsatisfactory ones which had passed the dresser would be thrown out and charged to the moulder, or rejected before any machining cost had been added.

Costing Department.

The costing department was often neglected, but he attached as much importance to it as to any other part of the foundry. But in arranging the method of costing he would take great care not to carry system too far. It should not be introduced if it made the fixed expenses too high.

An experienced foreman would keep things straight, and he would certainly appoint the best foundry manager he could find, who knew his business and was strong but just. To such a man he would give absolute control in regard to the workmen, reserving to himself the purchase of materials, the determination of the selling prices, and a fair criticism of results.

DISCUSSION.

Mr. Pell said if Mr. Cook would start a company to build ideal foundries it would undoubtedly be a good thing for the members of the Institution, but some of the points made in the address were open to criticism. Fourteen feet was a very low level for the roof. One must remember that the employer was expected to provide so much cubic feet of air for every human being employed on the premises. If the 14 ft. gave them that amount no doubt it would be all right.

In his time he had heard a good deal about cupolas, and he expected to hear more. The fusion of linings had caused him much trouble, and he raised the question at a meeting in Manchester, and the conclusion arrived at by some of the members was that his tuyere area was not sufficiently large. Since then he had made his tuyeres 4½ in. dia., instead of 4 in., and he proposed to increase it to 6 in. when he rebuilt.

Speaking of blast pressure, Mr. Pell said he was working with 15 ozs. According to Mr. Cook, such blast pressure should result in hard iron, but he had not found that to be so. The iron produced was not hard; some of it machined extremely well.

Replying to questions put by Mr. Barnes, Mr. Cook stated that they weighed every ounce of coke that went into the furnace, and every ounce of iron. With regard to the trouble from steam, he advised the employment of mechanical ventilation. An expert should be called in and a fan of sufficient power installed.

Mr. Layfield said he had been concerned in putting up a new foundry, and many of the points mentioned by Mr. Cook came up for consideration. On the whole they were in agreement with Mr. Cook. But his insistence upon mechanical ventilation was rather alarming. They were taking the walls up 15 ft. to the eaves, and putting in louvre ventilators; so, from what had been said, trouble was to be expected. They had no rounded corners, on account of expense. With regard to the plaster mould in a jobbing foundry many things had to be delivered the next day in lots of twenty or thirty. Such could not be done without the use of plaster moulds, which were satisfactory for a small number of articles. When 100 or 200 were required the plaster mould was no longer useful. For carrying the metal they had an overhead system which he thought was the best. The metal was carried overhead on a single girder upon a trolley. It was much quicker than carrying on the floor, but there was some difficulty when there were a lot of byeways or corners to run round. With a straight run the overhead system was certainly preferable. Could Mr. Cook give any information as to the value of the sand blast for small castings and was it worth while to install such a plant?

Mr. Cook replied that he had not mentioned the sand blast because it was so many years since they studied the question and decided that it was unsuitable for their work. It did not compare at all with barrelling and the ordinary methods of dressing. It was expensive. It was a better job in some cases but not in others. He did not approve of putting in louvres for ventilation purposes. They were of no use except upon a bright day, but the foundrymen had to make provision for the damp, foggy days—say, in November. With mechanical ventilation it did not matter how foggy a day might be, outside went the air. In the end mechanical ventilation was cheaper.

A vote of thanks to Mr. Cook concluded the proceedings.

London Branch.

SAND BLASTING.*

By E. L. Samson.

Probably all foundrymen agree that the fettling shop is one of the most unpleasant spots to be met in the foundry. In some cases attempts have been made to improve conditions, but one of the chief remedies is still wanting in most foundries, *i.e.*, a properly designed sand blast equipment and dust-exhausting arrangement. It is strange that sanitary factory inspectors are not giving this keener attention and insisting upon sand-blasting preceding final fettling operations. A properly sand-blasted casting, however complicated the cores, should be quite free from caked sand and powdery surfaces, allowing the final fettling operation, such as chipping and grinding, to be done without raising clouds of dust, adding to the practically unavoidable trouble of metal dust arising from the grinding operation. But from a purely commercial point also, sand-blasting pays, as shown by the following figures taken from actual practice:—

(1) To clean a machine frame 1 ton in weight, size 8 ft. by 12 ft. combination cored and straight work—

Hand cleaning	2 hours
Sand-blasting	30 minutes.

(2) Machine frame, 3 ft. by 4 ft., straight work—

Hand cleaning	30 minutes.
Sand-blasting	4 minutes.

(3) Mower frames, weight 75 lbs., 12-in. cores, 2 in. to 2½ in. diameter; three pieces—

Hand cleaning	1½ hours.
Sand-blasting	9 minutes.

(4) Journal boxes, weight 60 lbs., 90 pieces—

Time required to rumble ...	2 hrs. 16 mins.
Time required to sand-blast	1[illegible] hrs.

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* Paper read before the Institution of British Foundrymen (London Branch), December 9, 1921.

TABLE I.—*Showing the Capacity of Sand-Blasting Machine when the Distance of Work Piece and Angle of Blast are Constant, and the Air Pressure Variable.*

Air pressure per sq. in.	lbs.	20	30	40	50	60	70
Angle of blast	deg.	45	45	45	45	45	45
Distance of nozzle ..	in.	8	8	8	8	8	8
Bore of nozzle	in.	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$
Free air, per min.	Cub. ft.	28.21	30.53	34.09	38.73	42.51	45.40
Sand discharged per min.	lbs.	17.00	20.20	25.60	31.50	36.90	41.50
Sand consumed per min.	lbs.	1.93	2.46	4.60	6.35	9.40	12.20
Usable sand remaining, per min.	lbs.	15.10	17.70	21.00	25.20	27.50	29.30
Iron removed per min.	lbs.	0.00469	0.00601	0.00781	0.01094	0.01562	0.02031

TABLE II.—*Showing the Flow of Air from Nozzles in Cubic Feet of Free Air at Given Pressures and H.P. of Single Stage Compressor at Sea Level.*

Bore of Nozzles.	Pressure in lbs.		20	30	40	50	60	70	80
	$\frac{3}{16}$ in. ..	Cub. ft.	17.10	22.50	27.50	32.80	37.50	43.00	47.50
		H.P. ..	1.40	2.32	3.26	4.49	5.74	7.22	8.65
	$\frac{1}{4}$ in. ..	Cub. ft.	30.80	40.00	49.09	58.20	67.00	76.00	85.00
		H.P. ..	2.53	4.12	5.99	7.97	10.25	12.77	15.47
	$\frac{5}{16}$ in. ..	Cub. ft.	48.17	62.89	76.70	90.70	105.00	119.00	133.00
		H.P. ..	3.95	6.48	9.36	12.43	16.07	20.00	24.00
	$\frac{3}{8}$ in. ..	Cub. ft.	69.00	90.00	110.45	130.00	151.00	171.00	191.00
		H.P. ..	5.66	9.27	13.42	17.81	23.10	28.73	34.76
	$\frac{1}{2}$ in. ..	Cub. ft.	123.00	161.00	196.35	232.00	268.00	304.00	340.00
		H.P. ..	10.09	16.58	23.91	31.78	41.00	51.07	61.88

In addition to the actual tumbling time given, 1½ hours were lost in packing into mill and taking out, while with the sand-blast tumbling barrel this only took a few minutes.

High versus Low Pressure Plants.

Before describing plants such as manufactured in the U.S.A. in detail, where sand-blast equipments of the most various designs are used to meet special requirements, it is intended to give a few data of sand-blasting, especially with reference to high-pressure air plants as made in the U.S.A. compared with low-pressure plants. Most of the plants here are designed for air pressures from 12 lbs. to 30 lbs. per sq. in., while in the U.S.A. the majority of plants are using from 40 to 80 lbs., and even higher pressures. The reasons advanced for using low pressures, *i.e.*, wear and tear on plant and danger, have all been over-

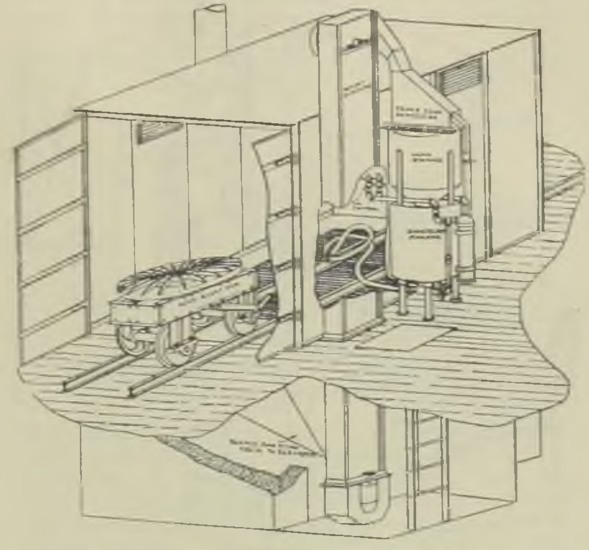

FIG. 1.—PERSPECTIVE SECTIONAL ELEVATION OF DOELCAM SAND BLAST INSTALLATION WITH CAR AND TRACK.

come by properly designed plant, and, as regards the plea that increased power is required, it has been satisfactorily shown that, while a more powerful compressor is needed, the actual cost to remove, say, 1 lb. of iron or steel is less in the high-pressure than in the low-pressure equipments. This also settles any theoretical argument on nozzle velocity.

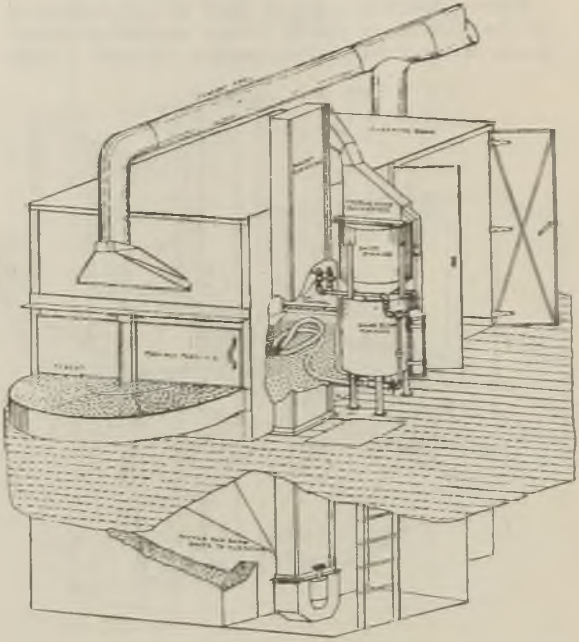

FIG. 2.—PERSPECTIVE SECTIONAL ELEVATION OF A DOELCAM SAND BLAST INSTALLATION OF ROOM WITH TABLE.

The following are figures from a Paper presented to the American Society of Mechanical Engineers by Mr. W. T. Magruder, Professor of Mechanical Engineering to the Ohio State University. These are details of practical commercial tests made under the direction of Mr. Magruder. Some of the principal figures are shown in Table I.

These figures are of a very interesting character, in so far as the actual air consumption is concerned, as compared with provision usually made in practice. Taking a 5-16 in. nozzle, Table II shows the approximate flow of air under various pressures from orifices into the atmosphere in cubic feet of free air per minute.

It will therefore be noted that whilst in practice provision is usually made for 119 cub. ft. of free air at 70 lbs. pressure, in this test it was shown that the consumption of free air per min. for the same orifice and 70 lbs. pressure was only 45.40 cub. ft., while at 30 lbs. pressure it was 30.53 cub. ft. It appears, therefore, that the actual air consumption is less than usually provided for, but of course losses in transmission have to be considered. Yet, even if the standard practice figures are compared for high-pressure and low-pressure plants, the following is shown:—For a 30-lbs. air pressure sand-blast on a 5-16-in. nozzle, a compressor would be installed giving at least 62.89 cub. ft. of free air per min. and requiring, say, 6½ h.p. to drive. For a 70-lbs. pressure plant and a 5-16 in. nozzle, a compressor would be installed giving 119 cub. ft. of free air and consuming, say, 20 h.p.

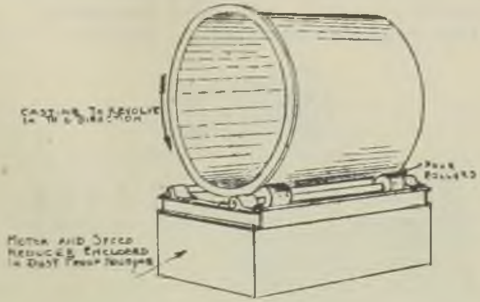

FIG. 3.—REVOLVING ARRANGEMENT FOR CLEANING CYLINDRICALLY-SHAPED CASTINGS.

Abrasive Power Considerations.

From this it will be noted that practically double the quantity of air is provided for in the high-pressure plant and nearly three times as much power is needed. But, if the abrasive capacity of the two plants is taken into consideration it is shown that the 30-lb. pressure plant removes 0.00601 lbs. of iron per minute, while the 70-lbs. pressure plant removes 0.02031, *i.e.*, 3½ times as much as the former. The test, however, shows that the air consumption is 45 cub. ft. and 30 cub. ft. respectively, *i.e.*, the high-pressure plant requires only about 50 per cent. more air than that worked by 30 lbs., but does 3½ times as much work, and for lower-pressures than 30 lbs. the comparison becomes still more favourable.

Here enters another factor, and that is the power required to drive the complete equipment, which includes the raising of the abrasive and dust collecting. The usual British practice is to raise the abrasive and dust above the dust collector, the heavy particles dropping into the sand-blast machine proper, whilst all the dust has to be handled by the exhaust fan. This means a great loss of power. Considerable economies can be effected by special dust-collecting chambers that are independent of the raising of the abrasive material. These will be described at a later stage.

Fig. 4.—Specially-designed Apparatus to Deal with Railway Carriages.

The Cost of Sand Blasting.

It is calculated that with a ¼-in. nozzle, 100 lbs. of free air and 70 lbs. pressure a plant, complete with dust collector and sand elevating and screening, requires 25 h.p. to drive, and 10 to 15 tons of castings may be cleaned in eight hours. The cost of sand-blast plant, compressor and motor is roughly £1,500. Allowing three hours for bringing and removing the work to the table, about 100 units of power would be used in five hours, which, at the high figure of 3d. per unit, would mean:—

	£	s.	d.
Per day	1	5	0
One workman per day	0	12	0
One labourer per day	0	8	0
Sand and nozzles	1	3	0
Plant repair	0	2	0
Amortisation of plant in five years	1	0	0
Total	4	10	0

Based on 10 tons of castings this would mean 9s. per ton. The above figure for sand is based on the table figure showing actually used-up sand of about 1¼ tons in five hours. By using chilled-steel-shot instead of sand, the cost can be reduced and the output increased. With 30 lbs. pressure, British plants, requiring about the same horse-power owing to the exhaust fan swallowing up a great many units. the output would be nearer 5 tons per day than 10, making the blasting cost double of what is stated above.

Modern sand-blast plants may be classified as follows:—Sand-blast rooms, cabinets, tumbling barrels, sanitary table equipments, conveyors.

Sand-Blast Rooms.

The sand-blast room is usually constructed of sheet steel, and the size to be adopted depends upon the class and size of work to be dealt with.

A great feature of the American plants is the handling of the abrasive material, sand or shot, as compared with British practice. Fig. 1 shows that the sand drops by gravity through perforations or grids in the floor of the sand-blast room into a hopper, which gravitates the sand or shot to an elevator. The abrasive material is elevated, drops on to a mechanically-operated screen or sifter, all large particles (above a definite size screen) are removed on the top sieve, while the finest, and not usable, sand drops through the second screen, and the good sand flows back to a sand storage tank above the sand-blast machine proper.

This whole mechanical equipment is outside of the sand-blast room, and consumes only a small amount of power. The air control for the sand-blast machine is suitably arranged inside of the room. The air in the room is renewed by means of a fan, placed at the far side of the dust-collecting arrangement, *i.e.*, fresh air is drawn through openings in the sand-blast room. The dust is drawn through the dust collector, so that the fan, if dust and air are properly separated, only handles pure air, which may be returned to the room if desired or blown into the atmosphere without any detriment to the surroundings. The actual dust-collecting arrangement will be described later on.

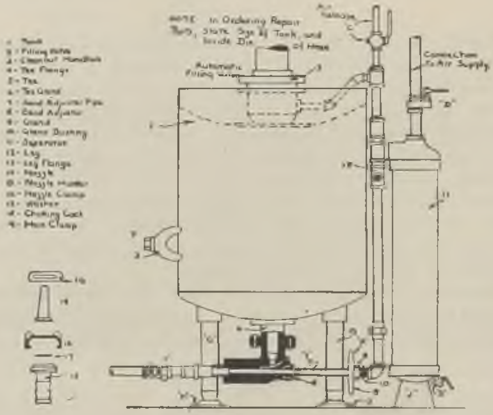

FIG. 5.—DETAILS OF A SAND BLAST MACHINE.

The air in the sand-blast rooms should be changed at least eight times per min., while most existing plants in this country are based on two to five changes per min., with the result that clouds of dust make vision practically impossible and fresh air must be supplied to the operator through a helmet to make his existence possible. Roughly speaking, a room 8 ft. long by 8 ft. high should be provided with an exhaust fan having a capacity of, say, 5,500 cub. ft. per min., at 3 in. water gauge, special allowance being made in this figure as a result of practical experience, and this does not allow for the fan having to raise the abrasive. Any height above 8 ft. may be neglected when calculating the air volume required.

Dust nuisances in sand-blast rooms cannot, however, be entirely avoided but by fitting a revolving table at one end, half of which is always outside the room, the loading up can be done by a workman who is not affected by the sand-blast operation. Overhead runways, trucks or special mechanically-operated appliances are economical for bringing the castings to and fro and tilting the work pieces while the sand-blasting operation is in progress. A revolving table is shown in Fig. 2 and a tilting appliance in Fig. 3. This has an internal motor in a dust-proof base, the piece being revolved and tilted when required. Fig. 4 shows a large building specially designed for the cleaning of steel railway trucks.

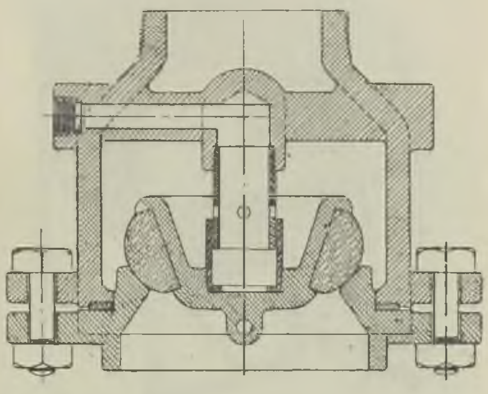

Fig. 6.—Doelcam Automatic Feed Valve.

Attention is here drawn to the simplicity of the positive sand-blast machine proper, used in connection with sand-blast rooms and some of the other equipments. In Fig. 5 it will be seen that the machine has no mixing valves of any description, as the sand drops through a tube (4), where it is met by the air at (7) and carried along, resulting in a very thorough mixture and high-nozzle velocity. The flow of sand is adjusted by means of an adjuster handle (A), after which it requires no further attention.

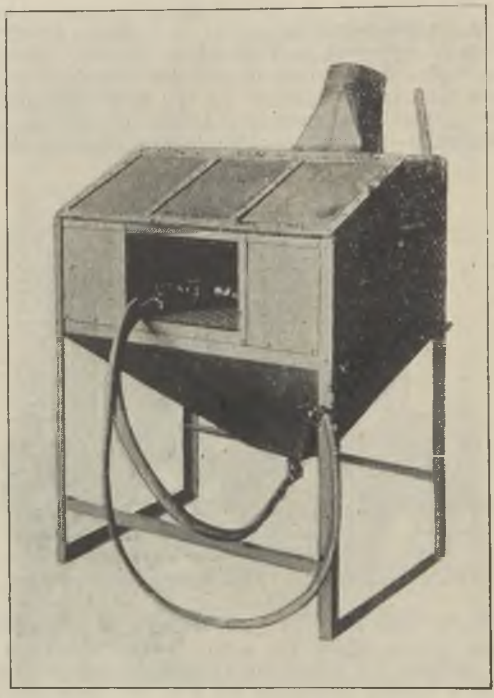

Fig. 7.—A Typical Sand Blast Cabinet.

A choking cock (18) is provided which, by means of a turn or two, will blow out wet sand or obstructions. It is very important, however, that a large-sized air receiver should be used near the sand-blast machine to take care of any moisture carried along in the air piping, as moist sand is very troublesome, and unless good dry sand is obtainable, chilled steel shot is preferable for many purposes unless very fine surfaces are to be obtained. The sand-blast machines may be had with a circular valve at the top, which automatically closes as soon as the air pressure comes into action, *i.e.*, no further sand can drop from the sand storage tank. This is shown in Fig. 6.

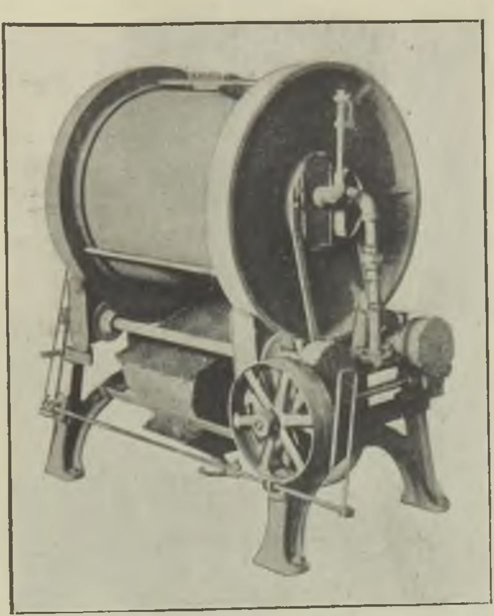

FIG. 8.—INJECTOR TYPE OF TUMBLING BARREL.

Sand-Blast Cabinets.

A typical cabinet is shown in Fig. 7. Cabinets are largely used for small castings not requiring a very high abrasive action. The sand blast used is of the injector or suction type, *i.e.*, the sand-blast nozzle has a double hose line, the one being connected to the sand storage hopper below the cabinet, the other to the air line proper from the compressor. The air, rushing to the nozzle through the air-pipe line, sucks up the sand through the branch hose and then blasts the mixture on to the casting. The sand is used over and over again, the dust being exhausted at the rear of the cabinet into a dust-collecting arrangement. No armholes are required in this cabinet, as the exhaust from the fan is sufficiently powerful to take away all the dust, but a rubber screen is provided to protect the operator against

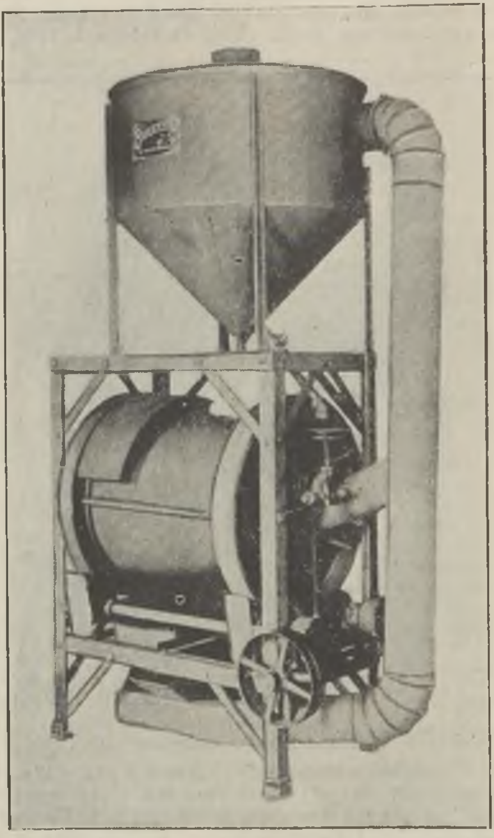

FIG. 9.—GRAVITY TYPE OF TUMBLING BARREL.

any rebounding sand. He can clearly view the operation through inspection doors on the top of the cabinet, powerful electric lights being provided for.

Sand-Blast Tumbling Barrels.

It is a fallacy to believe that water tumbling or rattling is a good medium for cleaning castings. The process is expensive, and actually hardens the surface, especially of brass castings, so that machining is made difficult instead of easy, as in the case of sand-blasted parts.

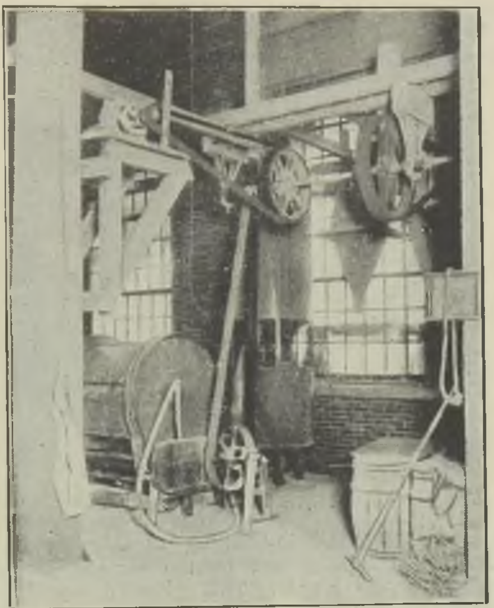

FIG. 10.—POSITIVE TYPE SAND BARREL.

There are three standard types of sand-blast tumbling barrels used in the U.S.A., but special types or combinations have been supplied to meet special conditions. These barrels are classified as:—(a) Injector type; (b) gravity type; (c) positive type.

Injector Type.—This type as shown in Fig. 8 is similar to that described under sand-blast cabinets, *i.e.*, the sand is sucked up and blown through the nozzle by means of the air current from the compressor. This injector type is recommended chiefly for brass work not requiring strong abrasive action, but by having pressures of, say, 80 lbs. and up, this type barrel is used with the best results also on malleable iron castings.

Gravity Type Tumbling Barrel.—The principle of this type, which is illustrated in Fig. 9, is that the falling abrasive sand or chilled steel shot is met by the air current and carried to the nozzle. This gives a very good abrasive action and gravity feed-type machines are therefore suitable for practically any kind of work. The sand may be elevated by the same fan as is used for the dust exhaust, or the abrasive material is elevated by means of a bucket elevator and dumped into a sand storage tank, from which it falls to the nozzle. The latter method is generally preferred.

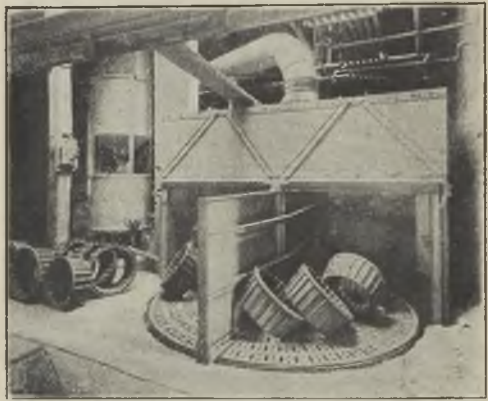

Fig. 11.—Sanitary Sand Blast Equipment.

Positive Type.—This type of sand-blast barrel, which is shown in Fig. 10, implies a separate sand-blast machine, as previously described, which, in combination with the sand-storage tank and bucket elevator, forms the most satisfactory installation that can possibly be obtained. It is specially suitable for steel castings, drop forgings, or malleable castings which are badly crusted. It also has the advantage that the hose can be detached and readily used for blasting large castings in an adjoining room or cabinet. In all the machines noted the actual

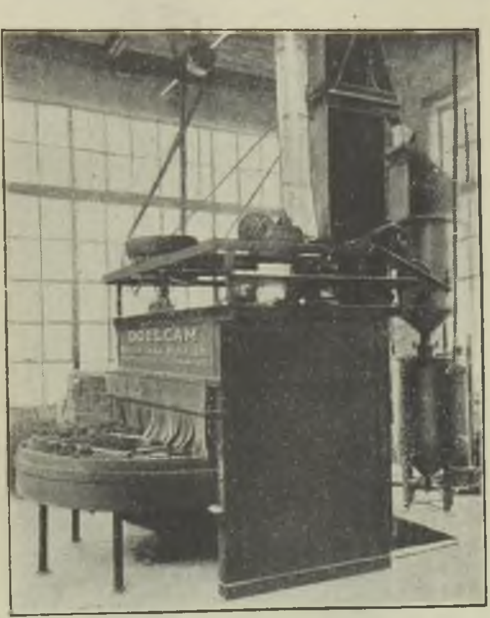

FIG. 12.—SAND BLAST TABLE PROVIDED WITH AUTOMATICALLY ROTATED TABLE AND OSCILLATING NOZZLES.

screening of the sand is done below the barrel, *i.e.*, it is sifted and strained after use so that only good sand has to be raised again.

Sanitary Sand Blast Table Equipment.

This is the type of plant in which the operator stands right outside of the cabinet. These equipments are made with either hand-rotated tables, in which case the operator holds the nozzle and works it through a rubber curtain. as illustrated in Fig. 11, or with automatically-rotated tables provided with oscillating nozzles, so that only a man is required for putting the castings on the table and removing them after they have passed under the nozzles. This equipment is shown in Fig. 12.

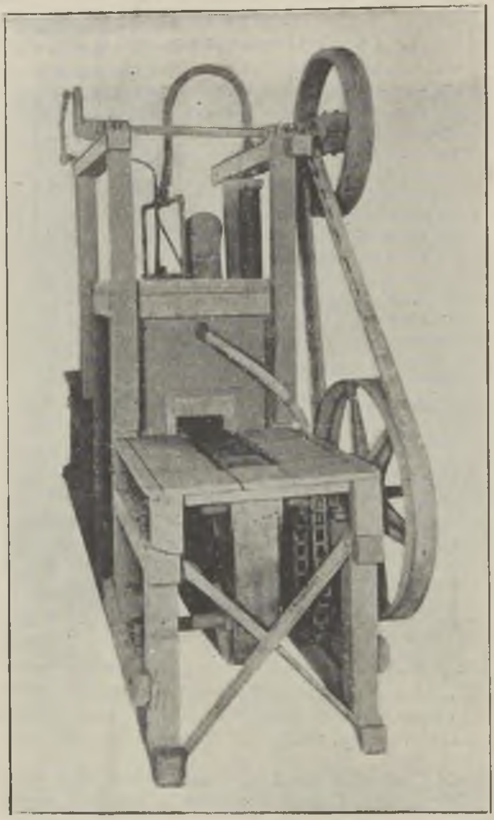

FIG. 13.—HORIZONTAL SAND CONVEYOR.

It will be readily recognised that the use of such tables must, unfortunately, be limited, as the size of castings may frequently prevent the installation of such plant, as otherwise the tables would become too cumbersome or the cabinet too high. On the other hand, where sufficient quantities of large and small castings have to be dealt with such an installation is ideal for the latter, while for the larger castings a sand-blast room would have to be adopted.

Sand-Blast Conveyors.

As the name implies, transporters or conveyors are used to bring the material to a sand-blast cabinet, fitted with automatically-driven nozzle carriages, which allow of vertical or horizontal adjustment of the sand-blast nozzles. These appliances are only in their infancy, and constant improvements are being effected. It is the ideal machine for blasting plates, springs and tools. The conveyor may be horizontal, as shown in Figs. 13 and 14, or vertical. In fact, the appliance is always designed to meet special conditions. Thus, for instance, an equipment might have nine or more nozzles, of which some are cut out if a narrower piece than the widest provided for is to be blasted. The equipment is practically automatic; the results achieved are astounding, as only labourers would be employed to bring the goods to the conveyor or take them off, while one competent man would supervise the blasting operation, that is, he would have the materials put

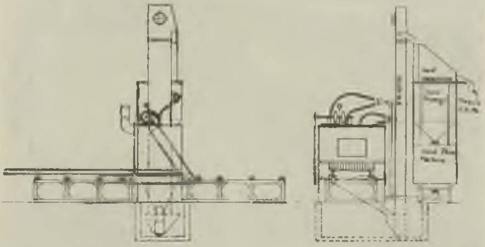

FIG. 14.—A SAND-BLAST CLEANING TABLE OF THE LONGITUDINAL TRAVEL TYPE.

through once more if the cleaning operation is not completed.

Fig. 15 shows a combination of a sand-blast room with table and a cabinet, and Fig. 16 shows a sand-blast room with work bench for small castings, and a dust-collecting arrangement, which exhaust from the bench direct.

Dust Collecting.

This is really the greatest problem in connection with any sand- or shot-blast plant, and most plants used in this country utterly fail in making suitable provision for dust collection. To send fresh air to the operator through piping in the helmet gives some assistance, but surely something should be done to improve the lot of the sand-blast operator, whatever the cost may be. Cyclone dust arrestors are mostly very inefficient, and if, as in the case of British plants the same exhauster is used to raise the abrasive material and the dust, the cost of the necessary power together with the upkeep of the fan-blades is very high.

Fig. 15.—Combination Sand-Blast Room and Cabinet.

The problem of dust-collecting is by no means solved, but great improvements can be made by introducing a separate dust-collecting unit in connection with the sand-blast machine, instead of using the exhaust fan for lifting the abrasive as well as the dust produced. There are various methods of dealing with the question, and Fig. 17 shows an appliance which is called a turbine dust arrestor, and for which Patents are pending. From the outside it looks like a cyclone dust arrestor, but the interior shows a special construction of circular baffles, which greatly contribute towards the collection of the dust. In fact, an efficiency of about 85 per cent. is attained, *i.e.*, only 15 per cent. of the dust particles are drawn into the fan from where they are blown out into the atmosphere, or are dealt with as desired. The dust collected in the dust arrestor drops out of the bottom through a gate, and can either be collected in sacks or flushed away. This unit can be placed wherever convenient between the sand-blast equipment and the exhaust fan. As will be seen from the illustration, the dust piping is connected up at (R), while at the top is the pipe line connection to the fan. This type of arrestor can be used either on suction or pressure. It is comparatively cheap, but there must be many in-

FIG. 16.—SAND-BLAST ROOM WITH WORK BENCH FOR SMALL CASTINGS AND DUST COLLECTING ARRANGEMENT.

stances where the problem of dealing with the 15 per cent. of dust may become a pertinent one.

The next step was to design a dust-collecting unit, Fig. 18, consisting of a system of cloth screens, which is termed a screen-type dust-arrestor. This is a steel housing in which a number of cloth screens are arranged, these, on the average, having an area of about 50 sq. ft. The size of the housing and the number of screens to be used naturally depend upon the volume of air and dust that have to be dealt with from the sand-blasting machine. These cloth screens are fastened to frames which are wide at the top and taper at the bottom; in other words, they are wedge shaped. They are pivoted at the top, but hang loose at the bottom. The reason for this is that means must be provided to easily jar off,

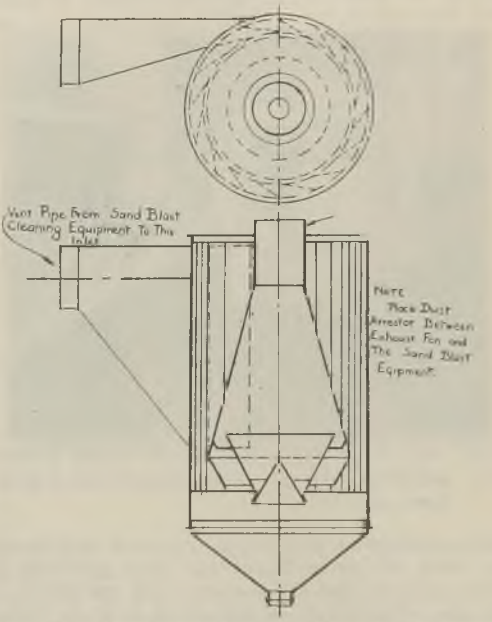

FIG. 17.—DOELCAM RAREFIED DUST COLLECTOR.

or knock off, the dust that settles in the cloth. Specially simple jarring mechanism is provided for at the outside of the housing, and this consists of a number of hammers worked by a crank, which tap against the housing and successfully clear the pores of the cloth if the operation is effected two or three times a day. All the dust collected in the pores then drops off into a hopper at the bottom of the housing, from where it can be flushed away.

This is a very efficient unit which can be placed at any available spot between the sand-blasting equipment and the exhaust system. It gives an efficiency of nearly 100 per cent., *i.e.*, all the dust is collected. The only drawback with this unit is that working under a partial vacuum the power consumed is comparatively high, though otherwise comparing very favourably with the practice in this country previously explained.

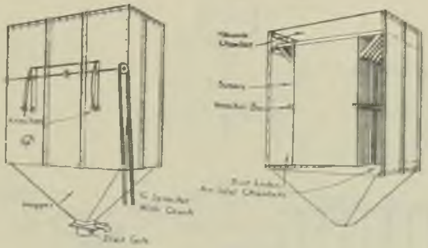

FIG. 18.—A DOELCAM SCREEN TYPE DUST ARRESTOR.

The ideal system is shown in Fig. 19. This is really a combination of the turbine dust arrestor and the screen type dust arrestor, utilising the advantages of both. The turbine dust arrestor will not take out all the dust. The screen-type dust-arrestor, working under partial vacuum system, the loss of power and its consequent efficiency is fairly low, yet if, for instance, the screen type dust arrestor were used so that the dust is pressed through same instead of drawn, the result would be the rapid wear of the fan wheel and congestion of the arrestor. If the two machines are combined—and this is termed the double grip system—the dust-laden atmosphere may be sent through the turbine arrestor by suction, taking out all the heavy particles, while the finer dust is pressed through the screen type arrestor, the same fan, of course, being utilised. Thus all the dust will be collected, and there is an increase of power efficiency of at least 40 per cent.

It will be clear that in the turbine dust arrestor, where baffles or pockets are placed all around the circumference, a suction is created in each pocket, and the heavy dust is drawn into same, collected and then falls into the hopper. The speed of the air being considerably reduced, say, to less than 500 ft. per min., the heavy dust is easily collected, and the remaining 10 to 15 per cent. only has to pass through the exhaust fan, and, this being very fine material, the wear and tear on the propellor blade is not so heavy.

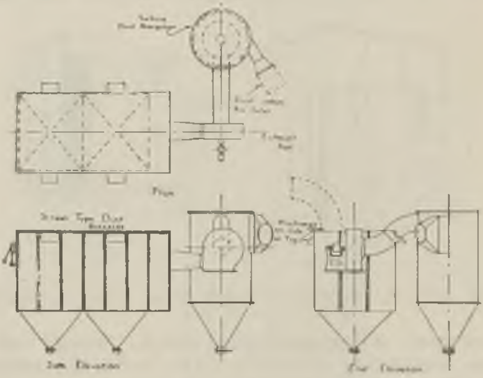

Fig. 19.—A Double Grip Dust Collecting System.

The question of cost has to be contended with, but a time will come when the sanitary and humane side of sand-blasting equipment will receive the keener attention of the Factory Inspector, and this Paper has shown in what directions improvements can be made.

To sum up, all castings should be sand-blasted, after coring, before final chipping, fettling and grinding operations. Special dust collecting chambers of ample size and with proportioned capacity fans should be insisted on to avoid dust nuisance.

The presence of the operator in the blast chamber proper should be and can be avoided, except where large castings have to be sandblasted.

High-pressure air is more efficient and less costly in operation than low-pressure for sand- or shot blasting.

Lancashire Branch.

THE SOLUTION THEORY OF ALLOYS, WITH SPECIAL REFERENCE TO CAST-IRON.*

By Dr. F. J. Brislee.

There is apparently a great difference between a water solution of common salt and cast iron or brass, but it is nevertheless a fact that the correct understanding of the behaviour of water solutions led to the elucidation of the nature of alloys. It is difficult to over-estimate the great importance of this discovery and its influence upon the progress of our knowledge of the nature of alloys.

It was thought that an explanation of the theory of alloys from this point of view might be helpful to the foundryman.

The understanding of this theory renders clear many obscure points in foundry work, and, what is of still greater importance, it provides a weapon wherewith to attack the troubles and difficulties which so often arise.

How Common Salt Solutions Freeze.

Now if we consider, in the first place, a water solution of some well-known salt, sodium chloride, for example, a simple experiment will show that the quantity of salt which a definite weight of water will dissolve depends upon the temperature, but for each definite temperature a given weight of water dissolves a certain quantity of the salt. Tables are given in reference books recording the weight of various salts which will be dissolved by 100 parts by weight of water at different temperatures. These are called "*solubility tables.*"

It follows, therefore, that if the quantity dissolved by a certain weight of water increases with rise of temperature, then if a solution is prepared as strong as possible at a high temperature some of the salt will separate out when it is

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* A Paper presented before the Lancashire Branch of the Institute of British Foundrymen.

cooled to a lower temperature. This fact is made use of in the ordinary purification of salts of various kinds. When a solution of salt is prepared, say, of sodium chloride, a dilute solution at 100 deg. C. and cooled down in a tube with a thermometer in the solution. During the cooling the liquid is kept stirred, so as to prevent local cooling. After a time particles of solid will appear, or, in other words, the solution begins to freeze. If the solution is dilute, then the crystals which separate first are pure *ice*, and the remaining liquid portion becomes more concentrated. The temperature at which the first ice appears is lower than the freezing point of pure water; how much lower depends upon the strength of the solution.

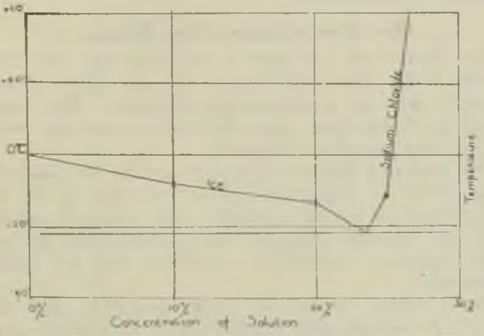

Fig. 1.—Showing the Behaviour of Salt Water under Decreasing Temperature.

Now if the cooling be still carried on more and more, water separates in the form of ice, and the still fluid remainder becomes more and more concentrated, until such a concentration is reached that it solidifies as a whole. Considering the behaviour of a solution of common salt, it is found by experiment that:—

(1) Pure water freezes to ice at 0 deg. C.

(2) A 10 per cent. solution of common salt begins to freeze at -8 deg. C., and, by continued cooling, more and more ice separates and the remaining fluid portion becomes more and more concentrated, until it contains 23.5 per cent. of salt (NaCl), when it solidifies at -22 deg. C.

(3) A solution which contains 25 per cent. of NaCl begins to separate crystals of solid salt at −12 deg. C., and the remaining fluid portion becomes more dilute until it contains only 23.5 per cent. of NaCl, when it instantly solidifies at −22 deg. C.

(4) Finally, a solution containing 23.5 per cent. NaCl solidifies as an unchanged whole, without separation of either ice or salt. This relationship can be denoted by a diagram, Fig. 1.

Such a diagram tells all the facts about the behaviour of the solution when heated or cooled, and any point on the curve denotes a definite concentration of the solution corresponding to a definite temperature.

How Silver-Copper Alloys Freeze.

The behaviour of such a solution can be compared with the behaviour of an alloy of two metals, such as a silver-copper alloy. The similarity in behaviour can readily be seen by comparing the two Figs. 1 and 2.

The melting point of pure silver is 960 deg. C. Pure silver is separated along the line A B, the liquid portion becoming richer and richer in copper until it contains 72 per cent. silver and 28 per cent. copper, when it solidifies as a single substance.

Pure copper melts at 1,090 deg. C., and the line C B denotes the solidification of various percentages of silver and copper until the mixture, 72 per cent. silver and 28 per cent. copper, is reached, when it solidifies as a simple substance.

How Eutectics are Formed.

A dilute and a concentrated solution behave similarly, in that both separate the excess of one or other constituent during the cooling. Thus, a strong solution of salt separates solid salt, and a dilute solution separates solid water until the same concentration is reached from both sides. It may here be pointed out that a solution of salt in water may be looked upon either as a dilute solution of salt in water or a concentrated solution of water in salt.

Referring once more to the common salt-water solution in Fig. 1, it is evident that the final liquid portion has a composition which is independent of the original composition, and thus finally solidifies and melts at a constant temperature. This point is called the *cryohydrate point* in water solutions, or the *eutectic* in case of alloys.

The eutectic may then be defined as a mixture of two (or more) metals which have a definite melting and solidifying temperature, and very frequently their melting point is lower than that of either of their constituents.

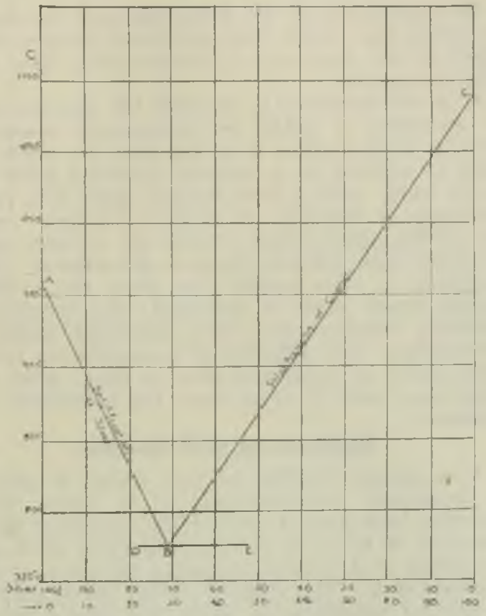

FIG. 2.—SHOWING THE BEHAVIOUR OF SILVER-COPPER ALLOYS UNDER DECREASING TEMPERATURE.

There is an apparent difference between salt solutions in water and solutions of one metal in another, but there is no real difference, and the laws of one apply to the other. A great many facts have led to the conclusion that solid solutions or solutions in the solid state can exist. Consider, for example, that hot iron will absorb hydrogen, and if hydrogen gas be passed through a red-hot iron tube it will find its way through the walls of the iron. Platinum and palladium both absorb hydrogen in considerable quantities and allow it to spread through the metal. If pure iron be treated with carbon the metal will be found to be penetrated by carbon, although neither is in the molten state.

Microscopic Revelations.

The application of the microscope and the study of metals has shown that profound changes take place in the structure of metals when they are alloyed together.

It is not necessary to describe the preparations of specimens of metals for microscopic examination in detail; suffice it to say that the metal or alloy is polished on a suitable polishing machine, or by hand, until a level surface, quite free from scratches, is obtained. It is then "etched" with an etching agent, which attacks the different constituents with different degrees of readiness. The specimen is then washed free from the etching agent, dried, and, if tarnished, the tarnish is carefully removed and then examined under a microscope. The difficulty of manipulation varies from metal to metal and alloy to alloy; some are very easy, and in some cases the difficulties are extreme.

Importance of Solid Solutions.

If a series of alloys of two metals A and B is examined microscopically it is found that, starting from pure A and adding successive quantities of B to it, a certain proportion of B can be added to A without changing the form of the crystals of A. This state of things persists up to a definite concentration of B, and then a second form of crystal makes its appearance. This is exactly analogous to the fact that water will dissolve a certain quantity of common salt at 100 deg. C., but if a larger quantity be added to the water it will separate out and remain in the solid state, so *that solution + solid salt are in equilibrium*, the only point of difference being that in case of metals the solution is a solid at ordinary temperatures, and they are called "solid solutions," or "homogeneous solid solutions."

The solid solutions play an extremely important part in modern metallurgy.

If the melting or, better, the solidification, of the metal be followed by means of a thermometer or pyrometer additional evidence can be obtained as to the nature of these solutions. Consider the cooling of a substance which undergoes no change of state, *i.e.*, does not solidify—for example, a piece of platinum heated to about 1,400 deg. C., which is below its melting point—and suppose that readings of the pyrometer are taken at definite time-intervals. The results can then be plotted on a curve, and a smooth curve will be obtained (Fig. 3.) In the second case, suppose the cooling of a mass of molten metal, such as pure copper, the cooling being followed in the same way. At first the cooling takes place rapidly, then there

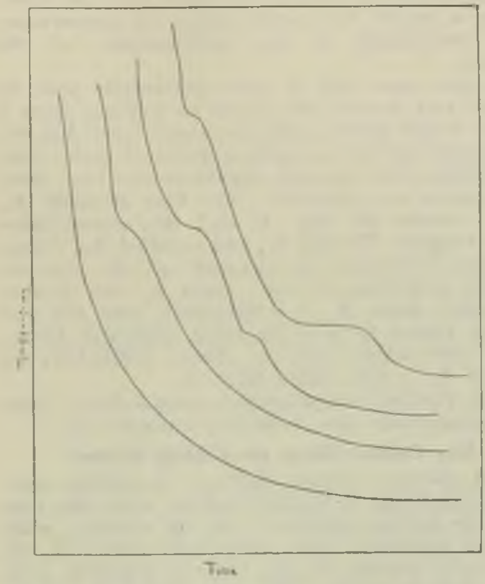

FIG. 3.—TIME-TEMPERATURE CURVES, SHOWING HOW INTERNAL CHANGES BRING ABOUT HALT-POINTS.

is a halt for a few moments while the mass solidifies, and then the cooling takes place regularly once more. If the same series of observations are taken for an alloy like silver-copper, or lead-tin, the cooling curve of alloys containing less than 45 per cent. copper and 55 per cent. silver, or less than 76 per cent. silver and 24 per cent. copper, will show only one halt point, but for alloys containing from 55 per cent. to 76 per cent. silver a second halt point makes its appearance. This corresponds to the solidification of the eutectic.

In the same way if pure electrolytic iron be melted and heated well above its melting point a halt is found to take place at about 1,600 deg. C., corresponding to the melting point of pure iron; the cooling then proceeds regularly until two other halt points are observed. The first is called A_3, and is about 890 deg. C, and the second takes place at about 770 deg. C. and is called A_2. These changes correspond to changes in the thermo-electric properties of iron; above A_2 iron is non-magnetic, below A_2 it is magnetic, and the iron is now known to exist in three allotropic forms, viz., γ iron stable above A_3, β iron stable between A_3 and A_2, α iron stable below A_2.

Still further investigation shows that these points vary with the amount of carbon.

How Carbon Affects the Cooling of Iron.

Iron shows a great tendency to combine with carbon and also to dissolve carbon, when the iron is in the molten condition. In the ordinary blast furnace method of iron production from the ore the ore is placed in the furnace together with coke and limestone. The ore, which is chiefly oxide of iron, is reduced to metal, and the hot molten metal coming into contact with carbon in the form of the fuel and in the form of gas as CO and CO_2 dissolves a considerable quantity of carbon. Part of this carbon is dissolved in the metal as carbide, but much is rejected on cooling as graphite-like plates, whilst a part remains combined with the iron as iron carbide, which remains dissolved by the molten iron, and even after solidification.

In ordinary grey pig-iron the combined carbon is low and the free or graphitic carbon is high, 3.0-3.5 per cent. and even higher; white iron, on the other hand, contains the carbon, almost wholly as combined carbon—that is, as carbide of iron dissolved in an excess of iron, or a solid solution of carbide of iron in iron.

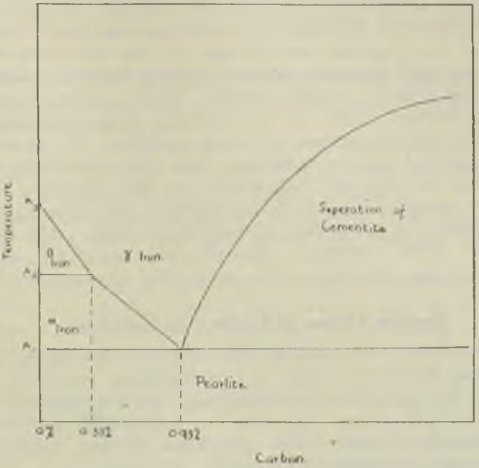

FIG. 4.—SHOWING THE BEHAVIOUR OF NON-IRON-CARBIDE ALLOYS WHEN COOLED FROM THE LIQUID STATE.

The product of the blast furnace—grey cast iron—contains, in addition to carbon, small and varying quantities of silicon, manganese, phosphorus and sulphur, all of which modify the properties of the resulting iron, and confer some desirable and some undesirable characteristics upon the metal. By judicious blending of different brands and grades of iron, according to their analyses, it is possible to obtain cast iron with different strengths and suitabilities for different purposes.

Cast Iron Regarded as a Carbon-Iron Alloy.

For the present cast iron will be considered as a carbon-iron alloy, and for sake of simplicity the influence of the remaining constituents will be ignored, or, more correctly, assumed to be present in such small amount that their influence upon the properties of the iron is negligible.

If cast iron is considered in this light it becomes evident that the proportion of carbon which will dissolve in iron at different temperatures is an important constant. Now iron at a high temperature will dissolve a large quantity of carbon; and just as a solution of salt in water which is saturated at 100 deg. C. will separate solid salt when it is cooled to 15 deg. C., so the iron on cooling will separate carbon in the form of plates of graphite as it cools down. It has been shown that molten iron at its melting point dissolves 4.3 per cent. carbon to form carbide. It should be pointed out in passing that the solubility of carbon in iron is influenced by the presence of other metals, *e.g.*, both manganese and chromium increase the solubility of carbon in iron. On the other hand, silicon, phosphorus, sulphur and aluminium diminish the solubility of carbon in iron.

Various Forms of Carbon in Cast Iron.

Further, it is evident that carbon can exist in several different forms in the resulting iron:—

(1) As graphite in hexagonal plates, which is left behind when the iron is dissolved away in hydrochloric acid. The graphitic carbon content is greatly influenced by rate of cooling.

(2) As carbide of iron, Fe_3C, which contains 93.34 per cent. iron and 6.66 per cent. carbon. The formation of carbide is favoured by slow cooling and hindered by rapid cooling. The carbide carbon plays an important part in the heat treatment of steel.

(3) Temper carbon is formed when iron poor in manganese is subjected to long annealing at a temperature above that required to form the carbide, but below that necessary to produce graphite. The temperature is 720-850 deg. C., and the change is favoured by hammering. Tempering carbon is often produced when iron is softened by annealing.

(4) Hardening carbon. This form is dissolved in iron, uniformly distributed, but in variable amount.

All fluid iron contains hardening carbon only; when it solidifies it produces graphite, then carbide, and, by long heating, temper carbon. If the iron containing the above varieties of carbon is melted the solution of the constituents takes place in the reverse order.

Finally, it is a point of interest to note that Moissan prepared diamonds artificially by saturating molten iron at a high temperature with carbon, rapildly cooling the mass, and then removing the excess of iron by solution in hydrochloric acid.

How Constituents Separate when Cooling Cast Iron.

The various forms of iron which separate as the metal cools are:—

Pure iron, which can exist in three allotropic forms, is termed "ferrite," the three allotropes being distinguished as α, β and γ ferrite.

The separation of *ferrite* is strictly analogous to the separation of ice from the common salt solution.

The carbide of iron Fe_3C is called *cementite*.

The eutectic is known as pearlite, and contains about 0.89 per cent. of carbon. It is looked upon as a mixture of cementite, 14 per cent. and ferrite, 86 per cent.

The general form of the equilibrium diagram is shown in Fig. 4.

This is based upon two conclusions of Goerens, who made a very important advance in the development of the diagram, and showed that:—

(1) The carbon in molten iron is in solution as carbide.

(2) The system must be considered strictly to be one of iron—iron-carbide.

It is evident therefore that the molten metal which collects at the bottom of the blast furnace consists of a saturated solution of iron carbide in iron. As the molten iron cools carbide is thrown out of solution, and, being unstable, it dissociates into iron and carbon with the separation of graphite.

As the iron freezes the eutectic splits up into solid solution and carbide, and the latter persists or dissociates, according to the rate of cooling and other conditions.

The pearlite can then change into carbide and free iron, and the carbide, dissociate with separation of graphite, producing perfectly soft iron, free from combined carbon, or the combined carbon will persist and produce a harder iron.

Cupola Changes.

The changes in ordinary cupola melting are very similar to those which take place in the blast furnace. The charge of pig-iron which is introduced is melted with suitable additions of scrap, etc., so as to give a product with the requisite composition and properties. As the metal melts it comes into contact with the strongly heated coke, and it dissolves more or less carbon: how much depends upon the time the metal and fuel are in contact. The metal which collects at the crucible of the cupola, and which is tapped out, may not be saturated with carbon. The influence of the other constituents of the iron, silicon, manganese, etc., all exert an influence upon the solvent power of the iron for carbon, and by constant conditions and careful selection of materials according to analysis iron suitable for different castings can be obtained.

So far, the general theory of the nature of cast iron has been dealt with, and the clear understanding of this is the key to the gate of the road along which progress may be made. It will therefore repay a careful study and mastery by each one engaged in foundry work.

Methods Necessary for Elucidation.

The question may now be asked, How are these facts elucidated? And the answer is by aid of the microscope and by aid of the pyrometer and chemical analysis. The methods of thermal analysis, which depend upon the rate of cooling of the same quantity of each alloy under similar conditions, show the proportions of the various components and phases which separate during the cooling from each alloy. A short consideration will make this clear. Suppose a quantity of a lead-tin alloy containing lead and tin in the eutectic proportions is allowed to cool from a temperature well above the melting point of the mixture, *e.g.*, 350 deg. C. The cooling takes place regularly until a temperature of 180 deg. C. is reached, when the alloy begins to solidify and the latent heat of fusion is evolved. This tends to keep the temperature constant, or, expressed in other words, there is a halt in the cooling curve. Now this halt will exist for the longest time for the eutectic mixture, and when the composition of the alloy differs from the eutectic there will be two halts, one corresponding to the separation of the pure metal, the second to the solidification of the eutectic. The time of the existence of the second halt will be proportional to the quantity of eutectic present, provided that the conditions of the experiment are kept constant.

The results are plotted with the length of time of halt at the eutectic point for the ordinates and the percentage composition of the alloy for the abscissæ. In this way a diagram is obtained which shows the quantity of eutectic present at any definite mixture of the two metals.

Ascertaining Eutectic Points.

The eutectic compositon is determined by making a series of melting point determinations of alloys of varying mixtures of the constituents, and the microstructure of these alloys is also determined. Consider two metals A and B. The melting points of A and B will be first determined, and then a small specimen of each will be examined under a microscope. Mixtures of A and B in varying proportions, by steps of, say, 10 per cent., are examined in the same manner, and the separation of one constituent on the other can be seen under the microscope. The eutectic composition has always a fairly definite and characteristic structure, and the separation or disappearance of one or other phase will be clearly evident. This, added to the single halt point on the cooling curve, proves the eutectic point.

Observations are then made so as to fix the composition more exactly, by examining mixtures of the metals which differ from each other by only a small percentage until such a composition is reached that no separation of a second constituent takes place, or, in short, the alloy behaves as though it were a single substance.

The composition of each alloy must be settled by analysis, it being inaccurate to rely upon the composition from the mixture fused. The losses by oxidation, etc., *i.e.*, pit losses, cause errors which are best corrected by analysis.

Variables.

The variables in all classes of work upon alloys in the foundry are temperature composition, rate of cooling. The composition is liable to vary with loss due to oxidation or too high a casting temperature, unknown compositions of scrap metals, but by careful use of accurately analysed material these can be avoided and the composition kept constant. The rate of cooling is much more difficult to control, even though the casting temperature is constant. The rate of cooling depends upon the shape of the mould, the moulding sand, the moisture content of the sand, and the external temperature of the air. If iron is saturated with carbon when molten and suddenly chilled, so that the carbide cannot dissociate into carbon, pearlite, and hard castings may result owing to a high percentage of combined carbon.

Slow cooling, on the other hand, will lead to separation of carbon in the form of graphite, and may result in porous castings, especially when the graphite segregates into spots.

It therefore follows that a consideration of the conditions of a cast will furnish a certain amount of guidance in the avoidance of faulty castings and in remedies for faults. A certain amount of guidance only, because there are so many variables that it is almost impossible to control all at once. Nevertheless, the assistance given by these facts proves useful in providing a means for attacking a problem and for avoiding a failure.

Malleable Cast Iron.

The French metallurgist, Reaumur, discovered a method of softening cast iron by heating iron castings embedded in oxide of iron. This is the basis of the English method.

The American or Blackheart process involves not only the elimination of some of the carbon, but also the change from the combined to the free state; the free carbon forming a kernel, which is black, hence the name.

The production of malleable cast iron necessitates the use of white and mottled irons. The interest for the present purpose is the removal of carbon from the solid iron by means of the oxygen of solid oxide of iron. It is an excellent example of a chemical reaction taking place in the solid state. It is found that the removal of carbon takes place not only in the portions in contact with the oxide of iron, but even into the interior, provided the heating is continued for a sufficient time. It is customary, however, to decarburise to a certain depth only, depending upon the use for which the castings are designed. The process by which the decarburisation takes place is probably the first formation of carbon dioxide from the carbon and oxide of iron at the surface of the casting; this gas penetrates the casting at the high temperature, and the carbon dioxide becomes changed into carbon monoxide by the carbon in the interior.

The Chemistry of Malleablising.

The carbon monoxide then passes to the surface of the casting and, coming into contact with the oxide of iron, becomes again converted into carbon dioxide, and the cycle proceeds:—

$$2Fe_2O_3 + 3C = 4Fe + 3CO_2.$$

$$CO_2 + C = 2CO.$$

$$Fe_2O_3 + 3CO. = 2Fe + 3CO_2.$$

The exact mechanism of the malleablising is not entirely clear, and it is unnecessary to discuss at present the various theories proposed, but to give some brief idea of the chemical reactions involved in the process. It might here be pointed out that according to one theory the carbide must be dissociated and carbon precipitated as annealing carbon before it can be eliminated; the other theory holds that this precipitation is unnecessary.

It is well known that to produce malleable castings it is not essential to eliminate the carbon, but only to precipitate it, *i.e.*, to decompose the carbide or cementite.

It seems highly probable that both reactions take place in the English and American methods, but to different extents.

The interesting point is the ease with which carbon can be eliminated in the solid state, and it is another instance of penetration of a solid metal by a gas which passes in as CO_2 and out as CO.

Sheffield Branch.

SEMI-STEEL.

By John Cameron.

At a meeting of the Sheffield Branch of the Institution of British Foundrymen, held on January 20, Mr. John Cameron, of Kirkintilloch, Scotland, gave an address on "Semi-Steel." Mr. John Watson presided.

Mr. Cameron, in opening, alluded to the unfortunate name, "Semi-Steel," as misleading. Some of them would remember that about twelve months ago the Editor of THE FOUNDRY TRADE JOURNAL gave this subject great prominence, calling attention to the misleading name, and suggesting "Fontoid." This was a step in the right direction, but he thought it rather artificial, and that it was possible for the combined brains of the Institution and the British Cast Iron Research Association to find a satisfactory name for semi-steel.

As ironfounders they were to-day being called upon for better quality of castings, with diminished weight to meet the developments of higher speeds in engineering. He thought the claims of semi-steel, in this respect, were worthy of serious consideration.

Quite a number of interesting articles had been published on this subject in the technical journals. Some writers were most eulogistic, claiming that cylinders, electrical and machinery castings were being gradually turned over to semi-steel specifications. Other writers denounced it, and maintained that equal results could be got from cast iron. He made special reference to the excellent Paper, "What is Semi-Steel,"* given by Mr. Field to the Birmingham Branch, and published in the Proceedings of the Institution.

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* See Proceedings, 1920.

The lecturer made it clear that the semi-steel he wished to speak about was cupola melted, with proportions of mild steel varying from 15 per cent. to 40 per cent. He intended to treat the subject not so much from the theoretical or scientific, as from the practical foundryman's point of view, considering first the advantages, and on the other hand pointing out its limitations, difficulties and disadvantages. Semi-steel did not displace steel or malleable cast iron. It was simply a high-grade cast iron, with fewer impurities and better structure. Unless cupola practice was properly regulated and controlled, the castings, while strong, were likely to be hard and difficult to machine.

Properties of Semi-Steel.

Strength.—Semi-steel was much stronger than grey cast iron as regards tensile, transverse and compression tests, toughness and resistance to shock. An example was instanced of a strong flanged bend for the bottom of a pump pipe line for a colliery. An early casting having proved defective, through inexperience of the proper gating, was struck with a heavy hammer to be broken up, but although several attempts were made, this could not be done, and the casting was kept for exhibition and trials for many months.

Physical Structure.—Semi-steel is close grained, homogeneous, free from hard spots, blow-holes and defects. The graphitic carbon is finely broken up, the phosphide eutectic small, well-distributed and frequently in well defined " mesh " formation.

Machining Qualities.—It machines easily, taking a fine polish: two striking characteristics are its faculty for taking a clean-cut screw-thread, and a clear and clean punch mark.

Resistance to Wear.—Owing to the formation of the graphitic carbon, along with the close grain and high tensile strength, semi-steel was very satisfactory for such castings as cylinders, pistons, gear wheels. McLain claimed that it was a self-lubricating metal, and from general experience it has been found an excellent metal for the castings mentioned and others.

Equal fusibility and fluidity to cast iron could be obtained, and the claim is made that it is superior to cast iron as regards resistance to heat, *i.e.*, for fire-bars, and also for many electrical purposes.

Aerial Bomb Manufacture.

His firm's experience, in the first place, was on aerial bombs. They had altered a cupola on the lines laid down by McLain, when they were asked to submit samples. These proved satisfactory, and they were soon under full swing turning out semi-steel on a large scale for a year. At one time 1,400 bombs of one particular pattern were produced daily.

Semi-steel was found to be extremely useful for certain types of munitions. It was used by the U.S.A., France and Germany long before our Government considered the material. America, towards the end of the war, had arranged a tremendous output of about 30,000,000 semi-steel shells, and there was no doubt that had the war lasted some months longer, semi-steel would have displaced steel in many cases. Experiments were carried out for some of the larger bombs, and the trials were very satisfactory, particularly in regard to fragmentation. His first contract was taken in the expectation that there would be trouble in maintaining the minimum tensile test of 14 tons, but the results of the tests were surprising. The firm submitted over 400 test bars which were pulled by officials at Glasgow University. The first failure was bar No. 140, the second in the same week. On investigation it transpired that the foreman had changed the moulder, and when the bars were made by the original moulder, who understood the importance of care and correct gating, no other failure was recorded until after the Armistice. The bars in question were cast $\frac{5}{8}$ in. dia. by 5 in. long. This admittedly was a small bar, and gave better results than the usual bar of larger diameter. He knew that this was a vexed question, but submitted that the $\frac{5}{8}$-in. bar was a fair test for castings under $\frac{3}{8}$ in. thick. The average tensile test from these 400 bars was over 18 tons. Their record bar was 21.9 tons, but higher results had been obtained by friends in England and in Glasgow, where a mixture of 50 per cent. hematite, 40 per cent. steel, and 10 per cent. scrap yielded 22.5 tons.

Low Phosphorus Necessary.

In 1918 ironfounders found it very difficult to obtain pig-iron of good quality and consistent analysis. Hematite was not available and such pig-irons as could be obtained had to be used. The Scotch brands gave satisfactory results, and yielded good hot fluid metal. Cleveland iron was tried, but owing to its high phosphorus castings were apt to be brittle. He was a firm believer in keeping phosphorus low in semi-steel. The average analysis of about a dozen bombs resulted:—

Silicon 2.10, graphitic carbon 2.55, combined carbon 0.5, sulphur 0.065, phosphorus, 0.587, and manganese 0.65 per cent.

In this analysis the total carbon was low, and the sulphur and phosphorus within safe limits. Probably greater tensile strength would have been obtained had the silicon been lower, with the combined carbon and manganese higher.

In the physical structure was revealed the secret of the greater strength and improved properties of semi-steel. The lecturer emphasised the benefit of frequent microscopic examinations to ensure the best results being maintained. Chemical analysis was useful in itself, but must be taken into consideration with the physical structure.

In closing the case for semi-steel, the lecturer claimed for this material that founders could take the pig-irons and scrap in every day use, and by judicious mixing produce a high-class, strong, close-grained metal capable of transverse and tensile results, that could only be otherwise obtained by using cold-blast, or other special and expensive pig-irons.

Difficulties and Disadvantages.

Considerably more care and supervision was essential. In the experimental stages a good many failures occurred. This meant extra work, which was generally passed on to the foreman, and explained the reluctance of many to persevere.

It was essential to have cupola practice right, particularly in regard to correct supply of air.

His first attempts resulted in very dull metal due to volume of air being too high. There were difficulties with bad scrap and unsuitable coke. Special attention had to be given to correct gating and quick pouring. One special feature about semi-steel was, that it froze or set at a higher temperature than cast iron. This made it unsuitable for thin castings of large area.

Attention was called to a series of test-bars which had been poured from the same ladle with intervals of 2½ minutes. Deterioration in the later pourings was obvious. Trouble due to this was experienced in the early stages, and proved very difficult to trace. Eventually it was discovered that one or two moulders at the far end of the shop were holding up the metal. When this was remedied the trouble disappeared.

Another disadvantage was that to ensure the very best results he had to admit, after a good deal of experience, that semi-steel had to be handled on a fairly large scale. When only one or two charges were required, semi-steel could be produced from a cupola using ordinary iron, but he had never obtained such good results or such good metal as when semi-steel was melted on the larger scale.

Cupola Practice.

There was no subject on which foundrymen had such varied opinions and practice as the cupola.

Each cupola should be studied in itself. It was worth persevering until it yielded its proper quantity of good, hot metal, and was clean at the end of the day's work. To begin with, his firm lined a 54-in. cupola to 40 in. The bed was lowered and tuyeres remodelled to ensure a soft blast. This particular cupola worked well from the very beginning. He had a feeling that for semi-steel a small cupola from 36 in. to 42 in. dia. was the easiest to control, and within these limits the air could be forced to the centre by comparatively little pressure. His experience was that one row of tuyeres was quite satisfactory, and gave considerable economy in consumption of coke. Much more attention was being given to cupola practice to-day, especially with regard to the high-blast fetish so popular with our forefathers.

In summarising cupola practice the lecturer said that air should enter by volume not pressure: he recommended a large tuyere area, and emphasised the importance of measuring all charges, coke, metal and especially air. For the latter, air-blast meters were easily obtained and adjusted. For light repetition work he recommended small charges evenly distributed.

In conclusion he warned his audience to use suitable and clean scrap, avoiding small and often dirty punchings under 1 in. dia. They need not be afraid to use the scrap in fairly large pieces, but should never use turnings or borings.

The sand should be used as dry as possible, and care taken to avoid a too liberal use of the "swab."

Samples of semi-steel were exhibited, showing fracture, machining, polish and thread obtained, also the malleability obtained by moderate annealing. Slides were also shown showing general structure, particularly as regards grain, small graphite, and mesh work formation of the phosphide eutectic and also causes of blow-holes and defects.

Birmingham Branch.

THE EARLY HISTORY OF IRON WITH SPECIAL REFERENCE TO CAST IRON.

By J. Newton Friend, D.Sc., Ph.D., F.I.C. (Carnegie Gold Medallist).

The story of man's progress from the earliest dawn of human intelligence to the present day shows how, partly as the result of experiment and partly by force of circumstances, he has been led through the early Stone ages to the discovery of metal; how the metals came to be differentiated, and how great an impetus was given to the onward march of civilisation by the comparatively modern discovery of cast iron and of the manifold uses to which it may be put.

The Stone Age.

At the dawn of the human era, when man was just emerging from the brute creation and depended for his very existence upon the skill with which he could defy and repulse the attacks of animals more powerful than himself, he would seize upon any stones, branches of trees, or other hard materials lying at hand for purposes of offence or defence. As years rolled by he would learn to prepare in moments of quiet for future emergencies, and would thus single out stones, etc., which appeared to him specially suitable for the purpose, and keep them by him, just as we read that David, thousands of years later, "chose him five smooth stones out of the brook" prior to his engagement with the gigantic Philistine. Later on it would occur to him to improve upon the natural shapes by chipping, and he would soon discover that flint is particularly amenable to such treatment. His earliest attempts would be crude, and oft-times his implements would scarcely be distinguishable from chance products

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* A Paper read before the Birmingham Branch of the Institution of British Foundrymen on Dec. 14.

of nature. Such stones are termed *eoliths*,[*] and have been the subject of many discussions by various antiquaries, some postulating human agency, and others denying it.

Gradually man became more efficient, and his implements began to bear such decided marks of skilled workmanship that no longer can any doubt remain as to their origin. These stones, still crude and rough (Fig. 1), are known as *paleoliths*.[†] These were of several types. Some were flint flakes, probably for use as knives or arrow heads, and were chipped from a suitable lump of flint in directions parallel to the cleavage planes either by blows or by pressure. The point of application of the force can sometimes be seen. The residual centre portion of flint is termed a *core*, and some of these, together with the flakes detached from them by paleolithic man, have been discovered at various times; they present an appearance not unlike that shown in Fig. 2.

Fig. 1.—A Paleolithic Flint.

In course of time the shaping of flint implements became a highly developed art. Tools of exquisite workmanship were frequently evolved. This was particularly the case in Egypt, where the flint knives that date back to just a little before the First Dynasty, *circa* 4400 B.C., are described[‡] as "undoubtedly the most remarkable

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[*] Greek *eos*, dawn; *lithos*, stone.

[†] Greek *palaios*, ancient.

[‡] King and Hall, *Egypt and Western Asia in the Light of Recent Discoveries*. S.P.C.K., 1907, p. 14.

stone weapons ever made in the world." Such stones are termed *neoliths*,* and are not confined to flints, but comprise numerous other stones, such as quartzite, jade, and even Cumberland hematite. These were rubbed or ground to shape and polished as shown in Fig. 3. Some of the knives were even curved like a sabre, and the arrow heads were ofttimes beautifully symmetrical. Some of these are known in country districts at the present time as *elf-shot*, a name that explains itself, and, mounted in silver, they were worn some years ago as charms against poison, witchcraft, and the like.

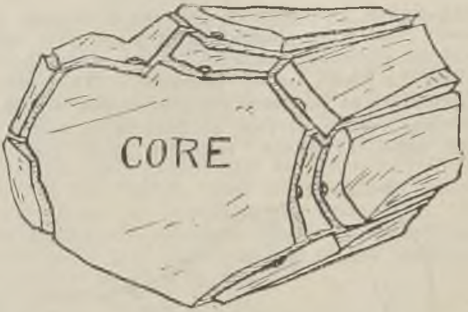

Fig. 2.—A Paleolithic Flint Core with Flakes.

Neolithic men were great builders, and it is to them that we owe such wonderful stone circles as exist at Stonehenge and elsewhere. That at Stonehenge probably dates back to about 1800 B.C.

During his wanderings in search of suitable stones early man occasionally stumbled across native metals, such as copper and iron, the former terrestrial, the latter in most cases meteoric. Finding that they did not crack on being hammered,† that they possessed great tenacity and admitted of being rubbed to a fine, hard edge, he would greatly prize them, and pieces would be handed down from father to son as valued heirlooms. This does not constitute the beginning of

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[*] Greek *neos*, new.

[†] Even meteoric iron can usually be cold worked. See Zimmer, *Journal of the Iron and Steel Institute*, 1916. No. II., p. 306.

what antiquaries term the "age of metals," for man, at the period of which we speak, had no idea of the connection between native metals and the earthy ores around him. He regarded the metal as a particularly useful and, unfortunately, rare kind of stone, and probably there the matter ended in so far as he was concerned.

FIG. 3.—A JADE ADZE.

In the neighbourhood of Lake Superior, where large masses of native copper occur, there have been unearthed at various times axes, lance heads, and other primitive implements composed of this metal, all shaped by hammering. The Indians of the North Pacific Coast had learned to utilise the deposits of native copper in the Chilcat country north of Sitka on the Isle of Baranof, and the copper shields made by them travelled down the coast to Queen Charlotte's Island.*

The same kind of thing has been repeatedly observed also in connection with other metals by travellers within historic times. Sabine, who

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* Ridgeway, *The Early Age of Greece* (Cambridge University Press, 1901). Vol. I., p. 595.

accompanied Ross in his Arctic explorations in 1818, relates that certain Eskimos, who visited the party, carried knives consisting of blades, of what was afterwards proved to be meteoric iron, set into bone handles. The pieces of iron had been detached with great labour from the softest of three masses of metal of meteoric origin at Melville Bay, and had then been beaten flat between stones in the cold condition.

This undoubtedly represents exactly what primitive man would do in Europe ages ago. It has been suggested that, in so far as iron is concerned, the amount of meteoric iron on the surface of the earth is so small that early man would probably seldom have an opportunity of seeing any, and only in rare cases would he ever have used it. There is more meteoric iron known to science, however, than many people believe. Zimmer estimates its amount at approximately 246 tons, and in the days of prehistoric man there were all the accumulations derived from meteoric showers of the previous ages to draw upon. Hence, it is reasonable to suppose that meteoric iron must have been rather more plentiful than now, particularly when it is remembered that, owing to its nickel content, celestial iron is frequently highly resistant to corrosion.

The Age of Metals

Many centuries elapsed, perhaps indeed ages, before man discovered that certain "stones" on being heated in the fire yielded a new "stone" capable of being hammered into useful shapes, and differing from the original stone in most of its other properties. This new product is now called copper or bronze, according to its composition. At first, no doubt, it was a matter of accident whether bronze or copper was produced, a "natural" alloy resulting from the reduction of the particular ore at hand. Thus, as Gowland* points out, "in Hungary, where the copper ores are associated with antimony ores, the early implements contain antimony up to 4½ per cent., an alloy resembling bronze in many of its physical properties. Similarly, implements in Ireland and Egypt sometimes contain 2 to 4 per cent. of

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* Gowland, *Huxley Memorial Lecture for* 1912, Royal Anthropological Institute of Great Britain and Ireland.

arsenic, and in Germany from 2 to 4 per cent. of nickel. In England, where copper and tin ores are so commonly associated—as in Cornwall—the earliest implements are of bronze. . . . . Owing to the non-discovery of tin, or copper ores containing it, in early times in Ireland and their absence in Cyprus, the implements of the Early Metal Age in these localities are of copper, and this at a time when Central Europe was in the Bronze Age.'' Ultimately, however, it would be observed that the bronze was not a simple substance, but a mixture, and in this manner metallurgical knowledge gradually progressed both during and after the transition of man from the Stone Age to the " Bronze Age."

Very considerable metallurgical skill was ultimately attained, and eventually iron ores were reduced to the metal and an iron industry was established. This simple beginning heralded the dawn of the " iron age.'' The greater strength of iron, when once this metal had been isolated, would lead to the gradual replacement of copper and bronze for many purposes. Lucretius,* writing about the year 56 B.C., describes this transition with characteristic elegance when he says:—

" With copper† they would belabour the soil of the earth, with copper stir up the billows of war and deal about wide gaping wounds and seize cattle and lands; for everything defenceless and unarmed would readily yield to them with arms in hand. Then, by slow steps, the sword of iron gained ground, and the make of the copper sickle became a byword; and with iron they began to plough through the earth's soil and the struggles of wavering war were rendered equal.''

But not every nation had its bronze age. Just as copper did not in every case precede bronze, so iron was not in every case preceded by either of these metals; in Africa,‡ for example, excluding Egypt, man passed direct from the age of stone to that of iron. The same was apparently the case also in Southern India.§

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* Lucretius, *De Rerum Natura*, translated by Munro (Routledge) Book V., lines 1250–1316.

† *i.e.* Bronze.

‡ Gowland, *loc. cit.*

§ Vincent A. Smith, *Journal of the Iron and Steel Institute*, 1912, No. I., p. 183.

Evidently, therefore, the particular path by which man has advanced has been governed largely by natural circumstances, different countries and different tribes being ofttimes led by different routes. This may be represented by the following scheme:—

$$\text{Stone Age}\begin{cases}\twoheadrightarrow \text{Copper Age} \twoheadrightarrow \text{Bronze Age} \twoheadrightarrow \text{Iron Age}\\ \twoheadrightarrow \text{Bronze Age} \twoheadrightarrow \text{Iron Age}\\ \twoheadrightarrow \text{Iron Age}\end{cases}$$

The question now arises as to how many years iron—whether native, meteoric or manufactured—has been known to and used by different peoples.

In attempting to find an answer, it is important to bear in mind that the term "age" in the above scheme refers not to a period of time, but to a stage of civilisation. Just as the nations to-day differ in the relative degrees of their civilisations, so in past ages some of the peoples were living in their stone age, whilst others were using implements of bronze, and yet others had become familiar with iron. Thus, Britain was passing through her stone period at a time when iron was already known in Assyria, in Egypt, and probably also in China.* Again, the inhabitants of Thessaly continued to use their stone weapons and their peculiar native pottery long after the culture of the bronze age had penetrated into Crete and Southern Greece. They persisted in their use, indeed, until the Cretan bronze age culture had reached its decadence, and the time for the introduction of iron had practically arrived.† Similar variation in the grades of civilisation occurred even in one and the same small country, for means of communication were primitive or non-existent. Our own island is a case in point. At the time of the Roman invasion, 55 B.C., the Southern tribes used both bronze and iron implements, whilst the Brigantes in the north were still in their stone age.

Further, in the history of any one tribe or people it is seldom that a hard and fast line can be drawn between the stone, bronze, and iron ages,

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* See Brough, *Journal of the Iron and Steel Institute*, 1906 No. I, p 233.

† Hall, *Ægean Archeology* (Warner, 1915).

for these gradually merged the one into the other. During the early days of the bronze age, tools and weapons of that metal were used alongside those of stone. Nor could iron, at the date of its discovery, be expected to supplant immediately and completely its predecessor.

An interesting example of this transition is afforded by a dagger found in the River Witham.* The lower part of its sheath, which was of bronze, is slightly decorated with regular Late Celtic ornament—which fixes its period. The blade is of iron and the hilt of bronze, illustrating the overlapping of these two metals. Such examples are not common in England.†

In the prehistoric remains at Hallstadt, in the Austrian Tyrol, and at numerous other places, implements of iron and bronze have been found lying side by side, further illustrating this transitional period.

In addition to these natural periods of transition between the ages of stone, bronze and iron, during which the various peoples were being educated to more advanced stages of civilisation, there exist what may be termed artificial periods of transition. These may be temporary and due to the force of local circumstances. Such was the case, for example, at the Battle of Hastings in 1066, when many of the Saxons fighting under Harold's banner wielded stone hammers, probably on account of the temporary shortage of iron. Religious conservatism accounts for the persistence of many old customs. Thus the ritual knives of Joshua v, 2, were made of flint, as the employment of metal would have been irreverent. Herodotus,‡ writing about the year 450 B.C., mentions that the Egyptians when embalming their dead removed the brain by means of an iron tool, but, in order to remove the contents of the abdomen, they cut "along the flank with a sharp *Ethiopian stone.*" The use of iron for the one operation and stone for the other is interesting, the employment of the latter implement being evidently connected with religious ceremonial. The same explains the use of stone altars in our

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* Herodotus. See Rawlinson's Translation, Book II., chap. 68,

† Clinch, *Handbook of English Antiquities* (Gill, 1905).

‡ Reginald A. Smith, *A Guide to the Antiquities of the Early Iron Age*, British Museum, 1905.

churches to-day, these being the modern representations of the stone altars used by neolithic man when worshipping his gods, as for example, at Stonehenge. An interesting example of individual conservatism is given by Mariette[*] and by Maspero,[†] both of whom were acquainted with a Copt in charge of the excavations at Abydos. This man continued to shave his head throughout his life with a flint razor; as his scalp was scraped nearly raw by the operation he was wont to cover his head with fresh leaves to allay the irritation of his inflamed skin. He died when over 80 years of age in 1887, and was still wedded to his stone razor.

Iron in India.

Iron was known in India at a very early date. If the *Black Yajuveda* may be believed, it would appear that some form of iron cannon, or perhaps more correctly "engine of war" was in use between 2000 and 1000 B.C., say 1500 B.C.[‡] Between 500 and 200 B.C. iron appears to have been in frequent use, particularly for military purposes. Iron has long been credited with the power of warding off evil spirits, and the famous pillar at Delhi,[§] composed of this metal, has received no little worship. It dates back to about A.D. 300. It is 23 ft. 8 in. in height, 22 ft. being vertically above ground and 20 in. below. Its upper diameter is 12½ in.; its lower 16½ in.; whilst its total weight is approximately 6 tons. The legend connected with this famous pillar asserts that the metal had been driven so deep into the ground that it had pierced the head of the king of serpents, the god Schesnag, who supports the earth. It had thus a remarkably sure foundation. A Rajah doubted this, and ordered the pillar to be dug up, with the result that its end was observed to be moist with the serpent's blood. On attempting to replace the pillar, however, it was found impossible to transfix the wily reptile, and the pillar, in consequence, remained

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[*] Mariette, *Bull. Institut egyptien*, 1869-1871, 1st Series, II., 58,

[†] Maspero, *The Dawn of Civilisation*—Egypt and Chaldea. Translated by McClure. S.P.C.K., 1910.

[‡] Neogi, *J. Royal Society Arts*, 1914, vol. 63, p. 43.

[§] See Hadfield, *J. Iron and Steel Inst.*, 1912. I., 134 *Survey of India* (Four Reports made during 1862-1865), Simla 1871. St. John Vincent Day, *Proc. Phil. Society of Glasgow*, 1872, 8 No. 2, p. 235.

loose and shaky, symbolic of the Rajah's faltering faith. It has been suggested that the name Delhi is, in consequence, a corruption of a Hindoo word *Dhili*, loose, but a Hindoo Judge informed the author that more probably the name means "Heart's Delight," and is in no way connected with the pillar. The pillar is by no means shaky, however, but, according to Miss Gordon Cumming,* "is now as firm as a rock, and has even resisted the cannon of Nadir Shah, who purposely fired against it. The marks of the cannon balls are clear enough. Hindoos believe that so long as this column stands the kingdom has not finally passed from them. The pillar is a magnificent example of early forging. It was made by welding together discs of iron, the marks of the welding being plainly visible.†

A remarkable feature of the pillar is its freedom from rust. This is no doubt due to some peculiarity of its surface layer, for pieces broken away appear to rust with ease. Hadfield‡ analysed one such sample and found it to contain :—

C=0,080, Si=0,046, S=0,006, P=0,114, Mn=0,000.

The high phosphorus and low carbon, sulphur and manganese contents, all tend towards reduction of corrodibility, but do not suffice to explain the general immunity of the pillar from corrosion.

Another iron pillar stood at Dhar, or Dhara, but is now in three pieces, measuring 24, 12 and 6 ft. in length respectively; a fragment is missing. The total length thus amounted to at least 42 ft., so that originally the column would be double the height of the Delhi pillar. Mr. Vincent A. Smith,§ in describing the same, points out that "whilst we marvel at the skill shown by the ancient artificers in forging the great mass of the Delhi pillar, we must give a still greater measure of admiration to the forgotten craftsmen who dealt so successfully in producing the still more ponderous iron mass of the Dhar pillar monument, with its total length of 42 ft., which, like the

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* Miss Gordon Cumming "In the Himalayas and on the Indian Plains."

† See remarks by T. Turner (*J. Iron Steel Inst.*, 1912, I. 184) and his references to earlier authorities.

‡ Hadfield, addendum to paper, *loc cit.*

§ Vincent A. Smith, *J. Iron Steel Inst.*, 1912, I. 158.

pillar at Delhi, is of the Gupta period, or about the year 321 of the Christian era."

These are the only known large masses of iron in the world, and it is only within comparatively recent years that moderns have learned to deal with masses of iron approaching these in size. The question has been raised as to whence India derived her knowledge of iron. Babylon is suggested,* and it is well established that from very early times iron has been known in what is now Mesopotamia. Others suggest that the Hindoos discovered iron themselves.† This is very reasonable. There is, of course, no need to attempt to trace back the discovery of iron to one source. Just as at the present time discoveries are not infrequently made simultaneously in different parts of the world, so it is reasonable to suppose that in early days, when means of communication were slow and primitive, different nations or tribes may have simultaneously unravelled certain of Nature's secrets quite independently.

Iron in Egypt and Palestine.

Iron appears to have been known in Egypt for many thousands of years. During blasting operations in the Great Pyramid at Gizeh in 1837, a wedge-shaped piece of iron was found in an inner joint, and, if coeral with the Pyramid, must be from 5,000 to 6,000 years old. It was examined by Flight, who concluded that it was not meteoric. Evidently, therefore, iron was worked even at that early date by the Egyptians. Gowland‡ suggests that it may possibly have come from the Sinaitic peninsular, having been obtained there by the accidental treatment of some iron ore—which occurs side by side with certain of the veins of copper ore. The search for iron amongst Egyptian relics of later periods has yielded disappointing results. Indeed, the metal does not seem to have found wide favour amongst ancient Egyptians. This is the more remarkable as the Assyrians, with whom they were in frequent communication, were very familiar with iron, as will

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* For Northern India. Vincent A. Smith, *J. Iron Steel Inst.*, 1912, I. 184.

† Notably J. M. Heath in two papers on Indian Steel before the *Royal Asiatic Society*. 1837, Vol. IV.; 1839, Vol. V.

‡ Gowland, *loc cit.*

presently be shown. It is interesting to note that the earliest general group of tools found in Egypt was at Thebes, and dates back to 666 B.C.—the time of the Assyrian invasion. The modern Egyptian camel driver still wears iron rings, thus keeping up an interesting link with the past. As regards Palestine, it is generally conceded that iron was introduced 1200 B.C. by the Philistines,* who settled in Palestine about the same time as the Israelites, and who were a very cultured race. They were non-Semitic, possibly hailing from Crete. The constant petty skirmishes between the Israelites and the Philistines are readily understood when it is remembered that the latter possessed the fertile maritime plain whilst the Israelites occupied the relatively barren land above! Og, King of Bashan, about this time is reported† to have had an iron bedstead. No doubt the word bedstead would be more correctly rendered as "bier." In any case, that the dead king should be laid on a bier was quite a normal occurrence, and the fact that it is mentioned at all suggests that the unusual feature lay in its being made of iron.‡

The oldest pieces of iron hitherto found in Palestine are two pieces found in the water passage at Gezer.§ The curious part about this find lies in the fact that the passage had been sealed up prior to 1250 B.C., so that the pieces evidently date back to a time several hundred years anterior to that at which iron was in general use in Palestine. David was familiar with iron *circa* 1000 B.C., and the metal was evidently used at times for personal adornment, for a finger-bone with an iron ring corroded to it has been unearthed.¶ Certain iron knives found in tombs in Gezer are attributed to the Philistines,** and Goliath's spear is described†† as weighing 600 shekels of iron. In 2 Samuel xii. 31, the writer refers to "axes of iron" and "harrows of iron" in connection with David's victory over the people

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* See 1 Sam. xiii. 19-22. Josh. xvii. 16-18. Judges i. 19. v. 3.

† Deut. iii. 11.

‡ See article "Bed." *Encyclopædia Biblica* (Black, MCMI.), vol. 1.

§ Macalister, *Palestine Exploration Fund, Quarterly Statement*. 1908, p. 1.

¶ Handcock, *Archeology of the Holy Land* (Unwin), p. 210.

** Macalister, *Excavation of Gezer*, vol. 1, p. 299.

†† 1 Sam. xvii. 7.

of Rabbah. The fact that iron is specifically mentioned suggests that implements of this kind were also made of bronze. David's son Solomon is stated (2 Chron. ii. 7) to have had iron workers of his own, although he found it necessary to send to Tyre for his chief artificer or foreman. Furnaces for the direct reduction of iron ore were well known to the later Hebrew writers,* and the ore appears to have come from Lebanon.†

According to an old Hebrew legend, the humanised god Tubal-cain‡ was "an instructor of every artificer in brass and iron." The word "Tubal" is probably Babylonian, and connected with *Gibil*, the god of solar fire. "Cain," which is missing in the Greek version, means "artificer," and was probably added as a suffix to Tubal to explain why he was regarded as the father or instructor of smiths.§ It is possible that in the earliest form of the legend Tubal taught men the art of getting fire. The legend resembles the Greek and Roman myths of Vulcan. The Canaanites had chariots studded with iron at the time of the invasion by the Israelites, and these are referred to, not only in Holy Writ,‖ but also in historical inscriptions in Egypt. They were probably of Hittite pattern.

FIG. 4.—A BRONZE AXE HEAD; NORTH IRELAND.

Iron in Mesopotomia.

The earliest reference to iron in Assyria¶ dates back to 1400 B.C., where rings of iron covered with

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* Jeremiah xi. 4; Deuteronomy iv. 20; Kings viii. 51.

† Deut. viii. 9. Jeremiah speaks of iron from the *north*, Chap. xv. 12.

‡ Genesis iv. 22.

§ See *Encyclopædia Biblica* (Black, MCMI.), vol. 1, under "Cainites," sec. 10.

‖ Joshua xvii. 16, 18. Judges i. 19; iv. 3.

¶ Ridgeway, *loc. cit.* p. 615.

gold are referred to in the famous Tel-el-Amarna tablets. Ashur-natsir-pal, 885-860 B.C., states that in making an attack on Mt. Lara, in the fourth year of his reign, he cut a way for his troops with picks of bronze and *axes of iron!* The iron was obtained as tribute from various places, notably Carchemish, and later from Syria. King Sargon seems to have been the first to obtain iron from Armenia. The Assyrian King Ramman-nirari III., 810-782 B.C., is recorded as having received 3,000 talents of copper and 5,000 talents of iron as tribute from Aram Damascus.* In the ruins of the palace of Sargon II., 722-705 B.C., at Khorsabad, Victor Place discovered a storehouse containing an enormous quantity of iron, namely, about 350,000 lbs. This was mostly in the form of bars pierced with holes for convenience of transport. It was evidently a store of unworked metal ready to be made up into finished articles should the king require them. As Gowland† remarks: " This vast accumulation of iron indicates incontestably that the metal had been in use for many centuries previous to the time of Sargon, so that it will not be unreasonable to assume that

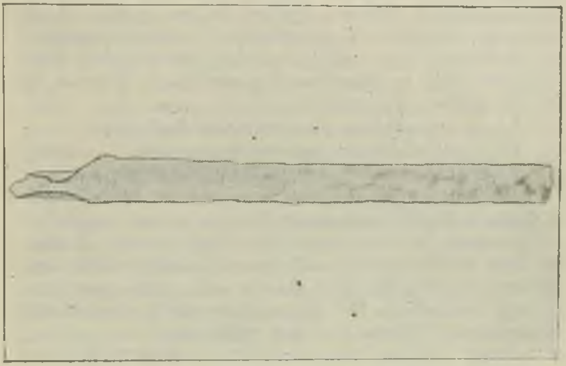

FIG. 5.—IRON CURRENCY BAR.

Found at Lyttleton. Length 12.72 ins., weight 1,933 grains.
From a drawing by Mr. W. J. Else, Curator, Worcester Museum.

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* *Encyclopædia Biblica* (Black. MCMI.), Vol. 2. Article "Iron.'

† Gowland, *loc. cit.*

the Assyrians were acquainted with iron certainly earlier than 1500 or even 2000 B.C."

Iron in Europe.

Turning now to Europe, it appears that Greece was the first country to use iron, namely, about 1400 B.C.[*] Homer (880 B.C.) was thoroughly familiar with the metal, and frequently alludes to it in both his Iliad and Odyssey, in which poems, however, he is describing a period anterior to his own, namely, about 1200 to 1400 B.C. The Trojan War was fought at the transition period in Greek history between bronze and iron. Hence it comes about that iron, gold and bronze are repeatedly mentioned amongst the treasures of the wealthy.[†] Thus Ulysses, in the guise of an old man, relates his experiences to the unsuspecting Gumæus, who has hospitably entertained him, and pretends to describe the wealth of Ulysses in far-off lands. He says :[‡]

> "I saw myself the vast unnumbered store
> Of *steel elaborate* and refugent ore,
> And brass high heaped amidst the regal dome;
> Immense supplies for ages yet to come."

Although highly esteemed, iron was not regarded as precious in the sense of being a rare metal. It was evidently a well-known commercial commodity, used both like slaves and cattle for bartering, as well as for the manufacture of peaceful implements. Thus we are told that

> "From Lemnos Isle a num'rous fleet had come
> Freighted with wine;"

and that the Greeks

> "Hastened to purchase, some with brass, and some
> *With gleaming iron;* other some with hides,
> Cattle or slaves; and joyous waxed the feast."[§]

It is instructive to note that, with but two exceptions, Homeric weapons were of bronze, whilst the tools were of iron. One exception is the battleaxe of

> "Great Areïthous, known from shore to shore
> By the huge, knotted iron mace he bore."[‖]

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[*] Montelius, *J. Iron Steel Inst.*, 1900, II., 514.

[†] See *Iliad VI.*, 48 ; ix., 365, 366 ; x., 379, 133. *Odyssey* xiv., 324 ; xxi., 10.

[‡] *Odyssey* xiv. Pope's translation.

[§] *Iliad.* Derby's translation, vii., 518–525.

[‖] *Iliad* vii., 141. Pope's translation.

Lang's explanation is undoubtedly the correct one, namely, that when iron was first manufactured its quality was uncertain, inasmuch as the necessary metallurgical skill to produce a reliable metal had not yet been attained. Hence it was not used for weapons where men's lives were at stake, except in solid lumps which could not easily bend or snap, as, for example, head of battle-axes,* for which keen cutting edges are not so necessary, the object being to give a heavy blow. Even in this case the axe is referred to as rather a curiosity. Strong, if indirect, support for the above view is afforded by the account given by Polybius† (205-123 B.C.) of the poor quality of the iron used by the Celts many hundred years later, namely, 223 B.C. The Romans inflicted a severe defeat upon them, and this is attributed to the fact that their long iron swords were "easily bent, and would give one downward cut with any effect, but that after this the edges got so turned and the blades so bent that unless they had time to straighten them with the foot against the ground they could not deliver a second blow."

If the iron at the disposal of the Homeric heroes was as uncertain as that mentioned above, it is no wonder that bronze was preferred for military purposes, since it would be giving an opponent somewhat of an advantage if a warrior had to halt on the battlefield and straighten his weapon.‡

Even if Homeric iron was not as poor as that of the Celts, it is easy to understand that unless its quality was such as to render it very appreciably superior to bronze, the latter metal would be retained by military conservatism, "just as the Fifteenth Century soldiers found the long-bow and cross-bow much more effective than guns, or as the Duke of Wellington forbade the arming of all our men with rifles instead of muskets."§

An interesting passage in the Odyssey shows that the Greeks, at the time to which we refer, had a certain knowledge of tempering. It is the account of the blinding of the gigantic Cyclops, by Ulysses,

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* See Lang. *The World of Homer*. Longmans, 1910. Chap. x.

† Quoted by Ridgeway, *The Early Age of Greece* (Cambridge Univ. Press, 1901).

‡ Berard, *Les Pheniciens et l'Odyssee* (Paris, 1902). Lang, *Revue Archeologique*, 1906–7, 280.

§ Lang, *loc cit.*

who plunged a fiery stake into his one and only eye. It runs:—*

"As when the smith an hatchet or large axe
Temp'ring with skill, plunges the hissing blade
Deep in cold water (whence the strength of steel)
So hissed the blade around the olive wood."

The Romans were skilled metallurgists, and established arms factories all over their empire. At an early date they were familiar with steel and the method of tempering it. Thus Virgil,† writing about the year 30 B.C., his classical work, *The Æneid*, graphically describes the smithy in full work. He says:—

"A flood of molten silver, brass and gold,
And deadly steel in the large furnace rolled;
Of this, their artful hands a shield prepare,
Alone sufficient to sustain the war.
Seven orbs within a spacious round they close,
One stirs the fire, and one the bellows blows,
The hissing steel is in the smithy drowned."

Some years later Pliny, who was born in A.D. 43, collected together, in his famous *Natural History*, much that was known of iron and steel by the Romans in his day—no inconsiderable amount. After discussing the different ores of iron, and the method of tempering the carburised metal by plunging it into water, he makes (Book xxxiv., Chapter 41) the following interesting statement, to which I have never seen attention directed. He says:—‡

> "*It is a remarkable fact, that when the ore is fused, the metal becomes liquefied like water, and afterwards acquires a spongy, brittle texture.*"

This can surely only mean one thing, namely, that the Romans occasionally obtained, probably by the accidental overheating of their furnaces by extra draught, small quantities of cast-iron in their furnaces. This probably represents the earliest mention of cast iron in existence. The metal would be of no use to them as it was, not having

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* *Odyssey*, Cowper's Translation, IX , 45962.

† See Virgil's *Æneid*. Translated by Dryden (Routledge, 1884), Book VIII. The italics are those of the present author. Virgil was born in 76 B.C., and was at work on the Æneid when about forty years of age.

‡ Pliny, *Natural History*. Translated by Bostock and Riley (Bohn, 1857), Vol. VI.

furnaces capable of remelting it for casting purposes, so it would either be thrown away or more probably be mixed with subsequent charges and passed a second time into the furnace. Pliny also mentions that at the time of the Second Punic War (218-201 B.C.) "many personages who had even filled the prætorship, wore rings of iron to the end of their lives." Presumably the metal was held in such high esteem as to serve for personal adornment. Pliny goes on to say that even in his day slaves wore iron rings covered with gold. The right to wear pure gold rings was apparently never given to slaves.

Iron in Britain.

For many years, probably several centuries, before the invasion of the Romans in B.C. 55, the Britons were familiar with iron. Their chariot wheels had iron rims, as is proved by remains found in Yorkshire, although it is very doubtful if they were fitted with scythes for laming hostile infantry,[*] as history books used to tell us, and as Boadicea's chariot is depicted as having in the statuary on the Thames Embankment at Westminster Bridge. Cæsar, however, mentioned that the Britons were accustomed to use bars of iron in place of coins as currency, and several hundred of these, which have escaped more or less the ravages of time, have been found and lodged in different museums, notably the British Museum and in the museum at Worcester.

The bars resemble swords, and consist of a flat and slightly tapering blade with blunt vertical edges. A rude handle is formed by turning up the edges so as to meet one another at a point some 2 ins. from one end.

It is only quite recently that the true nature of these currency bars has been discovered, the credit being due to Mr. Reginald A. Smith, of the British Museum. The bars resemble swords so closely that they were formerly regarded as unfinished ones or as some kind of tool.[†] It is not at all impossible that other currency bars are lying unrecognised in

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[*] See R. A. Smith, *A Guide to Antiquities of the Early Iron Age*, British Museum.

[†] R. A. Smith, *Proc. Soc. Antiq.*, 1915, 27; 69. See also 1905, 20; 1907, 21; 319.

museums and in private collections, and catalogued under other names.

The improbability of these bars ever having been swords in a more or less half-finished state is summarised by Smith as follows:—

1. The bars have frequently been found in considerable numbers hidden away as if constituting a hoard, much in the same way as coins have been usually hidden. They have been found also right in the centre of British camps. This was the case, for example, at Meon Hill, Gloucestershire, where in 1824 some 394 bars were discovered in a heap.

   Now it seems much more probable that the ancient Britons would conceal their money at a crisis, rather than that they would stop to bury half-made swords.

2. Division of labour is a mark of civilisation, and in early British days such division was by no means in an advanced stage of development. In other words, the armourer who shaped these bars would himself produce the finished swords, if indeed swords they were to be. It is not probable that he would prepare a large number to hand on to another for the finishing process.

3. The bars vary considerably in size and weight, some bars being as much as 16 times as heavy as others. Thus only a small fraction of them could ever contain the right amount of metal to yield a sword of the period.

4. The most conclusive evidence, however, that the bars were never intended as swords lies in the interesting observation that the weights of all the heavier ones must originally have been simple multiples of the weights of the smallest ones.

Owing to the corrodibility of the iron, all the bars yet found have suffered some loss in weight. Fortunately, however, there are a good many which have been only relatively slightly oxidised, and it is possible to estimate roughly what their original weight must have been. When this is done, it is found that the weights approximated to 309 grams. (4,770 grains), or to some multiple or sub-multiple of this amount. In all, no fewer than six different denominations have been found, of the following presumed standard weights:—

		AVOIRDUPOIS	
	Grains	Grains	Ounces
Quarter	77	1,193	2¾
Half	154.5	2,385	5½
UNIT	309	4,770	11
One and a half	463.5	7,155	16½
Double	618	9,540	22
Quadruple	1,236	19,080	44

The reason for choosing the third denomination, namely, 4,770 grains, as the unit, lies in the fact that in the Cardiff Museum is a bronze weight which was found in association with enamelled bronze ornaments of late Celtic character near Neath, in Glamorganshire. On the top of this weight is engraved, the figure I., and it weighs 4,770 grains. A similar weight, but in basalt, lies, or rather did lie before the outbreak of the Great European War in 1914, in the Mainz Museum. It bears the mark I., and weighs 4,767 grains, that is, the same as the preceding within the primitive range of measurement. These weights represent half an attic commercial mina of the period prior to B.C. 160, and show that even at this early date Britain recognised the same standard weights as the Continent.

It is highly improbable that the early British would have six different sizes of swords; still less is it conceivable that the smith would go to the trouble of carefully standardising the weights of his swords when they were still in an unfinished condition.

The evidence clearly points to the supposition that these bars are indeed the currency bars referred to by Cæsar as used by the early Britons at the time of his invasion. The use of currency bars or blades may be traced back to the early Greeks, and survives to-day in some parts of Africa. As we have seen, in the Homeric period iron was used for barter. Dechelette, who was, most unfortuntely for antiquarian research, killed at the front in the early years of the Great European War, traced the currency bars back to the spits for roasting flesh. It is said that Pheidon deposited in the Heræum certain iron bars that had till his time, namely, prior to 600 B.C., done duty as money. Waldstein, during his excavations of the Heræum some years ago, discovered a bundle of iron rods which quite possibly constitute the remains of Pheidon's gift.

Iron in Central Africa.

Schweinfurth, who travelled widely in Central Africa, states that the only equivalent for money possessed by the natives in that region is that of the Bongo tribe, and is known as the "loggoh kul-dutty." This is an iron spade-like article formed in flat discs from 10 to 12 ins. in diameter. On one edge is a short handle,whilst on the diametrically opposite edge is a projecting limb something like an anchor. It is in this form that iron is stored amongst the treasures of the wealthy, and serves in place of money for commercial exchange and for marriage portions. In Cambodia, Indo-China, iron ingots are used as a special kind of money or currency. They are not weighed, but are as long as from the base of the thumb to the tip of the forefinger; they are two fingers in breadth, and one finger thick in the middle tapering off to either end.

We are inclined to smile at these crude methods of measurement, but let us not forget that three barley corns were at one time taken to measure an inch, and the heights of horses are still measured in "hands," a term reminiscent of the time when the span of the average human hand was regarded as a sufficiently accurate standard of measurement.

When the Cape of Good Hope was first colonised the Hottentots employed bars of iron and cattle in place of currency. On the west coast of Africa the *bar* is the unit of currency, and all merchandise is reckoned by the *bar*, which has a definite monetary value to-day, although originally it referred to the exchange value of a bar of iron of fixed dimensions, with which early European traders transacted business with the natives.

From the foregoing it is evident that the idea of using iron bars as currency dates back to very early times, and has been adopted by primitive peoples down to the present time. It must be confessed, however, that it is difficult to understand how the idea of using currency bars reached this country, since none of the peoples between Britain and Greece appear to have adopted the system. Possibly this is but another example of two peoples each independently hitting upon the same idea.

Two British currency bars were examined by Prof. Gowland, who reports that one (bar B) was similar in structure to iron produced by primitive methods, such, for example, as those adopted in the heart of Africa by the natives at the present time. The other (bar A) resembled, both in analysis (it contained nickel) and in structure, as revealed by the microscope, meteoric iron. This is an observation of particular interest.

The analyses were as follows:—

	Bar A.	Bar B.
Carbon	trace	0.08
Silicon	0.09	0.02
Phosphorus	0.69	0.35
Manganese	nil	nil
Nickel	0.23	nil

It thus seems fairly certain that the British were familiar with iron in the second century B.C., and very probably at an even earlier date. It is difficult to say when bar currency became obsolete in these islands, because different districts varied enormously in their relative states of civilisation. For example, an early writer states that even three centuries after Cæsar's first visit there were Britons living in outlying marshy districts, possibly the Cambridgeshire Fens, who "encircled their loins and necks with iron, deeming it an ornament and evidence of opulence, in like manner as other barbarians esteem gold."

Possibly Christ had treasure of this kind in His mind when He enjoined His followers not to lay up stores on earth "where moth and *rust* doth corrupt" (Matthew vi, 19). But the same idea of corrosion occurs in connection with the more valuable metals, namely, silver and gold, in James v, 3, so that one cannot be certain either way. It is interesting to note, by the way, that the Greek words translated *rust* in the above passages are not the same in the two cases.

Direct Reduction of Iron Ores.

All the primitive methods of reducing iron from its ore were "direct" methods, no attempt being made to obtain cast iron, which was economically unknown. Until mediæval times the furnaces were too low, and the blast too feeble to yield cast iron in normal work, although in exceptional circumstances it is possible that cast iron was occasionally produced in small quantity. Such a supposition would account for the remarkable statements of Pliny, to which attention has already been directed. Its brittleness, however, would render forging impossible, and its high melting point would prevent its utilisation for castings. The probability therefore is that it would be recharged into the furnace in subsequent runs.

There are several ways by which information has been obtained as to the manner in which primitive man reduced his ores. Two of the most important direct methods consist in studying the remains of ancient furnaces and in comparing these with inscriptions or documents also of ancient date. Another consists in learning how uncivilised races at the present time extract their iron from its ores in such regions as have not as yet been influenced by modern civilisation. Gowland men-

FIG. 6.—THE DYOOR FURNACE.

tions that the type of furnace still surviving (*i.e.*, in 1912) in India among the hill tribes of the Ghats is closely analogous to the prehistoric furnaces of the upper basin of the Danube and of the Jura district in Europe.

As regards the furnace used by the ancient Britons, R. A. Smith* writes: "Although there are various proofs that iron was produced in Britain centuries before the Roman occupation no furnaces of the earliest period have been discovered; and it is therefore probable that the ancient Britons employed the simple low hearth resembling the Catalan furnace of the Pyrenees, which has been in use there from very remote times to our own day. The source from which Britain derived the furnace and art of extracting iron from its ores, seems to have been the Mediterranean region, either the Eastern Pyrenees or North-West Italy; but it may also be reasonably held that the first iron furnace of

FIG. 7.—THE BONGO IRON FURNACE.

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* R. A. Smith, *A Guide*, etc., p. 4.

the Britons was derived from that used so successfully in the extraction of tin. It is not, however, probable that our islands were the earliest centre for the metal."

Reduction of Iron in Africa.

Schweinfurth * who during the years 1868 to 1871 was engaged in the exploration of Central Africa, gives several highly interesting accounts of the different methods by which the savage tribes made their iron. The furnace used by the Dyoor —a name meaning men of the woods or wild men —is made of clay. In shape it is conical, as shown in Fig. 6, but the tendency of the clay to crack limits the height of the furnace to about 4 ft. Fragments of ore are thrown into the cup-shaped portion at the top, the lower conical part having first been packed with charcoal. At the base are four openings, one of which is larger than the others, and is used for the removal of the slag, etc. The other three are to admit the long tewel irons, or pokers, which reach to the middle of the bottom, and keep the aperture free for the admission of air. Without stoking the openings would very soon become blocked up with slag. In reply to his inquiry, Schweinfurth was informed that bellows are never employed, as it was found that too fierce a fire was injurious and caused a loss of metal. It would be interesting to inquire if the supposed injurious effect was really due to the production of a little cast iron, which would be unworkable, and therefore a loss to the smelter. When the flames have penetrated through

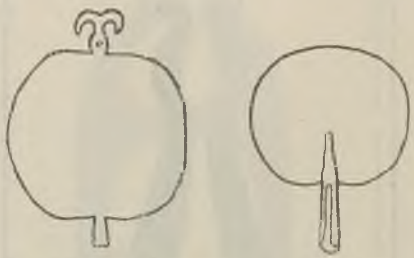

Fig. 8.—Loggoh Kullutty   Loggoh.

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* Schweinfurth, *The Heart of Africa* (Sampson Low),Vol. I.,p. 81.

the mass of ore and escape at the top of the furnace the reduction is presumed to be satisfactory. The metal has now sunk down into the hearth, is reduced a second time, and the heavy portion of the resulting product, which is detached in little leaflets and granules, is further heated in clay crucibles. The red-hot particles of metal are beaten into one compact mass with stone hammers, and by repeated hammering lose the bulk of their impurities. The final product is stated by Schweinfurth to be very homogeneous and malleable.

Fig. 9.—Native Knife (Zambesi).

The usual shape in which the raw material is used as a medium of exchange is in spear heads or in spades. Spear heads are about ¾ yard in length, and serve as currency throughout the Upper Nile. The Bongo, another tribe in Central Africa, prepare their iron in a somewhat more advanced manner.* After the harvest has been gathered in

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* Schweinfurth, *loc. cit.*, p. 124.

and the rains are over the clay furnaces are erected, of a shape shown in Fig. 7. They are 5 ft. in height, and are divided into three compartments, the middle one of which is filled with alternate layers of fuel and ore. The other two contain fuel only. The lowest section has four holes for the reception of tewels, and through which also a blast is applied by means of bellows. A fifth hole serves for the removal of the metal. The raw metal obtained in this way is exhibited in three shapes:—

1. *Mahee.*—Spear heads 1 to 2 ft. in length analogous to those of the Dyoor already mentioned.

Fig. 10.—The Osmund Furnace.

2. *Loggoh kullutty.*—The spade-like circulating currency of the Bongo, to which reference has also been made (Fig. 8).

3. *Loggoh* or *Loggoh melot.*—Spade-like articles resembling the loggoh kullutty, but without hooks at the top. These have a wide sale along the course of the Upper Nile.

The Discovery of Cast Iron.

Returning now to Europe, reference may be made to the Swedish or Osmund furnace, which for a long time was used in the production of iron (Fig. 10), and is ably described by Percy.* The

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* Percy, *Metallurgy—Iron and Steel* (Murray, 1864), p. 320, *et seq.*

ore, after having been dried by exposure to the air, was calcined in heaps, with wood as the fuel; the calcination was completed in two days. The ore was then smelted with charcoal in the usual way, the average output of iron being merely 1½ tons per furnace per week. In working up the bloom there was considerable loss, sometimes amounting to 50 per cent.

The Osmund furnace was eventually succeeded by the German Stückofen—an ugly name, for which no English equivalent has been given. The name originates from that given to the mass of metal or "Stück" extracted from the bottom of the furnace after smelting. This is seen (Fig. 11) to be a lengthened Osmund furnace, bulging in the middle; indeed, it resembles two such furnaces placed one upside down upon the other, and is clearly the forerunner of our modern blast furnace. The taller the furnace the longer the metal remains in contact with the fuel—other things being equal. Consequently, the introduction of the Stückofen led to the production, more or less by a series of oft-recurring accidents, of cast iron. As the height

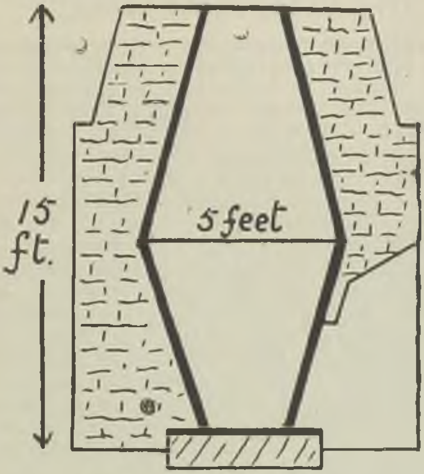

Fig. 11.—The Stuckofen.

of the furnace increased cast iron became the only product.

As to the exact date when cast iron was definitely recognised one cannot be certain. It appears to have been known in Sussex in 1350, and by 1400 was quite a common product. Sussex was in those days one of the chief homes of the iron industry, its stores of iron ore and wood providing the essentials. It was in the village of Buxted, not far from Crowborough, that

> " Master Hugget and his man John
> They did cast the first cannon."

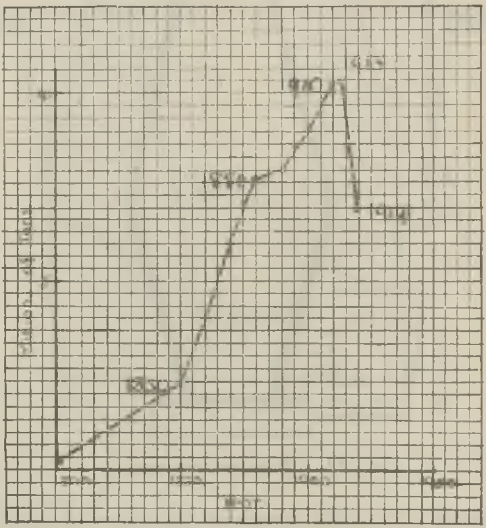

Fig. 12.—The Output of Pig-Iron Since 1800.

At first cast iron was used exclusively for casting purposes. Its earliest application was on the Continent, but its use began to be general in this country about 1500. In 1516 a cast-iron gun called Basiliscus was made, weighing approximately 10,500 lbs. In 1588 the Spanish employed both bronze and cast-iron guns in their Armada, and some of these have since been raised from vessels sunk off the coast of Scotland, when the fleet had been dispersed. The production of ornamental cast-iron stove plates reached a high artistic level.

Eighteenth Century Developments.

Many attempts were made to utilise coal for the reduction of iron ores instead of charcoal, but it was not until about 1735 that the problem was satisfactorily solved, namely, by Abraham Darby, the younger, at Colebrooke, in Shropshire. Fifteen years later coal became a serious competitor with charcoal. In 1740 there were only 59 blast furnaces in England and Wales, the average weekly output being under 6 tons per furnace. In 1790 there were no fewer than 106 furnaces, 81 of which used coke, the remainder using charcoal. The average weekly output of the coke-fired furnaces was 17 tons per week.[*] In 1754 Darby[†] had some seven furnaces, and mechanically-driven engines to supply the blast.. The grandfather of this Darby, namely, John Darby, brought over some Dutch brass founders, and built a foundry in Bristol. Here he experimented about the year 1706 with cast iron, endeavouring to obtain castings in this metal, but without success. His Welsh apprentice, John Thomas, thought he saw what was wrong, communicated his ideas to Abraham Darby, the elder son of John, and these two secretly cast the same night an iron pot. For more than a century the secret was jealously guarded, and the process was regularly carried out, at Colebrookdale, successively by John, by Abraham the elder, and Abraham the younger.

About 1740 Huntsman perfected his process of making cast steel—a process still in use—and in 1784 Henry Cort introduced the puddling process. Cast iron was now being used for a two-fold purpose. In addition to casting it found employ as the most suitable starting-point for the manufacture of iron and steel. Consequently the demand for cast iron increased by leaps and bounds.

Conclusion.

Beginning with an annual output of approximately 250,000 tons of pig-iron, the nineteenth century saw the United Kingdom steadily increase her yield to about 2¼ million tons in 1850. From

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[*] See Summary in *Nature*, 1910, Vol. LXXXIII., p. 265.

[†] Scrivener, *History of the Iron Trade* (Longmans, 1854).

this date onwards the production increased rapidly to a maximum of 10,260,315 tons in 1913. Then came a rapid decline, the output for 1919 being only 7,398,000 tons. This was due to the war. If we accept the suggestion of Sir Robert Hadfield that the production of iron serves as an index of the state of civilisation, the break in the curve at this point (Fig. 12) clearly points to the demoralising effect of the war upon humanity at large. The author sincerely hopes that, should it ever be his lot to return to the subject, the curve will be found to have rapidly changed its direction and point towards renewed economic and industrial prosperity.

Lancashire Branch.

DISCUSSION ON JAR RAM MOULDING MACHINES.

At a meeting held on December 3, Mr. W. H. Meadowcroft (Branch President) in the chair, a discussion upon jar ram moulding machines was opened by Mr. J. Hogg (Burnley). He said it had been his opinion that machines of this type were making rapid progress, and it was curious that, although application had been made to many persons interested in their production, no one was willing to read a Paper on the subject before the Branch. The most that could be obtained was a promise to do something in that way in the future. He therefore proposed to give an account of his own experience, and he would ask the members to do the same, and to give a reply to the question whether jar ram moulding machines were suitable for both light and heavy work.

Poor Results Obtained.

A few years before the war the management at the foundry where he was foreman decided to improve the methods used in quite a number of jobs. At the time they had four pneumatic presser-head machines for small boxes, about 16 in. × 12 in. × 4 in., and they were turning out 3,000 castings per day. Other jobs were not wanted so rapidly, but were turned out in lots of 50 and 100. It was impossible to keep up delivery, and orders had to be sent out, sometimes to a distance. Therefore a change had to be made. They had no plates cast or mounted, so they started at rock bottom. The management desired to discover the machine most suitable for an all-round class of work, and the jar ram machine was recommended. The first trial was made with a straight-draw machine, which lifted up the box from the pattern, face-side-down. They mounted the pattern plate on the top of the flat surface of the table and rammed it up with a jar method, pressing a lever and giving it three or four bumps. The box was lifted up by means of little pillars away from the pattern, and then lifted off and put down on the floor. Stop valve and sluice valve castings were successfully made with that machine, which was simply and easily worked, and at first pleased him very much. For the making of small pillars in lots of 100, the machine produced fair bottoms. Another job—a 24-in. sq. grid or grate, strengthened by two fishbacks being cast on it—gave a very mixed experience. All the facing sand used for making the top was ground. Sometimes wonderful results would be given, followed by batches without a single good one amongst them. The employment of a man who was considered to be an expert did not alter matters. Very reluctantly the machine was sent back. It was naturally assumed that the difficulty with the grid top could be overcome by using a turnover-table machine, and one was installed. It drew the pattern away from the mould, face-side up. Not a single good result was forthcoming, and no matter what sand was used the core came up with the pattern every time. Finally the jar ram was given up.

Even where it was successful it had to be carefully considered whether the jar ram was quicker than hand ramming. The machine was stationary and the boxes had to be carried a certain distance. Each day the sand had to be carried back again to the machine and filled in the boxes, which occupied some little time. A large percentage of bad draws was another important item. In hand ramming a bad mould was rarely encountered, and the boxes could be left when they were turned over on the floor, and the sand was also at hand. The same thing applied to steps for staircases, which were 2 ft. long by 10 in. broad. Difficulty was never experienced in making those castings. On the other hand valve castings were made quicker and slightly better by the jar ram.

Vibration Troubles.

A point which had to be borne in mind was the shaking of the floor during the jarring. A bed of concrete 3 ft. 6 in. deep did not entirely prevent the shaking. At that time a number of tank plates, which carried no gaggers in the top parts, were being hurried along. The shaking of the floor so impressed him that he moved the job away to another foundry. The machine certainly turned out some beautiful moulds, but for jobs with lugs or similar contrivances on the side, trouble resulted from soft places underneath. This was overcome by jarring half-way up, and by horizontally imposing a rammer handle, and then filling again to the top. Even when it was charged up twice the mould came out with the plate thicker than it should be.

He was greatly impressed by the possibilities of the jar ram machine, but hand-ramming with the ordinary turn-over table, with which an intelligent man could get a good production on all classes of intricate castings, constituted more than ordinary competition. One advantage of hand ramming was that the ramming could be regulated. Certain jobs must be rammed very lightly and quickly: others, such as valves, required ramming more tightly.

Good Results Realised.

Mr. Clarke said during the last three years there had been put in at the foundry of the National Gas Engine Company at Ashton-under-Lyne six jolt-ram machines. Five of these were by Macdonald, of Glasgow; the other was a Britannia machine, which was used for making cores. There were two No. 9's worked by plate moulders, which produced such castings as pipe bends, T pipes, sole plates, outer pedestals, base plates and standards for petrol engines. One job was the exhaust box of a gas engine, which was from 14 in. to 15 in. diameter, and had a flange at the bottom joined by a core. The castings made on those two machines varied in weight from ¼ cwt. to 5 or 6 cwt., and all were cast in green sand. The plate was of steel 3 ft. 6 in. sq., ¾ in. thick. There were several holes drilled in the plate so that any kind of pattern could be put on. They were very successful indeed as regarded plate moulding; some boxes were made in aluminium, and varied in size, the largest being 3 ft. 4 in. sq. by 15 in. deep.

On a No. 12 machine heavier castings such as liners and cylinders were made, the weight varying from 6 cwt. to 15 cwt., and the dimensions about 3 ft. 6 in. diameter and 4 to 5 ft. long.

They were mostly dry-sand moulds. On this machine gas engine beds were cast in green sand with good results. The boxes varied from 5 ft. 3 in. × 2 ft. × 16 in. to 4 ft. × 2 ft. 9 in. × 2 ft.

A No. 16 machine had a plate 8 ft. long by 6 ft. wide, and the castings weighed up to 30 cwt. Whilst flywheels were unsuited to this machine, such castings as boiler shell casing, scrubbers, and other descriptions of gas plant came out very well. The boxes were 8 ft. × 3 ft. 6 in. × 21 in., also 5 ft. sq. × 2 ft. and 4 ft. 6 in. sq. × 2 ft. Floor plates had been made on this machine. They were 3 ft. 6 in. × 2 ft. 6 in. × 1¼in., thick ribbed, and were cast green, the results being quite good. Those four machines were working constantly at the present time; there were three plate-moulders on the two No. 9's, a moulder, a labourer and an apprentice on the Nos. 12 and 16. In ramming, both with green sand and with dry sand, the machines had given satisfaction, and judging from their performance he had no hesitation in saying that both light and heavy castings could be made. They could ram the moulds like stone, and there would be no fault to find with the castings. A few weeks ago he observed a moulder jolt a machine 102 times, and the next morning he ascertained that the castings were quite sound, without a sign of scabbing. Trouble sometimes arose, however. For instance, in making gas-engine beds it was found that the moulding machine was not altogether an advantage from the comparative cost aspect, in spite of a run of 80 castings without a failure. No trouble due to the vibration spoiling moulds had been experienced by the speaker.

Squeezer Machine more Rapid for Pillars.

Mr. A. L. Key said some years ago he had a 2 ft. sq. table machine, and flattered himself that he did some very good things with it. Some flat work could be made successfully with the jar ram, but in making a comparison with the ordinary squeezing machine on a particular job, he found that two girls, working under the same conditions, and apparently as hard, turned out twice as much work with the squeezer as they did with a jolt rammer with lifting pillars, similar to the one

Mr. Hogg had mentioned. In that shop they made firebars 5 in. deep and about 3 ft. 6 in. long. There were four bars in three slots. They were given to an experienced workman, but the results were very bad. He therefore put loose patterns on a board, put them on the jolt ramming machine, put a sprig in them, and allowed a labourer to operate the machine, with the result that less than 5 per cent. were wasters. In the matter of time there was no comparison. The labourer would jolt one in less time than a man would bed a pattern on the floor.

Venting Unnecessary.

A fundamental point was the temper of the sand. If the moisture was in excess it was against the principle of jar ramming, and the sand flaked and came away in cakes. He could make a flywheel on the jar-ramming machine in less than half the time that any man could make it on the floor, using a loose pattern. The best subjects were exhaust boxes, pipes and similar castings, where the sand could flow freely; when there were lugs or projections it was a different proposition, because the sand was falling away, and the only successful way was to block up the pattern. From experience he did not advocate the jar-ramming machine for light, flat work. For such work it did not compare with a good plate-moulder or a good power-squeeze machine for speed. The jar-ram machine would certainly successfully ram up a heavy job. A redeeming feature was that no venting need be used; yet no matter how hard it was rammed up bad results never came about, because it was self-venting.

More Poor Results.

Mr. A. Hill said his experience was with two machines, which had a 2 ft. sq. table. The first trial was with boxes about 17 in. × 12 in. × 3½ in. If they made eight boxes per day it was as much as they could get. When turned on the floor they dropped out of the bottom. To overcome the difficulty they had a wooden box made to put over top of the bottom part. It held three times as much sand as was required to ram up the box, so that the moulder had to lift three times as much sand as he would have done if he had been working on the floor, or with a hand-ramming machine. That machine was discarded. A turn-over machine was a decided success so far as making the bottoms, but when it came to the tops, which were practically all flat, the sand came down on the plate like a cone. They overcame that by putting two or three gaggers in the centre; then, if they did not use the vibrator until the box was just about to lift the pattern, they gave it a few light taps with a mallet, which undoubtedly helped. The vibrator seemed to shake the inside of the box and not touch the outside. But, although they did well on the turn-over, a plate-moulder could do about twice as much on the floor. On sluice valves from 2 in. to 3 in., hand-ramming was quicker, on 4 in. they were about equal, on 5 in. and 6 in. the jolt rammer was the better. The boxes were 6 in. to 8 in. deep. It was necessary to get a good head of sand on and scrape it off again before the box could be turned round without sand dropping away from the sides. With little jobs they never had any success. He could quite understand Mr. Cook raising the question of the depth of the boxes, because in textile shops it was called a special box if it was 6 in. deep; more usually it was 3½ in. deep. For that about 8 in. head of sand was needed, and it entailed much labour in throwing the sand as the machine stood about 2 ft. 6 in. from the floor. In loom sides the top parts were only 3 in. deep, and a jolt-ramming machine would never stand it, and one would have sand weighing three times that of the box. A loose-pattern moulder would make a larger quantity than the jar ram, with much less trouble.

In closing the discussion the CHAIRMAN said it was a most interesting topic, and many things had been said upon which the members could usefully reflect. Knowing the results which were obtained by plate-moulders in Lancashire, he thought it was difficult ground to exploit in the interests of jar-ramming machines.

Lancashire Branch.

FACTORY ACCOUNTS, COSTS AND STATISTICS.*

By R. Dunkerley (Works Accountant, Vickers Electrical Co., Ltd.).

The present depression in trade has probably brought home to many employers the fact that the day of management by rule-of-thumb methods is now practically gone, and that if they are to compete in the world's market prices must be rock bottom, and to get these it involves that production must be at its highest level and cost of production at its lowest level.

Every founder believes that he can attain this state of efficiency, and where it is not attained the blame is, in nearly every case, laid on the employees. This may or may not be justified, and to get at the facts the keeping of records is required—records not only of wages paid and value of materials used, but also records of output in relation to some factor, such as the man-hours per ton, cost per lb., selling price per lb., etc. It is also necessary that close and careful watch shall be kept on all the extraneous factors, such as cost of administration and general commercial expenses.

The extent to which statistics are necessary is, of course, dependent upon the size of the foundry, but even in the smallest foundry a book record accurately kept is far more useful in a case where rock-bottom figures are required than is the manager's general impressions and approximations of possibilities.

In making these remarks, the view is naturally taken of the larger foundry where it is necessary to keep some amount of scheduled information, but at the same time it ought to be understood that while fundamentally all foundries require information, the degrees of this and the degrees of apply-

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* A Paper read before the Lancashire Branch of the Institution of British Foundrymen.

ing it must be varied to suit the immediate conditions.

To speak of scientific management of foundries and works to some managers has the same effect as the waving of a red rag to a bull. Managers have been heard to comment that factories and foundries run on scientific lines rarely, if ever, pay dividends. Perhaps in some cases they were right, but if they went a little deeper they would probably have found that if scientific management had not been applied the firm would have ceased to exist.

We are a conservative people, and we require to have many things thrust upon us before we appreciate their value, and management on scientific lines has to be thrust on many managers before they appreciate it. It is believed that this same process is now forcing itself on foundries.

FOUNDRY CONTROL STATEMENT.

Debits.	£	s.	d.	Credits.	£	s.	d.
Balance of stock in hand and jobs in progress . .				Value of deliveries . .			
Total wages—							
Productive				Loss from trading statement . .			
Non-productive . .							
Total purchases of raw materials							
Total overhead expenses				Balance of stock in hand and jobs in progress . .			
Profit from trading statement							
Total . . £				Total £			

Form I.—*Foundry Control Statement.*

The boom period, which followeda the moulders' strike, appears to have given many founders the idea that if they could produce, that was all that was required. Now, in the slump period they are realising that production at any price is a thing of the past. It is necessary now to quote minimum prices, and the difficulty is to find what these are.

Continental competition is again entering the market at specially cut prices, and to retain business firms are quoting competitors' prices without realising what loss is being incurred. Prices for the home market have suffered in consequence, as the founder in many cases is only interested in the final figure, and if his general average comes out all right he assumes that it is a paying proposition and he is making all the money he can. How many founders consider the proposition of what business they are losing due to the high prices they are charging on one class of article to make up for the deficiency on another. If they knew the facts the probability is that they would reduce the business on which there is a loss to a minimum, where it is to be done as a policy, or eliminated altogether where possible, and concentrate on the more profitable lines, and it is to help to decide which class of goods fall in these categories that costing is useful to the manager.

Underlying Principles.

Costing information can be divided into three headings :—

(a) General statistics, dealing with information respecting output in relation to other factors, number of men, wages paid, etc.

(b) Foundry accounting, which deals with financial information in bulk.

(c) Foundry costing, which must deal with information in detail.

In advocating the introduction of efficient accounting and costing systems it is not the intention to convey the impression that the introduction of these will make a business a success. What is claimed, however, is that if proper use is made of the information provided it will be of the greatest possible assistance. Systems need not necessarily be elaborate, nor are top-heavy systems useful, but it is essential that the information obtained is accurate.

It is not fair that the line should have been taken up by the foundry manager, that the clerical people are there to gather the information without his help. It is necessary that the closest cooperation should exist between them, both in the compilation of the information and in the studying of the results obtained.

Essential Details.

The first essential to the success of any system is that proper details of all expenses be received and their dispositions acounted for. Firstly, the employee must account accurately for the money paid to him in wages, by giving details of the time he spends on the various jobs.

Secondly, money expended on materials shall be accounted for by keeping an accurate record of the material passing through the cupola and used in the foundry. This involves proper records of stores received and issued.

The third factor is that the whole of the overhead expenses shall be recorded under their various headings so that they may be watched, and in order that they may be distributed in such a manner as to ensure that each job bears its fair proportion.

COMPARATIVE FACTORY EXPENSES.

..................Department. Year 192....

No. of Working Days				
Factory No.	Description.	Last year's average. £	Jan. £	Feb. £
	Standing charges—			
	Depreciation			
	Fire insurance			
	Rents, rates, and taxes ..			
	General maintenance of buildings and grounds			
	General maintenance of buildings equipment			
	Sub-total			
	Indirect charges—			
	Purchasing and storekeeping ..			
	Stenog. and mailing			
	Undistd. sundries			
	Education			
	Works transport			
	Main production			
	Watchmen and janitors ..			
	Management, employment, and superintendents			
	Factory accounts and costing ..			
	Research			
	Furniture (direct)			
	Sub-total			

Form II.—(*Continued on Page* 611.)

To ensure the collection of all expenditure and to have a check figure against which to balance stock at stock-taking periods, some sort of a control account is necessary. This can be a simple one, as shown in Form I., or it can be more detailed.

In the account shown the first item is the value of the stocks held, and the value of the jobs in the foundry. This can be obtained either from stock records or from stock-taking valuation.

Then there are the wages paid. This is the total amount from the wages book. For purposes of control it would be advisable to divide these into productive and other. Purchases of raw materials are obtained from invoices, and should agree with amounts posted on stock records. Overhead expenses are the salaries and wages paid to employees not on the shop wage roll: for instance, foremen, salesmen, storekeepers, clerks, etc., the cost of repairs to plant; rents, rates and taxes; machine

Direct Charges—			
Steam			
Power			
,, Lighting			
Heating and ventilating			
Compressed air			
Water			
Gas			
Storekeeping			
Shop sweepers			
Miscellaneous shop labour			
,, material			
Testing new material and apparatus			
Charge hands			
Inspectors			
Foremen and assistant foremen			
Foremen's clerks			
Crane drivers			
Slingers			
Production clerks (dept'l.)			
Stationery for works depts.			
Overtime and night allowances			
Waiting for material			
,, tools and drawings			
,, instructions			
Waiting due to breakdown			
Waiting for power			
,, crane			
Maintenance of tools			
,, patterns			
,, cranes, small trucks, and handling apparatus			
Process and rate fixing			
Insurance, Health			
,, Accident			
,, Unemployment			
Defective workmanship			
Total			

Form II. *(continued).—Comparative Factory Expenses.*

STATEMENT OF FOUNDRY TRADING.

Details of costs.	£	s.	d.	Unit cost per lb.		£	s.	d.	Unit cost per lb.
Work in Hand (for previous month):					Castings Shipped:				
Section No. 1—Labour hours.					(Priced at class value.)				
Overhead per cent.					Section No. 1—Weight				
Section No. 2—Labour hours					Section No. 2 "				
Overhead per cent.									
Adjustment of Work in Hand:					Castings in Progress:				
Section No. 1—Labour hours					(Priced according to stage of completion.)				
Overhead per cent.									
Section No. 2—Labour hours					Section No. 1—Weight				
Overhead per cent.					Section No. 2 "				
Labour Costs:					Work in Hand:				
Moulding (from wages book).. ..					Section No. 1—Labour hours				
Coremaking " "					Overhead per cent.				
Fettling " "					Section No. 2—Labour hours				
Material Costs:					Overhead per cent.				
Pig-iron									
Scrap					Foundry Equipment:				
Coke									
Sand									
Plumbago, etc.									
Oil									
Miscellaneous									
Overhead:									
Estimated percentage									
Actual " (difference) ..									
Balance (if Profit)					Balance (if Loss)				
£					£				

Production details.	Lbs.	Material details.	Average Costs in pence per lb.		
			Nett output.	1st period Lbs.	2nd period Lbs.
Castings shipped		Pig-iron.	Labour		
" in hand		Scrap.	Overhead		
Less amount in hand at beginning of period ..		Coke.	Material		
		Sand.			
Net weight produced..		Oil.	Total cost per lb.		
		Plumbago.			

FORM III.—*Statement of Foundry Trading.*

purchases and all materials not used in actual production. In Form II. are outlined some of the charges under this heading. In this control account will also be shown the profit or loss made as given by the trading statement.

Foundry Tackle.

On the other side of the account is the value of deliveries; this, of course, is the value of the castings shipped from the foundry and also the value of certain foundry tackle made. This subject of foundry tackle charge is a much discusesd one, and probably it would he well to divide it into three grades. Firstly, that which is made for a specific job and which is afterwards no use. Secondly, that made for general use replacing other used tackle. Thirdly, that which is made and is an addition to the foundry equipment, and therefore must be capitalised.

The first, of course, should be included in the price of the job charged to customers and costed to the job.

Those coming in the second class should be credited to output at the prices of labour and material and charged back to overhead expenses against shop-equipment maintenance.

The tackle made for general foundry use and the value of which it is intended to add to capital should be passed through the foundry on a specific Order No., just as if it was a customer's order. The only difference would be that where an invoice would be rendered to the customer, the amount would be charged to the foundry capital account.

The balance of stock on hand and jobs in progress is again obtainable from the valuing of stock records or by an actual stocktaking valuation.

If the records are all correct, the two sides of the control statement would balance, and it is then sure that the cost charges keep in line with the financial books.

The common practice of the trade is to divide the products up into a series of classes. These may be on a weight classification, say 1 cwt. and over 1 cwt., or they may be in any variation of classification to suit the particular type of trade done. To provide for this, all the information which is required is the average cost per lb. of

GENERAL FOUNDRY STATISTICS.

	Period 1.	Period 2.	Period 3.	Period 4.	Period 5.
Cost in pence per lb.: Labour Overhead Material					
Total					
Sales price in pence per lb.					
Profit or loss in period					
Output in lbs. No. of working days					
Output in lbs. per man hour					
Overtime, per cent. to total hours					
Average hourly pay					
Wastage, per cent.					

Form IV.—*General Foundry Statistics.*

metal, and the prices charged for the various classes is in some predetermined ratio.

Generally, information of this kind is useful and easily obtained, but it does not do away with the difficulty of not knowing which are the paying jobs.

Monthly Statements.

Form III. is the outline of a general foundry monthly statement and trading account, which covers the main points which are essential to give an adequate idea of foundry productivity. Taking the production side first, and dealing with output, the first item is "Castings Shipped." This, of course, is the value of the castings actually despatched during the period. These are, of course, valued on class price, and assuming two sections or cupolas, the amounts shipped from each are given both in weight and in value.

The second item is "castings in progress." These are the castings, which at the end of the period, lie on the floor of the shop either in the moulds or unfettled. These, again, can be divided into the classifications and valued at class prices according to stage of completion, for the purposes of the statement.

The third item is "Work-in-Hand." This is the value of work which has been done on unfinished moulds or cores. If time is booked and cost records are kept, this is, of course, obtained by adding up the hours outstanding on the cost sheet at the end of the period. If no cost records are kept, it will be necessary for this purpose to have an approximation made of the hours represented by the work done. To this labour is to be added the overhead applied by the method adopted in the particular shop, and again the work would be divided into the various foundries.

The next item is the amount of foundry equipment made. This can be given in bulk. This item has already been dealt with fully previously in the Paper.

In the States no credit is given whatever to the foundry for the making of equipment unless it is standard equipment which is to be used for many jobs, in which case it is only made against a definite order and capitalised. In all cases it is assumed to be a manufacturing expense and either booked against general overhead or the labour and material is added to the particular job.

The addition of these items gives the total value of the output and work in hand.

On the other side of the statement is the value of work in hand at the beginning of the previous month—this will be an exact copy of the previous month's figures under output. This must be taken care of, as, of course, during the month, the output for that month will consist of some of the work partially done in the previous period. Therefore, obviously it is correct to charge the value of the work outstanding at the beginning of the month, and on the other side give credit for the work outstanding at the end of the month.

The adjustment between the amount transferred at end of previous month compared with value at end of current month is covered in the next item, and also it will be noticed that these figures are not included in the total expenditure for the month, but have a bearing on the cost per lb. of output, and are taken care of in the last column—either debit or credit, *i.e.*, where amount at end of period is more than at the beginning, this will be a credit, and where less it will be a debit, as obviously output will have been obtained at expense of work in hand.

Labour Costs.

The next item is labour costs. These are divided up into four headings—cupola labour, coremaking, moulding, and fettling labour. The costs of the cupola labour is, of course, added to the material cost for the month. This represents the labour which has been expended on the material up to tapping. The other labour, naturally, is the actual labour cost on the material at the various operations.

Material Costs.

Under the material costs are collected the values of the various materials which have been used during the period. This information will be obtained from the requisitions given to the storekeeper when materials are withdrawn and priced at the purchase prices of the material.

Overhead Charges.

Overhead expenses are divided into two parts—"estimated" and the adjustment for "actual." In charging out during the month the agreed percentage must be charged, since it is not practicable to wait till the month end before charging out, and this is what is covered on the statement (Form III.) as "factory expenses" (estimated). At the end of the period, when the total actual expenses are available, this amount is adjusted by the difference between the amount estimated and the actual. It may, of course, be a credit. The total of the two sides are then compared, and the difference is profit or loss during the period.

In the lower part of the statement are given the general statistics affecting the foundry.

The production details in lbs. consist of weight of castings shipped and in hand. The total of these less the weight of castings in hand at the beginning of the period gives the net production of castings during the period.

Under the heading of material is given the weights of the different ingredients passing through the cupola. The proportions of these is a good and useful index figure.

By comparing the net weight of the casting produced with the weight of material passed through the cupola, a wastage figure can be obtained. This should be a fairly constant percentage, and wide differences would naturally call for investigation.

By dividing the net output into the value against the various items on the sheet the unit cost of each of the different items can be obtained.

These unit-cost items will then be summarised into a cost per lb., as shown, and the suggestion is made that the placing on the sheet of the previous periods cost result, shows any immediate alteration. It is helpful also to show the net production during the period. A low production may influence the overhead cost very considerably, as whatever the production may be, the standing charges, for instance, remain constant.

The Utility of Summary Sheets.

For purposes of closely watching the information gained by a summary sheet such as this, tabulated lists of results can be obtained, and comparisons watched from period to period. Form IV. shows a sample of these statistics and general foundry statistics. They can also be usefully shown by graphs and thus easily visualised.

Individual Costs.

The system of average costs is, as previously mentioned, not of very great help when quotations for special jobs are required, and it is therefore necessary to get down to individual costs. At the outset of any individual cost system, it is essential that all time on specific jobs be recorded.

Time Recording.—The system of time booking varies in different foundries. In some time is recorded for the man, in others it is clocked, and again in others the man writes his own time out. Whatever system of time booking is in use, however, it must start with some means of identification of the job.

In the foundries where castings are divided into say three jobs, and no other detailed information is required, it is of course only necessary to book against one or two or three, as the case may be; but where an attempt is being made to collect information respecting individual jobs in a foundry doing varying work, it is necessary that an identification number be applied to every job. This can be the number of the order in consecutive rotation or the number of the pattern from which the job is made, and when notification is received by the cost clerk that the job is commenced, he will originate a cost sheet.

The next essential after booking the order number for identification, is the man's number or name, the time spent on the job, and most important is the quantity of castings produced.

This further subdivides itself into two parts, *id est*, those which are good, and those which are bad castings.

In the cases where piecework is in operation, these points are necessary from a payment point of view, but from a cost point of view it is necessary to have the details whether the job is done day work or piece work.

All this information, if on the time ticket, will of course be entered on the cost sheet of the particular job worked on.

Material Recording.—This appears to be a fairly easy proposition, but in practice it requires very close watching. In all cases it is suggested that the only satisfactory way of applying material to jobs is to cost the material at the cupola spout and charge the jobs with the quantity of material used at this cost. In the case where the foundry has only one cupola making one mixing, this of course is an easy proposition, as by adding together the value of all the materials used and the value of the labour on the cupola, and divide this by the weight produced, it will give the cost at the cupola mouth of the weight of the actual metal produced.

Where they are different cupolas and different mixings, then individual records must be kept and the cost at the mouth of the various cupolas obtained.

To ensure accurate records it is essential that in the first place the receipt of all metals and materials should be recorded in bulk on stores cards and details of all materials issued should be entered on the same cards. This stores record is very useful when ordering quantities are being discussed, and also affords help as to the quantities of stock to be carried. Obviously the keeping of excessive stocks quite apart from price fluctuations which may have influenced the keeping of stock, is really a policy which requires careful watching from the financial point of view.

The advantages to be obtained by getting a stock might easily be outweighed by the consequent inconvenience of having a large amount of capital locked up, and, generally speaking, it is a sound policy to keep the stocks as low as possible consistent with current requirements. Without proper records no manager can be sure he is working on the right lines, and is not carrying a stock either too big or too little, either of which may bo dangerous to the business.

All Materials must be Weighed.

In addition to the use which proper records should be put for stocking purposes, they are also necessary for costing purposes in providing information as to the amount of material withdrawn for the cupolas. All materials required should be requisitioned from the stores on proper slips, and materials put into the cupola should pass over the scales whether they are pig-iron, scrap, coke or any other material used.

Another important factor in obtaining the cost of the metal at the cupola spout is the labour involved in handling materials and working the cupola. These are definite charges to the material and men engaged on this work should book or allocate their time to the various cupolas or the various mixings.

Distribution of Overhead Charges.

Then comes the question of application of overhead charges. The usual method employed is (1) to add a percentage on the actual labour used on the casting or on the basis of weight of castings, either of which is a simple method of applying it, and (2) machine-hour-rate method.

The application of either of these methods has its advantages and its disadvantages, and a committee recently appointed by the American Foundrymen's Association to discuss costings have recommended to their members the application of overhead in two portions—one on the basis of time spent on the floor, and the other on a weight basis. The case of the bedplate adequately illustrates the application of overhead charges. In a bedplate, the time taken is out of proportion to the weight of the finished article, and if the overhead is applied on a time basis, the bedplate gets off lightly, but if applied on a weight basis it probably gets more than its proportion. A compromise has, therefore, been effected, by dividing the overhead expenses into two classes, those affected by weight and labour basis. Examples of those under the two groups are:—

Weight Basis:—Crane charges; sand and moulding materials and labour mixing, etc.; machine charges.

Labour Basis:—Foremen, clerks, etc.; heat and light; maintenance of buildings, etc.

In the larger foundries it is suggested that the division of the overhead expenses, if to be at all accurate, must be sub-divided still further, and the tendency is towards the view that it is essentital that foundry costs should be divided into material costs, moulding costs, coremaking costs, and finishing or fettling costs. Each of these factors would have its own specific overhead expenses, and although many of the overhead expenses would be general, it would not be a very difficult matter to allocate these in some fair proportion over the various sections.

Even assuming that all this information has been collected, there are, of course, many points which require very careful consideration before saying that the cost of the article has been obtained.

Wasters.

The first is the question of wasters. From a management point of view it is necessary that these should be classified under, at any rate, the headings of those for which the men themselves are responsible and those for which the management are responsible.

Obviously, in the long run, it is the number of good castings produced which affect the cost, but at the same time if an effort is being made to get the cost of the individual job one cannot afford to inflate the cost of that job and make future quotations on the cost, because, due to unforeseen circumstances, there were scrappers. Obviously it is best to eliminate from the costs the expenses both of time and material which have been expended on wasters and charge the figure to general overhead. The question naturally arises as to whether this natural risk is the correct procedure, as undoubtedly by charging the value of wasters to overhead the overhead percentage is being increased and so augments the cost of all products. But considered from a practical point of view, it is reasonable to assume that a certain amount of wasters are a normal condition of manufacture, and it is an accident in the majority of cases that the wasters are on one job and not an another, and therefore it is only fair that all castings should bear their proportion.

Where the job is the man's own fault and he is made to do it again, if he is on piecework bonus the manager assumes in many cases that he is doing it again at his own expense, but is he? He is using new metal and foundry equipment and he is also using the buildings, the light, and all the accessories of the foundry, and at the present time, with a separate cost of living bonus, he is being paid for this. The only correct thing for him to do is to re-book the time against the particular job in which he did the original casting and for a credit note to be passed through cancelling the cost of the scrapped work. This procedure, of course, would be the same whatever the cause of having to make a replace casting, whether it was the man's fault or the firm's fault. In all cases where specific costs are required, specific information of this kind must be obtained.

Controlling Factory Expenses.

Reverting back to the statistical information provided by statements similar to the ones set out in Forms 3 and 4, a detailed list of all expenses incurred in the foundry should be regularly provided, as shown in Form 2.

Too often these expenses are taken in bulk, particularly in a small foundry, whilst even those of larger sizes do not consider the matter important enough to get out in detail. It is only by close analysis of the factors of this indirect expense that real economies are effected, and it is these factors which will decide whether a price is a good one or not.

It is believed that the methods of production between one foundry and another are now getting so close that it will only be the savings effected by careful management which will bring the prices into line to compete in the markets.

In the past managers have been far too ready to consider the labourers about the foundry to be a miscellaneous charge. These men often work for days together on specific jobs—in many cases they are with the moulders constantly, and their time could be allocated on the same basis. It is, in fact, in such cases direct productive labour.

Then there are the factors of the extra cost for overtime and night shift, and there is the cost of supervision, the cost of the clerical labour, maintenance of patterns, maintenance of foundry equipment, charges for power, compressed air, and the loss due to defective work. These are but a few of the divisions into which expenses can be divided and studied.

The tendency when studying figures of this kind is to jump to the conclusion that they are too high and must be reduced without considering the effect the reduction is likely to have on the general production. For example, in all cases where a reduction of expenses is mooted the first person to be dismissed is probably the shop labourer. How many foundry managers have ever studied the question as to the effect on the productive capacity of the skilled man the taking away of the labourer has?

If the skilled man is required to do labouring jobs, the time so spent is being paid for at 50 per cent. higher than if a labourer is doing it, and also there is delay in getting the job out.

If during normal periods it is ascertained that the proportion of labourers to skilled men is correct, then obviously the reasonable procedure to take is to reduce the unskilled labour in the same proportion as the skilled is reduced. In many cases, however, reductions cannot be made in proportion. Take, for example, a shop where they only have one foreman, obviously the reduction of 20 per cent. of the men will not have any effect on the foremen required. Matters of this kind may seem to be irrelevant to the subject of costing, but the point is, that the information which is provided must be used and can be used to assist in the better management of the foundry.

It is not purely the compiling of records against individual jobs which constitute cost work—it is the compiling of all the statistics pertaining to the information compiled and the putting of them to the manager in such a way that they may be effectively used by him to assist towards the better management of the foundry.

DISCUSSION.

The Chairman (Mr. W. Meadowcroft) said after hearing Mr. Dunkerley they could realise that many difficult questions came up for consideration in costing. Perhaps the most interesting one was the provision which should be made for wasters. What was the method adopted by Mr. Dunkerley? Did he put a percentage on the cost of the individual jobs?

Mr. Dunkerley replied that if wasters were charged back to overhead expenses the cost of the job was automatically increased. There was another way of considering the matter. They arrived at the cost of the material, and divided by the number of good castings. Obviously an increase was automatically put on.

The Chairman said usually, when estimating for a job, it was just a question of taking the first cost. Now if it had been a risky type of casting and there had been bad luck with it, the cost might come out high. Was it the custom to quote on that basis?

Mr. Dunkerley pointed out that there was an item, " defective workmanship," which would cover the wasters. That increased the overhead expenses which were spread over the whole of the production, and it was allowed for in the quotation for the job.

The Chairman said perhaps they were looking at the matter from different points of view. In justice to the foundryman, a certain percentage should be put on for risky castings; otherwise there was a danger of quoting too low. Recently a firm who had a big foundry of their own had sent out drawings for work which was exceedingly risky, and no one had any data to guide him in estimating the price he should take, so that it was a gamble. Probably the foundryman would put a lump sum down for the risk. One could demonstrate on paper, but when the work got into the shop there were so many things to take into account, some so obscure, that one could hardly realise them, and thus it was very easy to make a serious mistake.

Classification of Wasters.

Mr. Dunkerley said before costing could make headway in foundries the idea must be eliminated that the intention was to interfere with the foreman moulder. A proper system should be of help to him. With regard to wasters and the adjustment of quotations, if a job had been made before, they were not guessing, but knew what they might expect, and the price could be fixed accordingly. Putting a little extra on was really for insurance, making provision for the element of risk. Suppose castings were divided into four classes. The foundryman knew whether a job would normally come into, say, class 3, and if he thought it was a risky thing he could put it into class 4.

Uncertainty of Labour Costs.

Mr. Jolley described the method adopted in the foundry he was connected with. According to whether the casting was faulty through machine-shop trouble, or bad workmanship, or material, a separate form was filled up. The particulars were entered upon a card. Then if at a future time a similar job was in hand, the foreman would call for that card and he would know what the job actually cost, as well as what the cost ought to be.

Mr. J. Simkiss said this subject had been much neglected by the Institution in the past. Speaking from the point of view of a large jobbing shop, it appeared to him that a system worked out on the lines indicated would cost a great deal. What happened in the foundry? An inquiry came along for a casting or a number of castings, and it was sent to the manager in order that a price for labour might be fixed, the overhead charges, with the cost of materials, being left to the cost office. Everything depended on the ability and judgment of the manager. He might miscalculate in his estimate of the time it might take. It might be that one foundry possessed the tackle needed to do that job efficiently, and another foundry did not; that would make a difference in the quotation. The speed of the workmen was another uncertain factor. He recalled a job which when it first came into the shop was given to one man on piecework, and he did it in two days. Later, when that job was sent in again, it was given to two men on day work, and they took four days. If it had been costed on the basis of the first man's time it would have proved very expensive for the firm. So many things cropped up in foundry practice that costing was a very difficult matter.

He understood Mr. Dunkerley to say that when extra tackle had to be made specially for a job, the cost of it should be charged to the purchaser. It seemed to him that was rather impracticable. He had never come across a purchaser who would pay for tackle which had to be scrapped afterwards. He quite agreed that there must be a spout charge, with the exception of particular mixings.

Another point which occurred to him was that in a 5-ton job the extra metal necessary for heads and overflow, and similar items, would be a small percentage in comparison with very light work where, perhaps, the runners would be from 50 to 75 per cent. In dealing with the latter, the percentage of metal melted to the quantity of casting produced must be taken into consideration.

He did not altogether agree with the author's remarks about labourers. Many times the time occupied by a job was quite as long after a labourer had been put on to assist as before he was put on. With regard to scrappers or wasters, in his own foundry those were weighed out every week, and the returns which came in were taken weekly and monthly. As a rule the percentage was low, and it was spread over the whole bulk of the work, and not allocated to specific jobs. In his own shop the percentage of wasters was less than 2 per cent., and the returns were less than 1 per cent.

Collected Information the Essence of Costing.

Mr. Dunkerley said Mr. Simkiss collected information that was the essence of costing, although Mr. Simkiss might use some other name for it. The extent to which one should go into detail depended upon the size of the works. Where only a few men were employed it would not be necessary to take separately all the items which he had set out. Admitting that the costing of individual jobs was difficult, how much more difficult must it be for a manager who had no records to recall what had been done when the work was in the shop before and take that as the basis for a quotation. Take the case of the job which was done by one man in two days and by two men in four days. But after all, the foundryman did not quote on what one particular man did; nor, for that matter, purely on what his own costs were; the market had always to be taken into account, and if the cost came out more than the price which enabled one to compete successfully in the market, what advantage was it to get the order? All the factors must be kept in mind. Suppose special tackle had to be installed to do a certain job and was afterwards scrapped. If at the end money was going to be lost, it was better to cut out that job. Why should anyone want to take work which was unsuitable for his foundry? Sometimes people wanted to keep their workmen together, and were willing to reduce their rates with this object. They should know exactly what it cost them to do that, and not be content with just an impression. For that purpose costing was essential. As to the question about the labourers, it was information worth having that a job cost more on one occasion with a labourer than without one, and whatever name it was called by, putting it on record was costing. It was not necessary to have an elaborate system in a small foundry; it must be modified as circumstances required: the essential thing was to keep accurate records

Mr. Simkiss remarked that with regard to the extra tackle, the point he wanted to emphasise was that when the casting was of a special character, if the purchaser would make inquiries of the foundries already equipped to deal with that class of work, and had the necessary tackle, the purchaser would get both the best results and price. If it was necessary to make extra tackle, its cost should be included in the quotation given, and if that was too high that founder was out of the market altogether.

The Effect of Apprentice Labour on Costings.

A visitor asked what was the best method of allocating overhead expenses when a job had been made by youths instead of by men.

Mr. Dunkerley said instead of allocating the overhead expenses on the basis of a percentage of the men's wages, they could be reduced to so much per hour; that is to say, taking the average expenses and the average number of hours over a normal period. In that case the average was the same for boys as for men, because the former were using as much, or even more, time, and so on. It was a difficult problem, but he knew it was being solved successfully.

The Possibility of Too Much System.

Mr. Key said a system could be carried too far. He was not saying that Mr. Dunkerley did that, but he would mention an incident that occurred when he was at a certain works. There were no records available in the foundry office, and in conversation with the manager he commented on this. The manager replied, "So and so," mentioning a competing firm, "make a job for a penny and it costs them 2d. for system; we make it for 2d., and it costs us ½d. for system. We pay a dividend and they do not.''

In making an estimate a foundryman would put on the direct labour cost—core-making, moulding and fettling—and allow a fixed percentage for ordinary risk if it was a straightforward job; if it was of a special character he would put on something extra. Then, if he was particularly anxious to get the work, he might take the responsibility of omitting that percentage. If he did not do so it might go to somebody who knew nothing about it, and would lose money in the end. That was an ordinary rule-of-thumb method, to allow a percentage for contingencies. Detailed foundry costing was a very expensive proposition; more so than in any other branch of the engineering industry. There might be statistics showing what had been done before in allocating charges, the cost working out to so much. but it did not follow that the same results would be obtained. On the first occasion the work might have been done by a good workman; the second time it might get into the hands of someone else who did not work so well. With one man a barrowful of sand would go round, where others would want three or four. They were bound to take into account the law of averages. Knowing whether it was to be done piece-work or day-work, they could work it out on that basis, and if the prices were worked out on the average standard they would not be far wrong. In his opinion it was the least costly method of keeping accounts and statistics, and in a small establishment they required the system to be as simple as possible. Of course, in some cases it was quite necessary to have details.

Mr. Dunkerley said he did not think the system would prove as costly as some people seemed to fear. If the cost was 3 per cent. of the total turnover it was time to examine it. In a small works the costing would probably be done by the clerks, in addition to their other work. Whatever name it might be called by, the foundryman should have information which enabled him to decide what his price should be. It was the man who guessed who failed. The principle of an established system of costing had been adopted in America to a much greater extent than here, but in this country it had been put into force by the master printers. They established a standard costing system for all printers, and men went about from one place to another explaining it. They were all competing on the same basis. In many cases the prices had gone up because they found they had been taking prices that did not pay them.

A vote of thanks to Mr. Dunkerley concluded the proceedings.

East Midlands Branch.

The annual meeting of the East Midlands Branch of the Institution of British Foundrymen was held on March 18 at the Loughborough Labour Technical College, Mr. W. T. Evans, of Derby, in the chair.

PRESIDENTIAL ADDRESS.

The past session has not been as successful as I hoped for, but as is well known, the particular business in which we are interested is going through the severest depression in its history. Our own particular branch covers an extensive area, and no matter where we hold our meetings, it means that our members have, in most cases, a considerable distance to travel in order to attend, and under present conditions we have many members who, however willing, could not have attended without sacrificing things at home which are more important.

We must not, however, be despondent, as I feel sure that when our members are in happier circumstances we shall see again many faces we have missed this session.

We have during the past session obtained a Royal Charter, and this, to the pioneer members, must give much pleasure, as they now see that their efforts were not in vain. This, again, should give an incentive to all craftsmen in our foundries to become active members of the Institution, with a corresponding increase in their status as workers in one of our key industries.

Another notable feature of interest to foundrymen has been the founding of the British Cast Iron Research Association. This association, which this Institution was instrumental in forming, has filled a long-felt want. From reports of the work which is being carried on, we, as foundrymen, will be able to obtain information to help us in most of our foundry problems, and for this reason the British Cast Iron Research Association deserves every foundry's support. No matter what the problem is, whether practical or scientific, it is tackled with every chance of success.

Our Secretary, Mr. Bunting, and myself, attended the meeting of the Belgian Foundrymen at Liège, and we cannot speak too highly of the courteous manner in which we were received, and also the freedom with which any information asked for was given.

We visited several large foundries and were allowed to see any process in which we were interested. One remarkable feature there was the amount of dry sand work, moulds for small brass castings of a few pounds weight being stoved before casting. There were not the number of moulding machines in use as in our foundries, but this, no doubt, will not obtain in the near future.

Many of their processes were identical with our own, and their production is not such as is reported in the daily Press. They have the same problems to face as ourselves, and if the British worker has the work and the plant, he can give as good results as any we saw during our visit.

Another feature is that the Institution has been successful in inaugurating what I feel sure will be the largest exhibition for foundry purposes which has ever been held in Europe. This exhibition is to take place at the same time and place as the 1922 Convention, to be held at Birmingham. As this branch was invited to the initial meetings, also as our past President, Mr. H. H. Moore, is on the Committee, I trust all our members will give the Exhibition their support. This Exhibition is not to be run for trade purposes only—its primary object is for education, and is in keeping with the aims of the Institution.

It will be seen from these remarks that, although the bread and butter side of our business has been a sorry mess, the Institute has forged ahead, and I feel the last year has shown to all who are interested in the foundry, ample proof of its intention to place the foundries of our country in a position second to none.

The Institution has an immense problem to face in order to bring the foundry trade of this country into the position it should hold. I know that we, as an Institution, do not have discussions for trade purposes, but I should like to say a few words which may be perhaps a little outside our chief object, that is, with regard to costing systems in the foundries.

For many years it has been the rule for some foundries to give an all-round price for castings, and this custom, which is entirely wrong, is a fruitful source of trouble. Engineers are, as a rule, fairly exact in their estimating for work, but when it comes to buying castings they expect the foundry to give the same figure for any job which comes along, the labour on which castings may vary from 1s. to 20s. per cwt. This does not give us, the founders, a fair chance. The engineer will not give anyone the same figure for, say, an intricate automatic machine as a mortar mill. Why the question of an all-round price for any job should be mentioned is absurd—all castings should have their cost taken out in a proper manner. If a casting is to be a good job, and a credit to us as founders, there is no room for guesswork. It is all very well discussing the carbon-iron diagrams, and not to know the exact cost of the article produced. Wonderful figures are given of melting ratios of coke to iron, but they are far from exact, and not to be relied upon for costing purposes, as very often the figures vary as much as 50 per cent.

This question of prices is to many of our members one of the worst features of the foundry business, and until such time as these anomalies are eliminated there will not be the labour conditions in our foundries we desire, for when the foremost thing in the business is run in such a manner there will not be the necessary capital forthcoming to modernise our foundries and plant necessary to meet the competition of other countries, and enable us as a nation again to lead in industry.

East Midlands Branch.

THE MANUFACTURE OF A MONOBLOC MOTOR CYLINDER CASTING.*

By W. T. Evans.

There has recently appeared in the foundry Press a series of articles on the above subject, in which were shown methods of production which the author has every reason to believe are contrary to those in use in most British foundries.

It is hoped these articles will bring before foundrymen methods of manufacture which will give much better results in production of patterns, core-boxes, moulds, and also sound castings.

Modern motor cylinders are without doubt amongst the most difficult castings which the foundryman has to produce and give the pattern-maker and moulder sufficient to do to obtain sound and accurate castings, which will be able to be machined in jigs without marking out, and therefore correct and true to pattern; also of a material that will tool easily and at the same time give a good ground finish without porosity or failure under water or oil test. It is one of the worst problems the motor trade has to face—the production of large quantities of sound cylinder castings. For to have numbers of these expensive castings scrapped at perhaps the final machine shop operation entails considerable loss, also reduced output. There always will be a percentage of wasters in this class of casting, owing to intricate designs, and the human element. The smallest particle of slag, sand, or small blow-hole, wrong casting temperature, faulty materials, very often means starting again at Genesis.

Tests to be met.

There are three tests which are generally applied, viz., a water test of 20 to 30 lbs. per sq. in. on the water jacket; a pressure test of about 500 lbs. on

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* A Paper read before the East Midlands Branch.

the barrels, and sometimes a cubic capacity test, and before long we shall be faced with a material test to a given analysis. Thus the foundry cannot leave anything to chance to achieve success under these conditions.

There are many motor firms who do not make their own cylinders, and this applies often when having their own grey-iron foundries, from which it would seem that firms are fully aware of the problems to be faced. What is very surprising is that under these conditions buyers will move their cylinder patterns about from foundry to foundry for a very small reduction in price. Very often this does not give the manufacturer a chance to achieve success, as he has no sooner overcome his initial troubles and the moulder and coremaker have become used to the particular difficulties obtaining when the patterns are withdrawn. Only those who are intimately connected with the foundry know how narrow the margin often is between success and failure, and very often it is only after days of thought and search that some small trouble is located and rectified. In all cases the machine shops should advise the foundry at once of any defect, however small, as very often this is easily overcome before any large number of castings are produced.

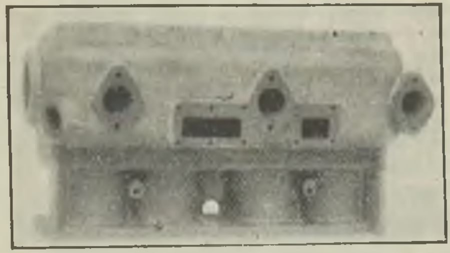

Fig. 1.—A Monobloc Motor Cylinder, the Manufacture of which is Described.

Difficulties to be Overcome.

It is impossible to emphasise too much the quality of the materials used in the casting. With modern machine-shop production conditions, viz., the use of expensive milling cutters, reamers, etc., any hard spots in the castings very soon ruin the tools used. The foregoing remarks will give the reader an insight as to the conditions to be faced and difficulties to be overcome.

The example taken is a four-bore mono-block cylinder with induction pipe cast in the water jacket, and used on a well-known British make of car. Fig. 1 shows this type, which is fairly common.

Pattern-making Details.

The initial step to success is a first-class pattern, and those who can carry out this particular work and see a successful casting made without much complaint from the foundry have reason to be proud of their efforts.

The question as to whether a wood or metal pattern and core-boxes should be made must be left to the individual and the conditions obtaining. In the writer's opinion, if a good, dry, hard wood pattern and coreboxes are made, with metal loose-pieces, prints, etc., it should be able to produce from them some thousands of castings, as with machine moulding on jar rammers, also the use of sea-sand mixtures for the cores, there should not be the wear that obtains under hand moulding conditions.

To commence the job, it is necessary to obtain a good, dry drawing-board, preferably of yellow pine, straight-grained, and free from any other defects. If the wood is straight-grained, the scriber used to make the lines of the lay-out will not be inclined to " run " from the straight-edge, which means a more accurate and neat drawing. The cylinder is drawn out full size, the necessary machining allowances being added after, and shown in coloured pencil. Having decided the method of moulding, it is necessary to show the joints of the pattern, also the junctions of the cores, then the outline of the " prints," showing the correct taper, as it is necessary to construct all coreboxes to suit such taper. No rubbing of the cores should be allowed.

With the methods here advocated the foundry can very often use existing moulding boxes, and for this reason the pattern-maker should make sure of the depth of the middle box-part, as it is necessary to make the middle joint of the pattern to suit. The foreman moulder should now decide which boxes he intends to use; also, if a certain output is required, the number of coreboxes necessary for such output, as under normal conditions it is best to construct the duplicate boxes at the same time to ensure interchangeability.

Cutting the Timber.

When these details have been definitely decided the whole of the timber for the job should be cut out, as this will give it time to season still further, as, no matter how dry such timber is, there is always some "running in" after being freshly cut, and this must be avoided if possible. The lay-out is here shown with all the necessary lines and sections to construct the pattern and coreboxes, and the setting out of the pattern, etc., should be carried out from the lay-out as far as possible, using the blue prints for checking purposes.

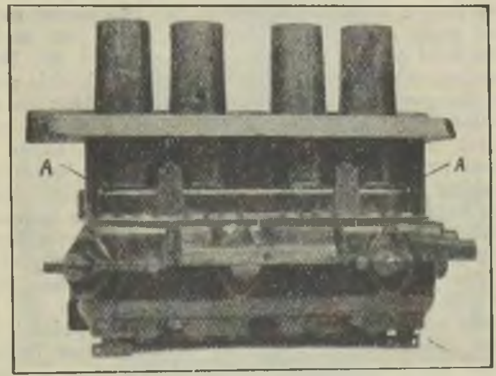

FIG. 2.—THE PATTERN, WHICH ADMITS OF TWO JOINTS. THE TOP PART IS ALL PRINTS, AND A A ARE INSERTED METAL WEBS.

Details of the Pattern.

There are two joints in the pattern, the first through the ports, the second behind the flange at the end of the barrels, and it is made for moulding on a jarring machine, and, to facilitate this, the middle part and top part of the pattern are of the same depth. The construction of the pattern is shown in Fig. 2. It will be noticed that the flange at the end of the barrels is not visible. This loose flange is built up and finished *in situ* on the pattern, then removed and fixed in a core-box to facilitate machine moulding. The finishing of the flange as part of the pattern ensures a perfect match of this part, when the core is fixed. This means that the top part of the pattern is all "print," that is, four round prints for the barrel cores, and the large flat print for the flange core. The prints for the barrel cores are made of sufficient depth to come just under the level of the box part when rammed up, thus leaving the corresponding holes through this part of the mould, which enables the moulder to see plainly the barrel cores when lowering on the top part. It is desirable to have plenty of taper in these prints, as when the top part is in place after making provision for "bringing off the air" from the barrel cores, these taper holes can be rammed with sand, which will keep the barrel cores from lifting, and obviate the use of weights, thus giving a clear top part for runner and riser boxes, etc. It will be understood that the barrel cores will be made with about half the length of "print" to that shown on the pattern. Ample taper in the print must be allowed for the flange core, as this core is fixed on the top of the middle part, and located by the mould, which means that the top part has to be lowered over it, and plenty of taper ensures that this core will not be moved, as it will be clear of its print until the core is almost down, thus avoiding a crush. The middle part of the pattern does not need much explanation. There are the two small bosses which have prints on the underside to facilitate moulding. The two webs shown at A, Fig. 2, are made of metal, and let into the solid part of the pattern.

All the fillets in the pattern are worked from the solid, and the joints in the wood are so fixed to allow for this feature. The bottom part of the pattern is entirely worked from the solid, with the exception of the prints, which are made in

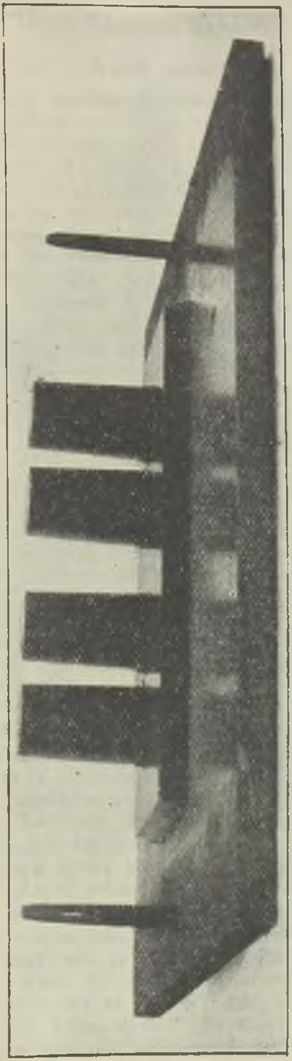

Fig. 3.—The Pattern Board.

metal, and fixed in position when the whole pattern has been sand-papered up and finished.

Pattern Boards.

The pattern is now mounted on the board for the moulding machine, as shown in Fig. 3. These boards have cast-iron strips bolted across them, which have been planed up to an even thickness. It will be seen that the board is rebated down to take the strip, and this cast-iron strip takes the weight of the mould when being jarred, and is made wide enough for this service, also saving the wooden board from wear. Cast-iron strips are more serviceable than mild steel, owing to the fact that the constant blows from the jarring operations stretch mild steel strips, thus causing them to curl up at the extreme ends, with the result that the box-part will not lie well on the board. These conditions are almost absent when using cast-iron strips.

This covers most of the pattern. It is desirable to make sure that all prints are on the full side to obviate rubbing of cores, as in most cases prints in a mould, when dried, are a little smaller, and the cores, when blacked, are very often a little larger, and if the pattern-maker will always bear this in mind he will save the foundry much trouble. Also, when once the rubbing of cores is resorted to, it is very rarely one gets two castings alike. One of the chief objections to machine-moulding this particular class of casting in the manner here shown is the provision of moulding boxes, and unless special methods are adopted and the quantity ordered is not a considerable number, it will not be a paying proposition to the foundry to make such box-parts, as with a three-part mould, each part of which is rammed separately, it is obvious that the joints of boxes must be planed, also that the middle parts must be interchangeable, and all of the same depth.

By constructing the pattern, as shown in Fig. 2, different depths of patterns can be accommodated in the same middle part, as the pattern-maker has only to keep the joint in each particular cylinder of the same depth as the moulding box, which means that the flange-print and core are either thicker or thinner as the case may be, and

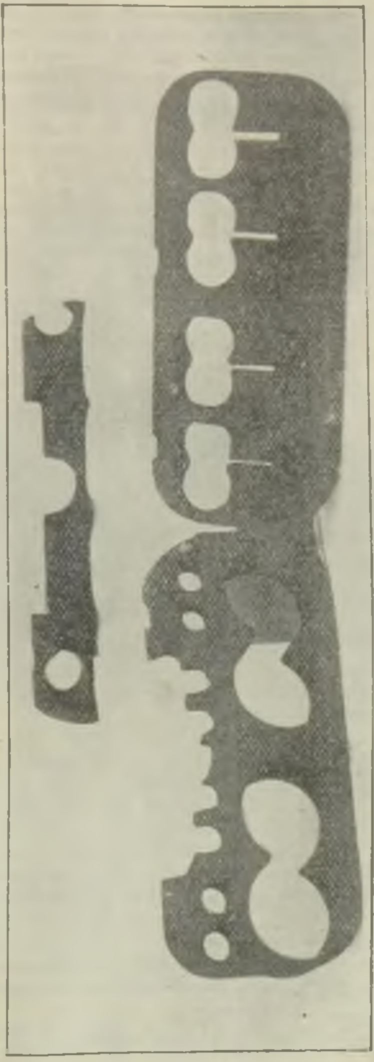

FIG. 4.—A SET OF CORES MADE FROM THE BOXES SHOWN IN FIG. 5.

as it is not necessary to have bars in the cope close to the joint there will be ample room for a somewhat thicker print and core, and the writer has seen as many as six patterns of different length moulded in the same boxes. This enables an order for cylinders of small number to be economically machine-moulded.

Core Boxes and Cores.

The method of construction of the core boxes will be seen from the illustrations, and they consist of three jacket boxes, top and bottom shell, and a loose piece behind the port holes of the combustion head core, induction pipe, small elbow, boxes for exhaust ports and barrel core box. The latter core-box is made to jar-ram the round barrel core, as this gives a core which is not so liable to scab, etc., as if rammed by hand.

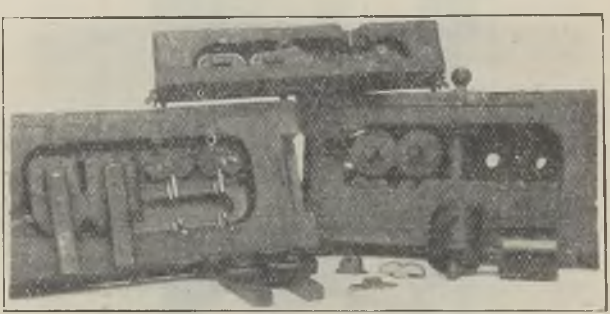

Fig. 5.—A Set of Core-Boxes for making a Monobloc Cylinder.

Fig. 4 shows the complete set of cores, and Fig. 5 a set of core boxes for their making. The Nos. 1, 2 and 3 shell cores form the water jacket round the cylinder barrels, exhaust pipes, etc. Very often there are only two jacket cores, but in this case there is the long thin core shown, which is jointed through the centre of the exhaust elbows to facilitate the fixing in the mould of the elbow cores, and this simplifies the coring-up operations.

It will be seen from Fig. 4 that the core-boxes for the jacket are all framed up, and the inside shape worked from blocks, which have been fitted to the frames. This is by far the best method to adopt for this class of work. The frames are loose, being fastened with bolts and thumbscrews to facilitate the drawing of the cores, to save unnecessary punishment to the core-boxes.

Fig. 6 shows the flange core-box, with the flange taken from the pattern fixed inside, also the runner, or spray, used for casting purposes in front of the core-box is the core from same. To the right of the flange-box is the induction pipe core-box, which is a fairly intricate and difficult core-box to make, and has to be jointed in three pieces. In front of this core-box is the resulting core. This core is made in two pieces, and glued together before being used in the mould. On the right of the pipe core-box are the combustion head boxes, with two cores resulting, one of which shows the dowel which locates the barrel cores. The small core shown in front of the flange core is one of the exhaust cores.

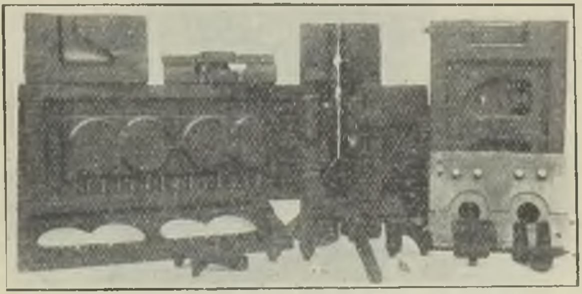

Fig. 6.—The Flange Core-Box.

Fig. 7 shows the outside of the induction-pipe core-box, the barrel core-box, and combustion head-boxes. In Fig. 8 are shown further details of the core-boxes, also the inside of the barrel core-box, with the plugs which locate the same on combustion head cores already mentioned. Fig. 9 shows a complete set of cores roughly placed together to illustrate further the loose piece of the shell core, and the flange cores.

FIG. 7.—THE OUTSIDE OF THE INDUCTION PIPE, THE BARREL, AND THE COMBUSTION HEAD CORE BOXES.

Materials used in Cores.

The whole of the cores, except the four barrel cores, are made from a sea-sand mixture. There have been many mixtures of sand for this particular class of core, associated with all kinds of core oils and binders, but after experimenting with a fair number of oils, the author finds that, for cheapness and general utility, there is none better than an equal mixture of linseed oil and molasses.

Some of the best results have been obtained from a mixture of 50 per cent. sea sand and 50 per cent. red sand, both dried, and then mixed with the required quantity of binder.

Cores made from this mixture will require very little packing, and in most cases will hold up green, which means that they will conform to shape much better than those made from sea sand alone.

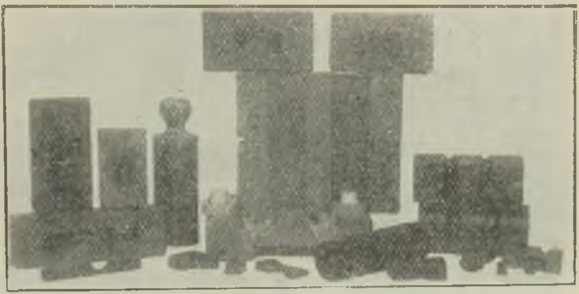

Fig. 8.—Further Details of the Core-Boxes, including the Inside of Barrel Core-Box.

The worst feature of cores made from ordinary sea sand is the difficulty of handling and mending when green.

Another and most important feature of a mixture of the two sands mentioned is that very few core irons or wires are required, which makes a very considerable saving in core-making and fettling of castings. Very often the only means of removing sand and core irons from these castings is through small round holes from ¾ in. to 1 in. dia. in the outside of the water jacket, and to withdraw any quantity of core wire through such holes is very often a tedious job, and a serious loss of time, and a mixture of sand, which overcomes the use of core irons, is necessary for success.

It is interesting to note that the skin on cores made from this mixture has a much finer and smoother appearance than when made entirely from sea sand, thus giving a better finish to the castings.

The barrel cores are usually made from an ordinary core sand, fairly open, and made on a small jar-ram machine, with the plugs for locating these cores in the mould at the bottom. This means that the core is closer and harder at the bottom of the mould than the top, giving every chance for the "air" to get away, also this gives little trouble arising from the "scabbing" of the barrel cores when the metal enters the mould. In fact, this trouble is very rarely seen from a machine-made core, whereas it has often been a source of complaint with cores rammed by hand.

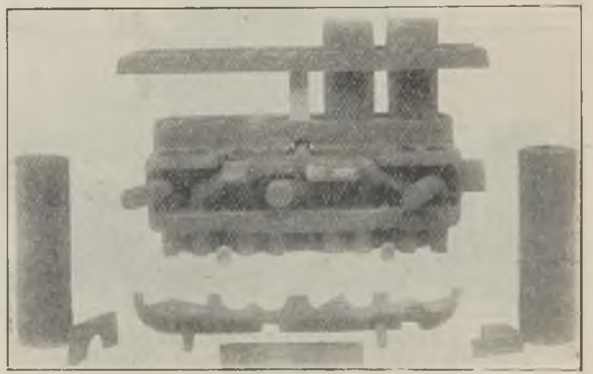

Fig. 9.—A Complete Set of Cores Roughly Assembled.

The Moulding Boxes.

Fig. 10 shows a complete set of moulding boxes. The one on the left is the top box or cope, the centre the middle part, and that on the right the bottom, or drag.

As shown, the bars in the cope are kept well back from the joint to allow for the variation in the flange print. The bars or grids in the middle part are made loose and fastened by two set-pins, otherwise it would not be possible to take the castings from the mould when cast. It will be seen that all corners are radiused, to overcome weakness; as the boxes are used for dry sand moulds, no handles are cast in, but only four snugs provided with a round hole for handling purposes. This saves considerable stove space when drying.

The snugs for the loose pins are double; that is, cast together in pairs, with brackets between, and when jig-drilled will keep the "pins" vertical when closing the moulds. Another good feature of the loose bars shown is that it is a simple matter to change these to suit the different contours of other patterns when necessary.

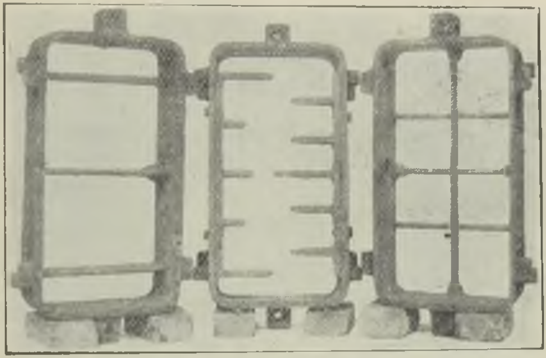

Fig. 10.—A Complete Set of Moulding-Boxes for Monobloc Cylinder Work.

Moulding a Casting

From the illustrations it will be observed that the moulding of this casting has been simplified by the use of cores in order to facilitate production on the machine, and this practice has become general. Very often patterns are made with pieces below the joint, which have to be jointed down, whereas a print and core will save time and risk, and the pattern-maker should always adopt this practice and save the moulder unnecessary jointing, as solid patterns which could be made easily in halves, but deep "lifts" hanging to the cope of a mould are a fruitful source of complaint, and a serious loss in output results.

The only operation in ramming, finishing and stoveing the mould which requires much explanation is that the middle part has a tendency to drop out if not properly handled. The practice is to ram up the required number of bottoms or drags, finish and black them, then proceed to ram the middle parts. When this part is taken from the machine the drags are close at hand, and the middle part is placed on its corresponding drag part and is then finished and blacked whilst in this position. These two parts of the mould are then stoved and dried together. This prevents the middle part from dropping out when green. The moulds are taken apart when dry, and blown out before casting.

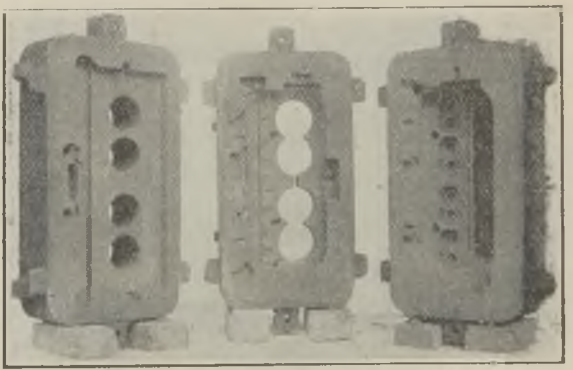

Fig. 11.—The Finished Moulds.

Fig. 11 shows the three parts of the mould, and illustrates that there is nothing to carry the overhanging sand of the middle part other than the bars or grids, so in some cases planed plates are used for the purpose of drying this part, but this is not necessary if care is used.

The cope is a very plain piece of the mould, and requires but little finishing. The runner is seen on the outside. This matches with the spray shown in the flange core-box, and is clearly shown in the view of the mould cored up ready for the cope. This part can be used green if there is not ample stove room.

Numerous methods of running this casting have been tried, but the method here shown gives the best results; that is, a number of small sprays running directly into the barrels, with two risers, one at either end of the flange. It is not insisted that this is an ideal method, and no doubt other ways of pouring this job would give good results.

Fig. 12.—The Mould Cored-up Ready for the Middle and Top Parts.

Some foundrymen may object to the flange of this casting being made with a core, but it will be evident that when the middle part is rammed up it has only to be strickled off to the planed joint of the box, whereas if the flange had to be moulded in this part the box would have to be made the correct depth of the flange of the cylinder, and therefore only suitable for one depth of casting. Further, with machine moulding, this flange would have to be bedded in whilst on the machine—the machine would be standing, and valuable time lost, whereas when a core is used the moulding is a simple job, and the machine can be operated to the extent of its output.

The pouring of this casting in a vertical position is, in the author's opinion, a much better and safer method than that of casting in a horizontal position. There are several reasons for this; first, that whilst cylinders can be made successfully horizontally, the author is in favour of pouring vertically where possible, as there is not the tendency for small pieces of foreign matter to lodge underneath the barrel cores, and as the bores must be perfect the less risk taken the better. Secondly, when moulded vertically, the coring of the mould is a very simple job, and the use of chaplets is almost eliminated in this particular casting, only two being used to hold the loose piece of the jacket core. When this casting is made jointed the opposite way, the jacket cores have to be carried on chaplets, and this is not satisfactory. Also all the cores are more difficult to make and fix in the mould.

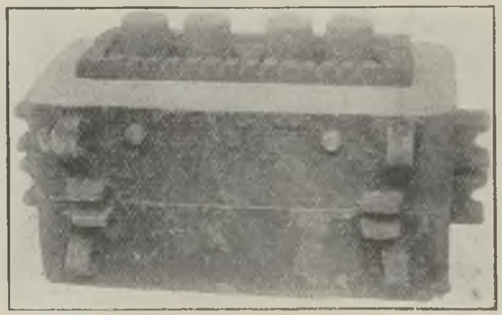

Fig. 13.—The Mould, less the Cope.

When the mould is ready to receive the round barrel cores, before placing these cores in position two plain, round wooden plugs are pushed through the middle part of the moulds and in the jacket cores. This ensures the outside of the cylinder barrels being in alignment with the jacket cores. and as very often the casting is jigged from the outside of the barrels, it is essential that the castings are true in this respect.

Fig. 12 shows the mould cored up ready for the middle part and cope to be put on, and is self-explanatory, and Fig. 13 is a view of the mould less the cope, and shows the sprays in the core, the method of fixing the core, which is simply placed on the middle part, and registered with the cylinder barrels, no further prints being necessary.

Provided the job is carefully cored up, with attention given to the vents, clean moulds laid down, and cast as hot as possible, good results should be obtained.

As mentioned above, there have been shown in the technical foundry papers the methods used in casting this particular job horizontally, and it is hoped that this Paper will show foundrymen the opposite methods used, with the result that they will be able to adopt whichever method they think will be of more service to them.

The chief points are: (1) By constructing the pattern as shown different depths or lengths of cylinders can be used in the same moulding boxes; (2) by making the flange with a core, the machine moulding is a simple job; (3) casting vertically is much better than horizontally; (4) the coreing of the mould is simple and safe, few chaplets being necessary; (5) the ease with which the cores can be made. All of these are in favour of the foundryman in his endeavours to produce this casting in the quantities asked for.

With reference to the iron used, these castings can be made successfully by the use of ordinary cylinder mixtures, or the so-called semi-steel mixture, with 15 to 20 per cent. mild steel, and a suitable analysis is Si 1.8 to 2.25, S 0.08, Mn 0.6 to 0.8, P 0.80 to 0.90, the carbon being slightly different if using iron without the addition of steel, the latter nearly always being lower in total carbon.

Owing to the low silicon content of the iron used, it is advisable to use dry sand moulds for this class of casting, as there are very thin sections in the water jacket, very often only 4 mm. thick. The tendency to get chill in this part of the casting is not so likely if cast hot in dried moulds.

DISCUSSION.

Mr. H. Moore, immediate Past Branch-President, said he hoped the lecture would be fully recorded in the Proceedings, for one result would be that they would be looked upon very favourably by other branches and would show what the East Midlands was capable. They had as a President a thoroughly practical man, who also knew his theory, and he was happy in complimenting Mr. Evans on the advanced work which was being carried on in his foundry.

Mr. Stevenson, seconding, said Mr. Evans had shown himself an expert on oil-sand cores. It was remarkable that though oil-sand cores had been in existence 25 to 30 years, how few foundries availed themselves of the innovation. A mono-bloc casting could not possibly have been made without oil-sand cores. He had been using oil-sand for some three years, and it had become so much in favour in the works that ordinary cores had been practically eliminated altogether. If a large core had to be made the core-box was lined with an inch or two of oil-sand, and the centre was filled in with floor sand. Sometimes, when the core became too hot. the whole of the centre tumbled out, leaving the complete shell sometimes only half an inch in thickness, which can simply be filled up again with floor sand and cast without any trouble whatever.

Mr. A. S. Clarke (Loughborough) pointed out that the absence of technicalities had enabled them to follow the making of these intricate cores.

In reply, Mr. Evans said there had been much experimenting at his works with mixtures, and the one he gave was the best for results, being cheaper and more efficient. It was very seldom they had blown cores. If any members wanted further information he would be happy to help them. Their foundry was quite open for inspection, and they had no secrets to keep. It was generally accepted in foundries that the vertical way was the one which gave the best results.

Lancashire Branch.

CUPOLA PRACTICE.

By J. Wood.

The object of this Paper is to point out some of the difficulties that have to be overcome in melting iron by the cupola process. There are many other ways in which iron may be melted, namely, by the electric furnace, the reverberatory or air furnace, the open-hearth furnace, and the crucible furnace, but for quickness and cheapness in melting iron the cupola cannot be excelled by any other furnace that is on the market at the present time. The greatest drawback to the cupola furnace is that the iron is in contact with the fuel the whole time and will take up some of its impurities if not properly cared for. The cupola is simple in construction and will need very little describing. It is probably due to its simple construction that it has been overlooked by the majority of ironfounders until quite recently, when judging by the interest they seem to be taking now, they are beginning to realise that it is an important factor in the successful working of a foundry.

Details of the Cupola Dealt With

The cupola to be dealt with is shown in Fig. 1. These cupolas are built in pairs and are worked alternately; that is, whilst one is in operation the other is undergoing repairs that are necessary after each day's blow. They are made up of mild steel tubes, 6 ft. 6 in. diameter and $\frac{3}{8}$ in. thick. These tubes are rivetted together and form the shell. On the inside of the shell, angle irons are bolted for the purpose of supporting the brickwork lining. The distance from the base plate to the top of the stack is 26 ft. On top of the stack is rivetted an elbow, and it is in this respect these cupolas differ from the majority. Generally, cupolas are built with a straight stack, on the top of which is placed a hood to prevent the sparks and dust from blowing on the foundry roof. Instead of a hood this type is provided with a square box, which rests on brackets rivetted to the stack of the cupolas and also bolted to the ends of the elbows. Openings are made in the sides of this box opposite the ends of the elbows. As the sparks and coke dust are forced by the blast up the stack, they strike against the elbow, which stops their upward motion, and are then blown into the box and fall to the bottom. An opening is made in the bottom of the box, around which is bolted a tube which may pass through the stage plates to within a few feet of the ground. A slide worked with a screw is fixed near the bottom of the tube. To remove the coke dust, etc., a barrow is placed beneath the tube, the slide is opened, and the barrow is filled in a few seconds. This greatly facilitates the handling of the coke dust, as it may be removed at any time of the day whether the cupola is in operation or not.

The distance from the base plate to the bottom of the hearth is 2 ft. 4 in. This space is filled up with broken bricks and floor sand rammed tightly, and is levelled off with a 2-in. layer of fireclay. The hearth is made on top of this. The distance from the top of the hearth to the centre of the slag notch is 1 ft. 3 in. From the centre of the slag notch to the centre of the bottom row of tuyeres is 9 in., and from the bottom row of tuyeres to the top row is 1 ft. 2 in. There are eight of these tuyeres, four in the bottom row and four in the top row, each of 6 in. dia. They are placed alternately and are so arranged that the inside ends are equi-distant from each other so that they give an equal distribution of blast. These tuyeres are provided with a wind belt.

The Lining.

Owing to the high temperatures to which it is subjected, the lining must be made of highly refractory material and must also be strong enough to withstand the abrasive action of the material charged on its way down to the melting zone. Too much care cannot be taken to avoid cracks and open joints in building the lining, as the molten

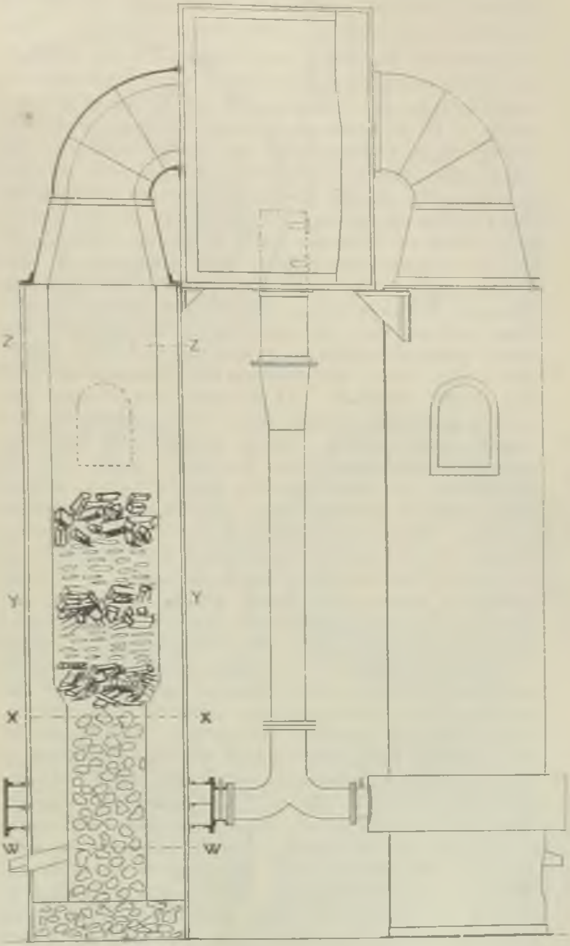

Fig. 1.—Sectional and Front Elevations of the Twin Cupolas Described.

metal and hot gases would penetrate these and shorten its life. The material used for lining cupolas is aluminous firebricks or blocks. The thickness of the lining will depend on the amount of metal required in the day's blow, but even in small cupolas the lining should not be less than 6 in. thick. It is better and safer to have a double lining than a single one, as in the event of an open joint being overlooked in the well of the furnace, the metal would find its way along the joint to the casing and probably put an end to the day's blow. Whereas with a double lining and bricks placed cross joint, the progress of the molten iron would be checked and the damage prevented. When pulling out the old lining it has been noticed that the metal has run between the badly jointed bricks and also between the inner and outer circle, but fortunately has not reached the casing or shell. It is many years since the author has had damage done to the casing by the liquid metal attack, which speaks well for the cupola linings and the material used. It is interesting to note that the cupola linings under the author's control last approximately twelve months. With cupolas that require a 9-in. lining or less it is advisable to maintain the thickness to the top of the charging door, above this a thinner lining of about 4 in. thick will be sufficient, because it will not be subjected to the same wear and tear as the lining below the charging door. With a cupola having a 12-in. lining or more it is only necessary to carry this thickness to the top of the melting zone, which may be from 20 in. to 30 in. above the top tuyeres. Obviously, the height of the melting zone will depend on the diameter of the cupola and the amount of air delivered. Above this, the thickness of the lining may be reduced, but not less than 9 in. This, of course, will cause a shoulder in the lining, but if properly tapered off, will not affect either the cupola or melting. There is no advantage in this except a saving of bricks. A further economy may be made by using hollow iron blocks, which may be inserted about 3 ft. 6 in. above the melting zone and carried to the top of the charging door. These blocks will last a considerable time. With the exception of the lower two or three courses and those directly

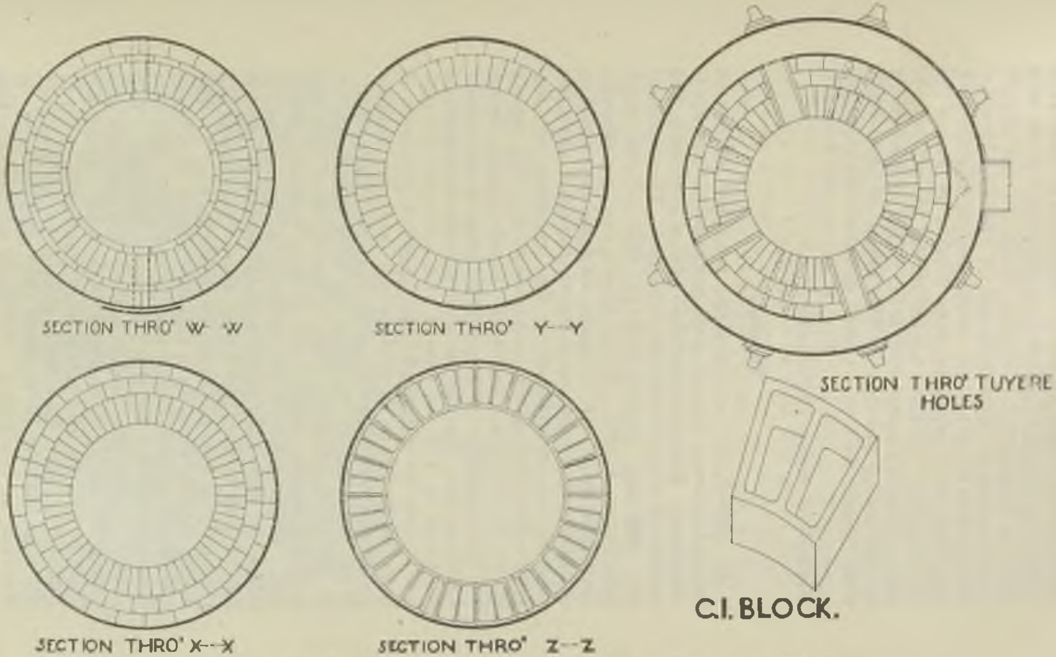

FIG. 2.—SECTIONS AT VARIOUS HEIGHTS THROUGH THE CUPOLA.

opposite the charging door, the blocks are very little worse at the end of twelve months' work, and may be replaced at a higher point in the cupola when relining. The diameter of the cupola after lining is 3 ft. 6 in. up to the top of the melting zone, which is approximately 2 ft. 6 in. above the top tuyeres. It then tapers off 4½ in. all round, making the diameter 4 ft. 3 in. This is continued to the top of the stack. The elbow is lined with 9-in. blocks and the spark arrester with square quarries 1½-in. thick. Fig. 2 shows the author's method of lining the cupolas.

Tuyeres.

As stated, the cupolas are provided with two rows of tuyeres, four in each row, and each of 6 in. diameter. They are provided with a wind belt, the volume of which is 63,480 cub. in. The ratio of the combined tuyere area to that of the wind belt is as 1 : 280. This allows for a sufficient accumulation of air to ensure an equal distribution of blast and a constant pressure provided that the delivery is maintained. The relation of the tuyere area to the cross sectional area of the cupola is as 1 : 6, the combined tuyere area being 226 sq. in. and the cross sectional area of the cupola 1,385 sq. in. The air necessary for combustion is delivered by a Roots blower and conveyed in overhead pipes to the wind belt. A blast pressure of from 10 to 14 ozs. is maintained, and the volume gauge registers an average delivery of 3,750 cub. ft. of air per minute. Experts say that 30,000 cub. ft. of air is required to melt a ton of iron and the authors records taken over a long period confirm this. If the delivery of 3,750 cub. ft. per minute is taken it will take eight minutes to deliver 30,000 cub. ft. and to melt one ton of iron. This works out at exactly 7½ tons per hour, as shown in Fig. 3. The works records show on a full day's blow of 50 tons per cupola rather better results than this, but this is accounted for by the furnace conditions. For example, when the metal is first charged into the cupola the lining is comparatively cold. After the blast is put on and more heat generated, a large amount of this heat that should go to pre-heat the iron before it reaches the melting zone is absorbed by the lining. To make up for this loss of heat it is advisable to charge with a little extra coke until the lining has become thoroughly heated. Of course, this extra coke will retard the melting a little, and each of the first three or four charges will require rather more than eight minutes to melt, but as the furnace becomes hotter and the charges above the melting zone receive the benefit of this heat, the extra coke may be left off, and there will be a perceptible increase in the rate of melting. But this is more noticeable in the afternoon's blow.

When charging for the afternoon the furnace is red hot, and the extra coke that was given in the morning's blow to heat up the lining is not needed. Some of the heat from the red-hot furnace is transferred to the iron charged, and when the blast is put on and the hot gases ascend the cupola from the melting zone the red-hot lining will absorb less heat from these gases, and more heat will thus be transferred to the charges of metal, and they will enter the melting zone in a much hotter condition and be more readily melted. The result of this is that the afternoon's blow is started at the same rate of melting as the latter part of the morning's blow, and as the melting continues the furnace becomes hotter and the rate of melting is increased proportionately. The average rate of melting over the full day's blow is $8\frac{1}{2}$ tons per hour.

Disturbing Factors.

The above results are only obtainable under favourable conditions, but unfortunately there are many things that may happen, any one of which is apt to upset the results. To mention a few: The coke may be of an inferior quality; the charges of iron may be too heavy or too light; the charges may not be distributed evenly; the coke may not be spread evenly over the charge; the volume of blast may be too low and the pressure too high; there may be a scaffolding of charges or a chambering of the cupola; neglecting the repairing of cupola by letting it get out of shape, neglecting the slag hole and projecting lower part of the tuyeres and several other faults, any of which may upset the proper working conditions of the furnace and cause bad melting and an inferior quality of iron.

Bad Coke Troubles.

Apart from any of these faults happening, it is still necessary, to get the very best results from the cupola, to have a good coke and a good supply of air. Fortunately, there is plenty of the latter, and it can be obtained cheaply. With regard to the former, it is found that when dealing with the best makers there is very little to complain of about the quality of coke. Of course, an occasional wagon of bad coke sometimes turns up, but it is the exception rather than the rule, and probably the coke, like the rest of the foundry materials, often get the blame that is really due to the human element. During the coal crisis and for several weeks afterwards when foundry coke was unobtainable, anything that had the appearance of coke had to be used. Some of this contained as much as 17 per cent. ash and 1.75 per cent. sulphur, but the worst feature about some of these cokes was not its composition, but its structure. Some of this was so friable that it could be crushed with the foot, so it can be imagined what the effect would be when dropping pig-iron on top of it from a height of 11 or 12 ft. When using coke of the above description, it was found necessary to increase the depth of the bed coke from 6 to 9 in. to allow for the crushing effect of the first charge. The weight of charges were also reduced from 20 to 17 cwts., and a little extra coke was allowed between each of the charges. This answered very well, and it can be stated that castings were produced without any serious increase of wasters and without the loss of a single day's output.

A coke that is chemically bad but has a fairly strong structure can, by taking proper precautions, be used with satisfactory results. For instance, with the analysis given above, this coke can only contain at the most 80 per cent carbon. Assuming that it takes 200 lbs. of coke containing 90 per cent. carbon to melt one ton of iron, then 200 lbs. of coke containing 90 per cent. carbon equals 180 lbs. of carbon, and 200 lbs. of coke containing 80 per cent. of carbon equals 160 lbs. of carbon. Assuming that the blower or fan is capable of delivering the requisite amount of air, namely, 30,000 cub. ft. per ton in a given

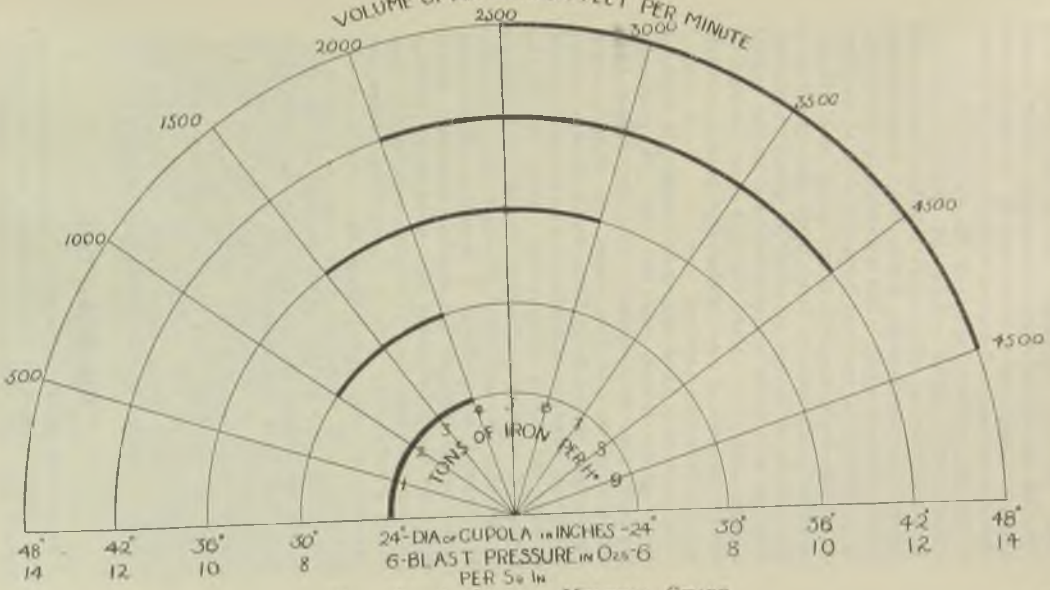

FIG. 3.—A CUPOLA MELTING CHART.

time, and that the tuyere area is such as to take the amount delivered, and the supply of air is constant in both cases, then one is trying to melt the same amount of iron with 20 lbs. less of carbon or 25 lbs. of coke, which is its equivalent, or in other words, instead of having sufficient coke to melt 2,240 lbs. of iron, we have only sufficient coke to melt approximately 2,000 lbs., thus leaving 240 lbs. to be melted. The consequence of this will be, although it may not be noticeable at the first or second charge melted, that to melt this 240 lbs. of iron it will have to draw upon the coke bed to the extent of 25 lbs. of coke for the first charge. The bed will be 50 lbs. of coke less after the second charge, and so on, until the bed is so lowered by the extra demand upon it that the metal is in close proximity to the tuyeres.

It is common knowledge what takes place under such circumstances, as the bed is gradually lowered the temperature of the metal falls off and there is an excess of oxygen over the carbon in the fuel. The result of this is that the iron becomes oxidised, runs sluggishly, and is only fit for castings that have not to be machined or tested. Further, the bed may become so low that the cold-blast will blow upon the iron and instead of melting, it becomes chilled and sticks to the sides of the cupola chambers, and if only one row of tuyeres are used stops further blowing for that day. The obvious remedy when using a low-carbon coke is to increase either the quantity of coke or reduce the weight of the charges. All foundries have not a chemist to advise them as to the carbon-content of the coke, but to those who are trying a coke, to which they have not been accustomed, and are not sure as to its quality, it is suggested that they try lighter charges than usual when filling up the cupola. Then by watching the rate of melting and the temperature of the metal as it flows from the cupola, it will be an easy matter to regulate the weight of metal in the succeeding charges to suit the coke.

High-Sulphur Coke.

The influence of high-sulphur-content of the coke can be neutralised to a great extent by the mixing of suitable brands of iron and by quick melting. It is well known that manganese has a strong affinity for sulphur. When we know or suspect that a coke is high in sulphur we mix a quantity of high manganese iron with the charge. The manganese will combine with the sulphur in the coke forming manganese sulphide. This will rise to the top of the molten metal and flow off with the slag. Some people try to eliminate the sulphur by using extra limestone, but the author prefers to use manganiferous irons, as an excess of limestone is apt to do more harm than good, as it will combine with the brickwork lining of the cupola and lower its fusibility, which will necessitate extensive repairs. Where the services of a chemist are not available, the presence of high sulphur can be detected at the cupola spout. An iron that has absorbed a large amount of sulphur from the fuel gives off sulphur dioxide fumes, which have a rather strong smell. The first charge of iron tapped, owing to its long contact with the coke, invariably contains more sulphur than the succeeding charges, and which, by the way, should not be used for small castings that have to be machined. If the succeeding charges should give off these fumes then steps should be taken to eliminate some of the sulphur by the above means. If the means are not at hand, either in the shape of high manganese irons or ferro-manganese, and soft castings are required, then the silicon content of the mixture should be increased.

Sulphur Prints.

A quick and reliable method of testing for sulphur is by means of sulphur prints. These prints enable one to determine the sulphur in iron to within a fair degree of accuracy. As the effects of sulphur on cast iron are many, and its influence is great, these prints often impart valuable information to the person concerned. When a sulphur print is desired a piece of iron casting or pig is taken, and a smooth surface obtained either by machining or an emery wheel, taking care to have the surface free from grease and dirt. A 3 per cent. solution of sulphuric acid is then prepared. A piece of ordinary bromide photographic paper the size required is now dipped in the acid and then pressed in close contact with the smooth surface of the iron. and held there for 30 seconds or 60 seconds as desired. The acid causes the sulphur to leave the iron in combination as a gas, which acts upon the bromide in the paper, producing dark or light sepia tints corresponding to the distribution of sulphur. The print is then washed in water and fixed by washing in hypo solution. If a series of these prints are made, say from 0.025 per cent. to 0.125 per cent., the laboratory estimation corresponding to each print being known, and are used as a standard, then any iron that comes along whose sulphur content is in doubt, a print can be taken and the sulphur determined approximately by comparison of colours.

Coke Beds.

A most important factor in the melting of iron satisfactorily is the coke bed. The depth of this will vary according to the diameter of the cupola, the amount of air delivered and the quality of coke, but it must be made and maintained at a sufficient height above the tuyeres to prevent the iron coming in contact with the blast. The size of the coke bed should not be determined by weight, as it is a fact that some cokes are heavier than others, and a big difference in the depth of the bed will take place if judged by weight. Moreover, even if only one quality of coke were used the cupola lining is gradually lessened after successive meltings, and the weight of coke that would be suitable for a newly lined furnace would not be sufficient for the same furnace after several days blowing. Therefore the safer plan is to have an iron rod cut to the required length, then by inserting it through the charging door the depth of the bed may be ascertained. When the bed is made of the desired height the charging can be commenced. The author's practice is to charge 20 cwt. of pig-iron and scrap, the amount of scrap will depend on the quality of pig-iron used. The pig-iron is charged first and placed as evenly as possible upon the coke bed, the scrap is then spread evenly upon the pig-iron; coke is then spread evenly over this. The process is repeated until the cupola is filled level with the bottom of the charging door. The chief point when charging the furnace is to see that the correct amount of pig-iron, scrap and coke is charged, and to ascertain that they are distributed as evenly as possible.

Chambering.

There are very few furnace-men who have not at one time or another experienced the chambering of the cupola. This is usually due to the coke bed or a portion of it being burned too low, probably through one or more of the following causes, namely, charging too heavily; charging the metal down the side of the cupola; uneven distribution of coke, *i.e.*, leaving part of the iron charged uncovered with coke, or charging heavy lumps of scrap. Any of the above irregularities are likely to originate the chambering of the furnace. Cupola chargers, as a rule, are not long in finding out that the metal melts much quicker at a red or yellow heat than it does at a white heat, and where large outputs are required they are apt to take advantage of this knowledge and charge more heavily than they should. Of course, where weighing machines are installed there is less likelihood of this happening. Assuming that the charges of iron are out of proportion to the coke charged. that is, supposing only sufficient coke was put on to melt 10 cwt. of iron, and either through a mistake or otherwise 12 cwt. were charged, then what happens is—there will not be sufficient coke charged with the iron to melt the whole of it, the remainder has to be melted with the bed coke, with a consequent lowering of the bed and also a lowering of the temperature of the iron, and each successive charge as it enters the melting zone will use up a portion of the bed coke until it gets so low that the iron is close to the tuyeres and the cold blast will blow upon and chill it. It then sticks to the sides of the cupola immediately above the tuyeres, and any molten iron that drops upon the chilled iron becomes chilled in turn and so gathers, and if steps are not taken to stop it it will soon extend across the cupola and preclude further melting for the day.

The same effect may be caused by charging too much iron down the side of the cupola, only with this difference, when the charges are too heavy the whole of the coke bed is lowered and the chambering is commenced all round the cupola. When charging down one side the chambering commences only on that side of the cupola where the bulk of metal has been thrown. The same thing applies when the coke has not been evenly distributed over the iron, that is, where part of the metal charged is left uncovered with coke, and instead of having a layer of coke between and separating each charge, iron to iron is charged. This has the same effect as charging too much iron down one side of the cupola.

Melting Large Lumps.

With regard to heavy lumps of scrap, it is interesting to note that the author has melted lumps of scrap weighing from 10 to 14 cwt. successfully, that is, without lowering the temperature or showing any signs of chambering; but the following precautions have always been taken, namely, waited until the afternoon's blow when the furnace has been at its hottest; given an extra quantity of coke; placed the lump of scrap as near the centre of the cupola as possible, and placed 4 to 5 cwt. of light scrap around and on top of it. The object of placing this light scrap around the heavy scrap is to get it to assist in the melting of the heavy lump. Owing to its thinner section it will melt much quicker, and as the molten metal runs around and over the lump it will assist in its melting. If the above precautions are not taken it is probable that the heavy lump of scrap will wear away a quarter of the bed coke and cause chambering.

Precautions Necessary to Prevent Chambering.

Having stated some of the causes of chambering, it will be as well to state what steps are necessary to be taken to remove it. An observant furnace-man can soon tell whether his furnace is working properly or not, and if not, if he is *au fait* with his work, will at once take steps to remedy the fault. First considering heavy charging, the first metal tapped may be rather lower in temperature, and the third charge tapped, owing to the lowering of the coke bed, will be still lower in temperature. The efficient furnace-man will know that there is something wrong, either that sufficient coke has not been charged, or that the charges of iron are too heavy, and he will at once take steps to remedy this by giving more coke to raise the bed to its proper height and reduce the weight of his charge. But it might be that before this extra coke and reduction of charges can take effect, that the coke bed is so lowered that the chambering has already commenced. In such a case, the only remedy is to stop-off the top row of tuyeres and prevent the cold blast from blowing on to the iron and melt with the bottom row of tuyeres only. This, of course, will lower the melting zone and retard the melting a little, but the hot gases rising from the new melting zone will have the effect of melting away the iron that has gathered about the top tuyeres. The melting must be continued with the bottom row of tuyeres, until the extra coke has reached the original melting zone and then the stoppers may be moved from the top tuyeres and normal blowing resumed.

Overcoming Difficulties.

When chambering has commenced through too much metal being charged down the side of the furnace or charging metal to metal, or by heavy lumps of scrap, it may be detected and remedied by taking the following steps. The furnace-man should make an inspection at regular periods to see that his cupola is working properly. This he is enabled to do by looking through the peep-holes that are placed in the centre of each tuyere lid. If on looking through these he finds that the coke at the end of the tuyeres pipes is burning brightly he knows that the furnace is working satisfactorily. But sometimes he will not be able to see into the cupola through one or more of these tuyeres; the coke instead of burning brightly is a dense dark mass.

This may not be serious, as it may only be caused by some of the slag dropping upon the coke and becoming chilled by the cold blast. On the other hand, it may be caused by chilled iron and slag. If the former it can easily be removed by inserting an iron bar through the tuyere pipe and poking it away. In this case after removing the obstruction another piece of coke will descend from the coke bed and take its place. If the latter is the cause then it will be more difficult to be removed, and if after its removal more coke does not come down to take its place, then the furnace-man should know that there is some obstruction above the tuyere that is preventing the descent of the coke. Steps should be at once taken to remove the obstruction; this can only be done by at once stopping off the tuyere or tuyeres and preventing the cold blast from entering the cupola, and by charging extra coke down that side of the cupola where the chambering has taken place. By the time the extra coke has reached the melting zone the obstruction will have been melted away by the hot gases generated by the lower tuyeres. All this only applies to cupolas that are provided with a double or more rows of tuyeres. If there is only one row of tuyeres and chambering has commenced it is highly improbable that the obstruction can be burned away by stopping off the tuyere, as there is not sufficient heat generated below the tuyeres to melt the iron away.

Scaffolding.

Another source of trouble in cupola practice is the scaffolding of charges. This may be caused either by the bad condition of the lining, or charging pieces of pig-iron or scrap that are too long, and becoming wedged against the sides of the cupola, thus holding up the charges above. If the scaffolding takes place near the charging door it may be liberated by poking at it with an iron bar, but if it takes place some distance down the cupola and it cannot be reacted with a bar the best plan is to stop blowing for a time. Then as the furnace cools down the metal will contract a little and thus liberate the scaffold. Another reason for stopping the blast is that, if blowing was continued for some time the coke that was put on to melt the charge would probably be burned away before the scaffolding was liberated, and the consequence would be dull iron. Extra coke should always be charged when scaffolding takes place, and the charges are held up for any length of time, as it is almost certain that some of the coke will have burned away and it will require this extra coke to raise the bed to its proper level.

Most furnace men will have experienced a difficulty from time to time in running off the slag. This may be due to an insufficient supply of limestone, or a tuyere placed too near the slag notch, or it may be caused by a leakage between the brickwork lining, allowing the blast to blow upon the slag as it leaves the slag notch. If it is due to lack of limestone the slag will be a thick pasty mass, and only continual poking with a bar up the slag hole will allow the slag to run. If a tuyere is placed too near the slag hole the cold blast will blow upon the slag and lower its fluidity, and in time, owing to its chilling effect, stop it from running out. An indication of slag being chilled by the blast is the presence of slag wool floating about the slag hole. When this appears it is advisable to stop off the tuyere nearest the slag hole. If this does not arrest the making of slag wool or allow the slag to run off freely, it is probable that the slag is chilled by a leakage between the bricks above the slag notch. Then the only action to take is to cut away the chilled slag and with a flat bar place some ganister on top of the slag notch and stop the leakage. Some furnace men will continue blowing until the slag is cut away from the slag hole, the time taken to do this may be 30 minutes or even longer, depending on its extent. In the meantime the slag is accumulating in the furnace, and this cannot but be a detriment to the quality of the iron, because the molten metal as it drops from the melting zone will have to pass through a thick layer of slag, which will not only lower its temperature, but the metal will take up some of the oxides from the slag and probably cause wasters.

Slags.

The temperature at which the metal is melted is closely associated with the composition of the slag, as is also the condition of the iron charged.

TABLE I.—*Composition and Colour of Cupola Slags.*

	No. 1.	No. 2.	No. 3.
SiO_2	53.00	45.00	50.80
Fe_2O_3	23.40	17.92	16.00
Al_2O_3	1.60	8.08	8.20
MnO	12.00	13.00	14.80
CaO	10.00	16.00	10.20
	Stoney Greyish Black.	Dark Olive Green.	Light Brownish Green.

If a rusty or oxidised iron is charged into the cupola the result is a black slag caused by an excess of oxide of iron. If the melting zone is not kept up to its proper height the metal will become oxidised and give the same effect.

The colour of the slag is a guide to its composition, as is shown in Table I. In the case of No. 1 the stoney black appearance is caused by an excess of iron, along with a fair quantity of lime and only a small amount of alumina.

No. 2.—The colour of this is due to the lower percentage of oxide of iron, and to an increase in the MnO and alumina.

No. 3.—The colour of this is due to a further reduction of oxide of iron and an increase in the percentage of MnO and alumina.

Shape of Cupola.

Another cause of bad melting is due to the cupola becoming out of shape. When a furnace is newly lined it should be as nearly circular as possible, and it is part of the furnace dresser's duty to see that it is kept so. But sometimes, probably due to a low blast pressure or an obstruction in front of the tuyeres, the blast will hug the sides of tho furnace; when this happens the lining is quickly scoured away. Now if the furnace dresser should neglect to build this up to its original size, or at least in a line with the other brickwork, then during the following blow more of the lining will be burned away, and a cavity will be formed. Heat, like anything else, will follow the line of least resistance, therefore instead of the charges getting the full benefit of the heat generated, a large amount of it will be wasted by it passing up that side of the furnace which offers least resistance. Some years ago trouble was experienced with a cupola. The iron could not be melted either sufficiently hot or fast, and at the end of the blow the furnace, in the region of the melting zone, was practically choked with iron and slag. The furnace man blamed the chargers, of course, so the author spent a whole day on top of the stage and saw that the charges of iron and coke were evenly distributed, but the result was the same. The next day after the cupola had been chipped out an inspection was made of the cupola, and it was found that the lining from the top tuyeres to about a foot above the melting zone had burned away to a depth of 6 or 8 ins., and that the furnace instead of being circular was egg shaped. The result of this was, that when blowing down with an insufficient stock in the cupola to confine the heat, only a portion of the last two or three charges were melted, the remainder being stuck to the side of the cupola in a pasty condition. Before using the cupola again the brickwork was rounded off, and no further difficulty was experienced.

Tuyeres Must Not Project.

Another fault that is likely to upset the chemical calculations of the mixture is caused by allowing the lower part of the tuyeres to project into the furnace. Anyone who has looked through the peep-hole of a tuyere will have noticed that the molten metal falls from the melting zone like drops of rain. Some of these fall on the projection and are immediately chilled by the cold blast. As the molten metal continues to drop on the projection the outlet of the tuyeres is gradually closed and the pressure of air is increased, if the same volume is delivered, which is the case where a positive blower is used. The effect of this is to Bessemerise the iron, *id est* owing to the increased velocity of the blast due to the closing up of the tuyeres, the air passes through the molten metal as it drops by the tuyeres, and oxidises the various elements in the metal, especially the silicon. The result of this is that although a mixture of iron has been charged to give a certain analysis after the allowances have been made for ordinary losses and gains in melting, a different result will be obtained. It may be that the chemist has calculated his mixture to give a silicon content of 1.5 per cent. at the cupola spout, but owing to excessive oxidation, due to the increased blast pressure, a silicon content of 1.2 per cent. is obtained, which will account for the complaints from the machine shop about castings being hard to machine.

Birmingham Branch.

BRASS FOUNDRY "IMPS."

By D. White.

The ancient writer, in dealing with evil, gives to it a personality, setting it up as something which is antagonistic to good, speaking of it as belonging to a certain kingdom and of its being possessed of great power, which it continually exercises in the frustration of all that is progressive and for the good of mankind. Finally he gives it the character of a wrestler, with which all true progress must engage.

Now across the path of every progressive foundryman there stands a host of opposing forces or evils, which may be called "Foundry Imps," in order that character might be given to them.

The Birth of the Imps.

The advent of the "Imps" can be imagined to be as follows:—

Many centuries ago, two imps (there must have been two on account of the numbers that have been here ever since) were cast out of the inferno on account of their wickedness.

These "Imps," finding themselves homeless, began to look for a suitable place where they might set up a colony.

Passing an iron foundry one day at casting time (Messrs. "Tubal-Cain & Company") Imphenous suggested to Imphenia that this would make an ideal squatting place, as it certainly resembled the old home more than anything he had seen since they left there, and as the people would have no means of catching them, they should be able to live comfortably and carry on their destructive work for many years.

So together they entered their fresh abode.

For a long period things went on very well, but as the number of the imps increased, fresh fields had to be sought for their exploits.

About this time a firm trading under the name of "Aeron & Company," casters of Precious Metals and other Nonferrous Alloys, came into prominence. The imps, after discussing the matter, decided to invade the Nonferrous Foundry also, and carry on their campaign of destruction there too.

The Creation of the Imp Army.

This deliberation was carried out with great success by the "Imp Army," and for many centuries they held the sway in every nonferrous foundry on earth, and to-day, in spite of modern science, they are as vehement in their attacks as ever.

One of the most vicious of the imp family is "Imp Oxygen," as quite 50 per cent. of the brass foundryman's troubles emanate from this small youth.

Like most other things and beings, this Imp is all right when in his proper place, and from a health point of view we gladly welcome him as a diluting agent into the thick atmosphere of our foundries—that is, of course, when he does not come in "draught" formation. Not only does he sustain life, but he is also the main support of combustion.

The nitrogenous chariot in which he rides is four times his own weight, and when this vehicle has brought him into contact with the red-hot coke of the furnace he alights and joins affinity with the carbon of the coke—dismissing his chariot of nitrogen, which passes, apparently unaltered, through the hot furnace to the atmosphere above.

The result of the "Imps'" association with carbon is that things become hot, this union being attended by something like 8,000 calories of heat; that is if the carbon is burned to carbon dioxide. In this capacity as a sustainer of combustion we again welcome him.

Now this little imp has an affinity for most created things; in fact, it is estimated that one half of the earth's crust is made up of the small chap, the other half consisting of materials with which he is associated, such as sand, rocks, iron, etc.

His affinity for copper is very marked, which, when in a hot viscous state, seems to bend to his overtures and receive him into its very heart. It is here that the subtility of this imp is manifested. He arrives in thousands at the bottom of the furnace to accomplish the work of reducing the solid copper to the molten state, and at the same time thousands more are in waiting in the upper regions of the furnace ready to attack the metal when the right temperature has been reached.

Results of the Attack.

Striking evidence of the effects of this union are to be found now as in all ages. in the worried countenances and lean banking accounts of many brass foundrymen.

It cannot be hoped in one short article to deal with all the disastrous results which are the outcome of a simple flirtation on the part of copper with this wicked little imp; yet the limited space at our disposal might be used in dealing with some points which, although common knowledge to many, may be that one thing lacking in the experience of some.

Once copper has embraced this wily imp there is produced a greater amount of gangerine, or Cu_2O inclusions in the metal than one would at first credit.

Fig. 1 shows the amount of Cu_2O (often referred to as dirt) produced by varying amounts of oxygen absorbed by the copper. The diagram shows that when molten copper containing less than 0.38 per cent. oxygen solidifies, copper crystallises out first, and later in between the copper crystals there solidifies a eutectic of copper and cuprous oxide. This eutectic contains about 3.45 per cent. of Cu_2O, equivalent to 0.38 per cent. oxygen.

When oxygen exists in copper above the eutectic proportion 0.38 per cent. oxygen, Cu_2O comes out first until the eutectic concentration is reached, when the mass solidifies. A glance at the concentration axis will explain the relation of oxygen to copper.

Now as the atomic weight of copper is 63. and that of oxygen is 16, it will be noted that for every part by weight of oxygen absorbed by the copper, or for every imp the copper embraces, nine times its own weight of Cu_2O is produced. Whilst the oxygen existing as oxide eutectic is in the proportion of 30 to 1.

The influence of this imp upon all metals is more or less disastrous. His union with tin forms hard crystals which can be crushed to powder; this gives rise to dirt and planes of weakness in the resultant alloys. Oxide of zinc, which is sometimes troublesome, is another of his products.

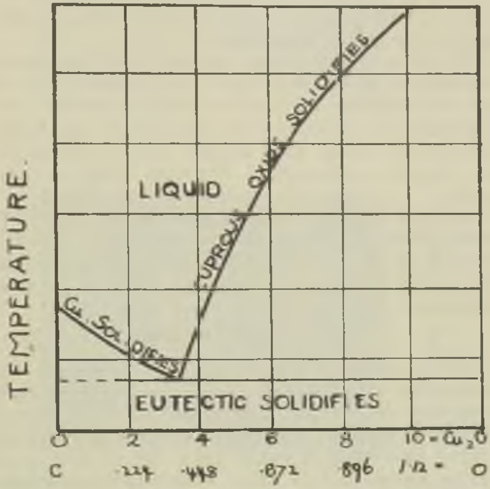

FIG. 1.—COOLING DIAGRAM OF THE COPPER-CUPROUS OXIDE SYSTEM.

These tenacious films, which tend to cause dross and cleavage planes in aluminium and manganese bronze alloys, is just another of this imp's sidelines.

Very often castings which machine up perfectly, and are apparently without flaw, fail miserably when under steam or hydraulic tests. Oxide of copper interspersed throughout the mass is mainly responsible for this evil. Castings which do not require machining, but have to give certain mechanical tests, often fail from the same reason; that is, Cu_2O inclusions.

Fig. 2 shows a micro-section of a copper bar after rolling; no doubt the annealing and working of the bar has given to the Cu_2O this peculiar formation. In cast-copper it appears in patches and a network of streaks, which weaken the metal in proportion to the amount of Cu_2O present in the charge. A good example of how the imp appears in gunmetal is shown in Fig. 4, reproduced from the work of Carpenter and Elam, and shows the weakening effect of Cu_2O in gunmetal castings. Fig. 3 shows a microphotograph of part of an ingot of commercial copper; here the "imps'" presence is again manifest.

The brass foundryman dealing with high-tension bronze should be thoroughly acquainted with the different brands of copper on the market, as it is possible in dealing with bronze of this type to drop two to three tons tensile, and 5 per cent. of the required elongation, through using a wrong brand.

In the foregoing remarks the possibility of Cu_2O inclusion in castings, caused by ceaseless efforts of "imp oxygen" in his attempts to bar the foundryman's way to progress, has been taken into consideration.

Gas Holes in Castings.

As the trail of the "imp" is followed, it is found that he proves himself to be very adaptable, possessing a perfect knowledge of the likes and dislikes of metals. He knows as well as any metallurgist that most metals have the power of dissolving gases, and in order that the foundryman's hours of sleep might be curtailed and his banking account still further depleted, he joins affinity with any stray imp of carbon in the neighbourhood of the furnace, and in the form of CO (carbon monoxide) presents himself to the molten charge for acceptance.

The charge of metal inside the crucible might be able to deny him an entrance, were it not for the "warm embrace" of the imp's friends outside, which finally succeed in bringing the charge into such a condition that it willingly becomes associated with this importunate little imp. As soon as he has gained admission he makes his presence known by expanding himself at a ratio of 1-273 part of his volume for every degree Centigrade added to the metal by his relatives operating on

Fig. 2.—Micro-section of a Rolled Copper Bar showing the Effect of Oxygen.

Fig. 3.—An Ingot of Commercial Copper contaminated with Oxygen.

Fig. 4.—A Micro-section showing the Weakening Effect of Oxygen in Gunmetal.

the outside of the crucible. When a certain temperature is reached, he mysteriously goes into solution and remains dissolved until such time as the castings are poured and the metal, through loss of heat, seeks to regain its stable form. As the temperature drops the metal seems to become conscious of the "imps'" presence, and in order to redeem its good name, which during its period of "softness" it had woefully lost, it seeks to expel from its mass this treacherous villain who is seeking to spoil its usefulness as a metal.

The expulsion of the "imp" can only be partially accomplished on account of the film of metal which has formed against the sides of the mould, behind which we often find masses of small cavities, which represent the volume occupied by the imps at the freezing temperature of the mass.

The Sulphur Imp.

It is not suggested that all gas holes in castings are the outcome of this "imp's" union with carbon as CO; for when sulphur is present in the gases of the furnace, one sulphur imp joins hands with two imps of oxygen, and as sulphur dioxide (SO_2) they are absorbed by the metal, and like CO, go into solution, only to be thrown out as the temperature of the mass is lowered.

The effect of sulphur upon copper-base alloys may be far more deleterious than is admitted by some authorities.

When we consider the nature of the ore from which above 80 per cent. of the world's supply of copper is extracted, namely, the "sulphide ores," with an average sulphur content of 35 per cent., the enormous affinity copper possesses for this impurity will at once become clear. Seeing, then, that those two elements are so closely linked together in nature, surely it is within the bounds of reason to suppose that molten copper will seek the companionship of the "sulphur imp" if brought within its reach.

A fundamental principle known to all smelters of copper ore would seem to bear out the above statement. The principle is, that in melting down a charge of copper sulphide ore, the copper has first claim on any sulphur present, and not until it is saturated does it allow the sulphur to associate itself with any other impurities in the ore.

Now the fact that manganese also possesses a great affinity for the "sulphur imp" is well known to many iron and steel foundrymen.

Manganese bronze may contain from 30 to 40 per cent. of zinc, and therefore should be thoroughly de-oxidised, seeing that from 1½ to 2 per cent. of zinc, if properly used, is sufficient to de-oxidise copper. Yet it is generally accepted that the addition of manganese to this alloy is for the purpose of de-oxidisation, and that it is on this account that the metal exhibits such valuable properties.

The above facts, coupled with observations which are outside the scope of this paper, have led the author to suggest that the chief value accruing from the addition of manganese to so-called manganese bronze is not so much de-oxidation as de-sulphurisation.

An experiment was made with three small ingots cast from an ingot of commercial copper. No. 1 was cast after being melted under a cover of charcoal; this showed a state of excessive oxidisation. No. 2 was melted with the addition of 0.5 per cent. of 30 per cent. manganese copper; the condition was only very slightly altered. To ingot No. 3 was added 0.5 per cent. of 15 per cent. phosphor copper; the appearance of this ingot, as well as the fracture of the metal, was all that could be desired.

It would be interesting to know if the research workers have followed the trail of the "sulphur imp" to its lair; that is, in connection with copper-base alloys. Nature would suggest that beyond the crystal boundary, in the close embrace of the copper itself, this imp finds a resting place, and there, in chemical combination with copper, a family is produced bearing the name of "copper sulphide." It is therefore reasonable to suggest that the diseases from which copper-base alloys suffer, of which season cracking is one, may find their genesis in the reunion of copper and sulphur.

The Hydrogen Imp

Hydrogen, under certain circumstances, is always present in the gases in the furnace, and may be greatly augmented if the coke should contain an abnormal quantity of moisture, as this gives rise to the formation of hydrocarbons.

It also associates itself with sulphur, producing a very troublesome gas named hydrogen sulphide. This gas is said to be responsible for 15 to 20 per cent. of the gas holes in gunmetal and most non-ferrous castings. Fig. 5 gives some indication of the damage these imps are capable of doing. This is not an uncommon sight in foundries where a "strangle hold" is not kept on the "imp army."

The Battleground.

The battleground on which 50 per cent. of the success or failure of the brass foundry is decided is the furnace room. The office may be equipped with the finest cost-keeping system extant, and yet find smooth running very difficult on account of the replace work, part machines, etc., which certainly follows in the trail of bad melting practice. There is more true economy in stocking a dozen crucible rings and covers than in providing an overstock of office furniture.

Having noted the character of these imps and their methods of attack, also the battleground on which they seek to arrest progress, the foundryman, if wise, will seek to instruct his furnaceman, not only to bring metal to a fluid state, but also to become conscious of his unseen enemies "the imps," who, though unseen, are nevertheless real. The conservation or holding back of knowledge of this character from the intelligent furnaceman is a ruinous policy, and one which has greatly hampered foundry progress.

By a simple object lesson a foreman may teach his furnaceman more in ten minutes than if left to himself he would learn in ten years.

To many furnacemen, oxide of copper is but a name, whilst hundreds of others have never even heard of it, although they may be mainly responsible for its production every day.

If the foreman will get his furnaceman to put a piece of sheet copper scrap or rod in the furnace, and when it has reached a red heat, withdraw it and allow it to cool down on a plate so that the oxide of copper formed can be gathered up and inspected by the furnaceman, who should be told that the material which resembles dirt is responsible for many of the gas holes and Cu_2O inclusions in castings. By this simple lesson he will understand one of the characteristics of the enemy, and thus he will be the better able to shield the metal from his subtle attacks.

The management should see that he is encouraged to do this, by keeping the tools in the foundry furnace room in good repair.

He should also be provided with a suitable flux or covering for the metal—charcoal, borax, and common salt in equal quantities is a very effective protecting medium. It is better to spend 10s. in putting the root of the matter right than to wait until the harvest and lose £20 through the production of bad fruit.

There should also be kept in a dry place a supply of 10 or 15 per cent. phosphor copper. It is a good practice to always use about 0.5 per cent. of the material in dealing with gunmetals of a low zinc content.

FIG. 5.—GAS HOLES IN GUNMETAL CASTINGS.

Coke for the furnaces should be of the highest calorific value, and should be broken in suitable pieces. This remark may seem superfluous, but the difference between good and bad metal has often been traced to bad firing, caused by the uneven condition of the coke. It is important that a charge of copper should be melted with the first charge of coke if at all possible, and for this reason it is better to have the furnaces a little too large rather than too small.

The Trail Hunter.

It may be interesting to recount the story of the old master-foundryman who was in difficulties over some 99 per cent. copper casting which weighed about 150 lbs. The castings as produced were useless, the metal being full of small holes.

He determined to find out the cause of these defects, and started out on the following trail:—First he examined the mould, which he concluded was by far too dense. A mould was then made according to his own instructions, which, he declared, would put the matter right. The result was no change in the condition of the castings. The trail then led him to the coremaker, whom he upbraided for making hard cores, and not using sufficient manure. This second attempt resulted in failure also. The coremaker was again visited, and asked to show him the manure he was using, which resulted in the horse being blamed. The root of the difficulty was in the furnace-room, where the copper had been carelessly melted, and the addition of the $1\frac{1}{3}$ per cent. of 15 per cent. phosphor-copper made whilst the crucible was in the furnace and the metal at too high a temperature. When the pot was drawn and skimmed off, immediately there formed a skin of oxide on the top of the metal on account of the phosphorus having passed off as a copper phosphide or slag. When this film appeared it was taken as an indication that the metal was ready for pouring, and of course this procedure resulted in the production of bad work.

The method adopted by the foreman was to melt carefully the copper under a cover of charcoal, and when raised to a sufficient heat, withdraw and allow it to stand without skimming until the casting temperature was reached. This temperature was ascertained by the application of an iron rod to the metal, no pyrometer being available. At the right moment the charcoal covering was skimmed off, the deoxidiser applied, the metal stirred and the mould cast. The result was good castings.

Human Element.

The " imps " encountered in the foundry proper are not so much associated with materials as with human nature itself; in fact they are often referred to as the "human element."

The most important of these is "imp carelessness," who is notorious for his untiring efforts amongst apprentices. He knows that if he can successfully form the character of the lad according to his own law, which may be summed up in two words "near enough," he has succeeded in putting a barrier in the way of improving the standard of castings; for a careless apprentice is a careless journeyman in the making.

The first fruits of his work are seen in the trimming shop. Here from 25 to 100 per cent. more time is required to deal with his work than with castings of a reasonable standard of perfection. Besides the time element there is to be considered the waste in metal caused by chipping, filing, and grinding, also the tools used in these operations. Following this there comes from the machine shop complaints that it is almost impossible to set these castings up true on account of their distorted condition.

Gating.

In dealing with small work, much trouble arises out of the careless selection of suitable downgates. The author prefers small downgates with ingates of a sufficient area, not only to run the casting, but to insure that it is fed whilst setting. This demands that the metal be cast at a slightly higher temperature; a practice which produces better results than when dull metal is used.

In making gun-metal castings for high-pressure work it is very important that height be given to the runner. When this class of work is of a heavy character, reaching a thickness of 2 in. or more, it is the usual practice in many foundries to chill the heavy parts of the castings, and also to feed the large risers with rods. Experience caused the author to abandon the use of both chills and feeding rods in connection with gun-metal work, except in very exceptional cases.

Twelve castings were ordered, weighing 5 cwts. each, which had to withstand a hydraulic test of 4,000 lbs. per square inch. The first one cast was chilled in all the heavy parts, and the risers were fed with rods until they set. The other eleven were cast without chills and were not fed in the manner described above, but an additional height of head was allowed. The only casting that leaked was the one which was chilled and fed, the leaking taking place where the risers had been.

This condition of weakness is just what one might expect to find in the metal after such treatment, and is caused by the agitation of the metal with the feeding rod, as the cooling mass passes through its range of freezing temperatures.

An example of the care required in the application of runners is shown in Fig. 6. This represents a short Admiralty gun-metal liner, which turned up spongy along the dotted line as shown. The casting was said to be suffering from all the diseases a scrap casting could possibly have; when the responsible man, after a close examination of the casting, concluded that the fault lay in the fact that only one downgate had been used, and that the flow of metal had been stronger at the runner side than at the side opposite, and as a consequence an over-lapping took place, resulting in the entrapping of the film which should have risen into the head provided for it. An additional gate put at the other side effected a cure. The

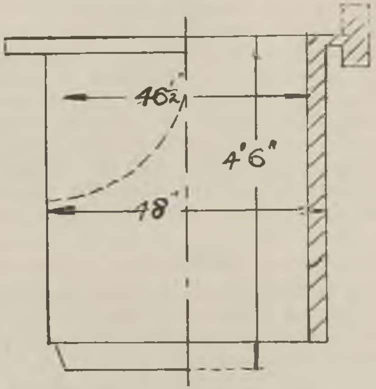

Fig. 6.—An Admiralty Gun-metal Liner, showing Sponginess along the Dotted Line due to Faulty Gating.

position of runners is a detail over which the "careless imp" should have no control.

Sand Selection.

Very often evidences of this imp's work are seen in the buying department. A consignment of sand arrives, the texture and bonding power of which renders it almost useless for a particular class of work. But the buyer has been persuaded by the vendor to order it, because it is cheap, and a neighbouring foundry is using it successfully. When at last the trouble cloud bursts, resulting in the loss of castings and capital, and the jeopardising of the firm's reputation, enquiries are made which reveal the fact that the other foundry is making castings principally in dry sand, for which the sand supplied is admirably suited.

Some time ago the author pointed out that 50 per cent. of the iron foundryman's trouble vanished when he mastered the cupola, and another 25 per cent. followed when he thoroughly understood the nature of the sand he was using. The same holds good in the brass foundry.

The refractoriness of sand is of great importance, and, of course, as its composition directly affects this property, it is necessary to keep as low as possible the fluxing agencies, such as alkalis, iron oxide, lime, and magnesia, as these elements greatly impair this property and produce rough castings.

The difference between the firm who is producing metal castings of an excellent quality and the firm which is not, is that the former has control of the "imps," while the latter, although unconscious of the fact, is being controlled by them.

DISCUSSION.

The Branch-President said he was particularly interested in Mr. Whyte's remarks as to faulty castings being attributable to bad copper, and he would like to know how Mr. Whyte came to the conclusion that the copper he used was faulty. Was he going by its physical nature? Probably that was not the case, or he would have found that the copper was bad before he used it. As to the question of downgates, he said that a considerable amount of correspondence and experiment on the subject was going on at the present time, particularly with reference to iron. There were a number of founders in this country who, having read and seen what was done at the foundries of Messrs. Ronceray et Bonvillain at Paris, were themselves experimenting with a reduction of downgates and runners. He thought very often the solution to foundry trouble lay not in increasing the size of gates and risers but in their decrease. But it was a fact that at Messrs. Ronceray's foundries they cast up to 7 and 8 cwt. and ran with only one downgate, and that only about five-eighths of an inch in diameter. He was also very much interested in Mr. Whyte's references to the effect of small quantities of impurities, and he thought that when students were learning about the elements found in iron and non-ferrous metals it would be an advantage if those elements were not introduced as elements but as the compounds in which they existed in the metal.

Professor T. Turner, in proposing a vote of thanks to the lecturer, said Mr. Whyte had been both practical and humorous, and was an illustration of the old saying that there is many a true word spoken in jest. Mr. Whyte had spoken of the imps of the brassfoundry, and, of course, he was referring to certain natural laws which were in operation in the foundry—laws of combination, solution, expansion, and so forth. He did not think we need consider that there were any evil laws in nature. They were all beneficial. It was only a question of ascertaining how they acted, and how they could be employed to advantage. He suggested that these imps, by proper management, could be converted into beneficent fairies. With reference to oxygen in copper, it was known that it had a very grave and injurious effect when present in the form of cuprous oxide beyond a very limited amount, but in brass the amount of oxygen that remained must be very small, because the zinc present combined readily with the oxygen and formed a scum, which was removed. It was not very easy by analysis to ascertain how much oxygen was left, but they knew it was very small. He spent some time in endeavouring to determine the amount of oxygen in brass without any considerable measure of success, but Professor Carpenter and one of his assistants introduced a method which gave results, but the analytical process was somewhat troublesome. With reference to the solubility of gases in copper and copper alloys, solubility increased as temperature rose. Gases left in solution in any large quantity tended to produce brittleness, and to cause the metal to be low in elongation. It was extremely important to pour the metal at the right temperature if they were to get the best results—free from gases and with the highest tensile strength.

The vote of thanks was seconded by Mr. W. J. Flavell, and passed with cordiality.

Mr. D. Wilkinson said if a casting could be so arranged that the feeders fed it without the introduction of a rod he had always found that method far more satisfactory than if a rod was introduced. The only trouble was that to feed a casting without putting in a rod meant that the feeder had to be considerably larger, involving more trouble in removing it and greater waste of metal. But in a very important casting it was better to make sure of success even at more expense. He was very interested in Mr. Field's remarks regarding Messrs. Ronceray's castings. More than twenty years ago he made a series of castings 25 cwts. each, and these were cast with a small gate, of which the inlet measured $1\frac{1}{4}$ in. × $\frac{5}{8}$ in. All the metal passed through that. It was exactly the same type of runner as Messrs. Ronceray showed in the diagrams printed in The Foundry Trade Journal, and it had been used in some parts of England fifty to sixty years ago. As to chills, he remarked that frequently the troubles one overcame by the use of chill were only removed at the expense of other troubles which the chill brought in its train.

Replying upon the discussion, **Mr. Whyte** said that as to the question of the selection of copper and how they arrived at the best brands, it was simply by trial and error. All the commercial brands, three of the principal brands at any rate, on analysis were pretty well alike. Mr. Whyte afterwards illustrated on the blackboard the methods employed in the casting of propellers.

Newcastle Branch.

CAST IRON AND ITS CHEMICAL COMPOSITION.

By O. Smalley.

Cupola-melted cast iron is a material of unknown thermal stability, a mechanical mixture of elements and compounds which only by careful manipulation can be arranged, within certain limits, to give physical properties that render it a reliable material of construction.

Because of its economic value, the metallurgist has long endeavoured to bring it into line with steel and other alloys whose physical properties are under reasonable control. Recent reports give the impression that our present lack of knowledge of the metallurgy of cast iron is a result of the scientist having concentrated his attentions elsewhere. To a certain extent this is true, because a knowledge of the constitution of a simple series of elements is essential to an understanding of a more complex series. At the same time, although cast iron belongs to the latter, it has been closely studied alongside with the simpler combination to which it is allied, viz., steel; and although a more comprehensive understanding of the physico-chemical properties of the iron-carbon and the iron-carbon-manganese combinations is possessed, it is only because they give rise to a series of true alloys, whilst the combination of elements known as " cast iron " does not.

Moldenke speaks of cast iron as a " conglomeration of elements which is little understood.'' This aptly sums the position up with regard to our present knowledge of the constitution of cast iron. In all there are 18 to 20 different elements in cupola melted iron which, giving rise to the presence of compounds of widely different chemical and physical properties, possesses certain definite limitations.

FIG. 1.—HEMATITE SAND CAST.

FIG. 2.—HEMATITE CAST IN 1-IN. SQ. BARS.

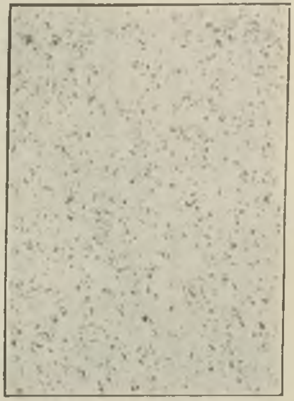

FIG. 3.—HEMATITE DIE CAST.

A recognition of these limitations and a knowledge of the fundamental principles controlling the production of any particular combination of physical properties is the urgent need of to-day, not development as a competitor with steel.

Chemical Composition.

The amounts of the usual elements in cast iron vary as follows:—C., 2.8 to 3.9; Si., 0.8 to 5.0; Mn., 0.3 to 1.3; P., 0.10 to 1.80; and S., 0.05 to 0.20.

The chemical composition of cast iron is somewhat analogous to that of a moulding sand; it indicates the principal elements present, but it does not give any idea of the chemical or physical constitution of the compounds formed and their relation to one another, which factors control its utility. In other words, chemical composition is of little value without a knowledge of the metallurgy of cast iron. Unfortunately, the metallurgy of cast iron, as previously stated, is so complex that as yet it is far from being a science: in fact, so many problems require immediate elucidation to-day that a close co-operation of the metallurgist and foundryman is essential to the successful production of commercial iron castings.

Semi-Steel.

Recently a large and reputable manufacturer of refined cast iron submitted for inspection various selling samples of his products. Amongst these was one which had been forged down to a wedge shape, so prepared to demonstrate the quality of this iron for the manufacture of high-grade cylinder castings. On analysing, the following composition was obtained:—C.c., 0.64; Gr.c., 1.21; Si., 1.32; Mn., 1.32; P., 0.082; and S., 0.060, proving it to be nearer a steel than cast iron, and to have been made by an oxidising process from steel scrap, pig iron and ferro-silicon additions.

What advantage is to be gained by the use of this iron in the cupola? Is it superior to refined iron made in the cupola to the following composition:—TC., 2.9; Si., 1.32; Mn., 1.32; P., 0.10; and S., 0.060, which, incidentally, can be prepared at one-third the cost? It may be argued that a refined cast iron cannot be prepared in the cupola from cast iron and steel scrap in that it will contain a high total carbon, maybe oxygen or oxide of iron—a much-discussed bogey of to-day—and be high in sulphur. Yet surely this is the material which the engineer means when he specifies semi-steel. It can be nothing more or less than cast iron melted with steel; it cannot be recognised from ordinary cast iron by chemical analysis.

Semi-steel is sometimes defined as low-carbon cast iron. This, however, is incorrect, there being little difference in the total carbon content of cast iron melted without steel and that melted with, say, up to 25 per cent. Nor is it safe to assert that steel is either detrimental or beneficial because of the oxygen introduced. If steel is melted with cast iron in a correctly-designed cupola, using a good hard coke, the correct volume of air, and is suitably fluxed, there is nothing to choose between semi-steel and cast iron so far as fluidity and the production of clean castings are concerned. The addition of steel, however, is beneficial in that it gives a closer-grained, tougher and better wearing iron, and improves the solidity of the casting as a whole. This is a conclusion proved by many years of practical experience.

This improvement is directly attributable to the quantity and form of the graphitic carbon present. It has nothing to do with oxygen, nitrogen or any of the so-called inherent properties of the irons employed. In fact, Cleveland, hematite, scrap mixtures yield results equal to specially-selected cold-blast or open-hearth refined irons if the form of the graphite is initially controlled.

This may be demonstrated in various ways: if molten mild steel, plus the necessary additions of silicon and phosphorus, is run through a small cupola charged with incandescent coke, an abnormally tough iron will be obtained, although of normal chemical composition.

If a microscopical examination be made of this synthetic iron, and also of ordinary cast iron, it will be found that in the former the graphite is finely disseminated through the mass, whilst in the latter it exists as coarse flakes.

The explanation of this difference is that in ordinary pig iron the total carbon content ranges between 3.0 to 3.9 per cent., and the graphitic carbon not only possesses different degrees of refractoriness, but exists in various forms determined by chemical composition and method of manufacture. Figs. 1, 2 and 3 illustrate the form of graphite commonly met with in cast iron. Fig. 1 represents a 3-in. square block of hematite cast in dry sand. Fig. 2, the same iron cast in the form of 1-in. bars, and Fig. 3 when die-cast.

Speaking generally, the coarser the graphite flakes the more refractory does it become. In the cupola it is doubtful if a higher temperature than 1480 deg. C. is ever reached. The maximum amount of carbon which a 2 per cent. silicon iron can hold in solution when just molten is round about 3.7 per cent. Assuming that the ordinary laws of solution hold for cast iron, then at 1480 deg. C. such an iron will dissolve about 3.95 per cent. C. Cupola melting, however, is extremely rapid, and the molten iron rarely reaches this temperature; in consequence, high-carbon grey irons melted in the ordinary way always contain, some free graphite.

This fact does not appear to be fully appreciated, although it may be proved by pouring the molten iron in cold water and examining it chemically or microscopically.

The effect, then, of coarsely-disposed graphite in the pig melted is to adumbrate in the molten metal the original structure and reproduce it in the finished casting to an extent determined by the rate of cooling during solidification. If, however, such a graphitic iron is rapidly solidified as by casting in chill moulds, the graphite flakes are broken up into a fine granular form (Fig. 3). Remelting this iron yields tough close-grained castings. This has been demonstrated by many large-scale practical experiments, melting in 8- and 16-ton cupolas, closely observing the quality of the finished castings and the physical test-results in conjunction with the microstructure.

That 10 to 15 per cent. mild steel should effect a further grain-refining influence if melted in conjunction with this chill-cast run-down iron can readily be understood. In fact, this mixture not only eliminates such common defects as open grain and sponginess, but renders possible the reproduction of certain physical properties to a remarkable degree of accuracy.

The maximum results obtained from daily test-bar records obtained from many thousands of tons of this iron made over long periods of time were:—C.c., 0.74; Gr., 2.41; Si., 1.5; Mn., 0.65; S., 0.11; and P., 0.50, which gave 16 to 19 tons per sq. in tensile, and 5.0 to 6.6 tons transverse on a 12-in. by 2-in. by 1-in. bar. The minimum results were C.c., 0.67; Gr., 2.43; Si., 1.8; Mn., 0.65; S., 0.100; and P., 0.75, which gave 14 to 17 tons per sq. in. tensile and 4.5 to 5.5 tons transverse.

Oxygen in Cast Iron.

Considerable discussion has taken place recently as to whether oxygen can be found in cast iron and its effect on the mechanical properties. That oxide of iron may exist in badly-melted iron is generally accepted, and that under such conditions the addition of steel will not materially assist. Whether oxygen exists in cast iron as a gas has yet to be proved; in fact, we do not pretend to understand the chemical equilibrium between iron, carbon and oxygen. Yet some investigators go so far as to state that oxygen is soluble in cast iron and that semi-steel owes its superior physical properties to the oxygen introduced by the addition of steel. J. Johnson, junr., who first published this statement, offers no premises for his conclusion, and from the outline given of his experiments one is quite justified in asserting that the improved physical properties are an effect of hydrogen or nitrogen gases, which it is common knowledge exist in cast iron, or to the form of the carbon or to a direct temperature effect.

Chemical Composition.

It is equally certain that dirty castings and blow holes cannot be directly attributed to oxygen, as cupola melted cast iron, no matter the care taken in melting, will give dirty and blown castings if cast at a low temperature; whilst the cheapest grade of iron, whether melted with or without steel, yields clean castings if the metal is correctly melted and is cast at a good temperature.

To investigate the question of the effect of oxygen and its oxides on the physical properties and production of clean castings, a continuous series of experiments have been carried out during the past twelve months on a large and extensive practical scale by treating various grades of iron with the most active deoxidants. Amongst those tried were cerium, uranium, calcium, vanadium, aluminium, magnesium, manganese and zirconium, all of which are well known for their ready affinity for oxygen.

Cerium.

In a recently-published American investigation the following conclusions were drawn on the effect of cerium :—

"Deoxidising by means of cerium gives the purified molten metal a better chance to set under natural conditions, being relieved from a too rapid freezing action with consequent formation of undue amounts of combined carbon. The metal, therefore, is easier to machine, is freed from gas and pin holes, has a less internal shrinkage, and increases the transverse strength 33 per cent. with a proportional increase in the deflection."

Attempts have been made to confirm these remarkable statements, introducing 0.01, 0.05, and 0.10 per cent. of cerium by means of a 70 per cent. Ce, Ferro-cerium alloy in stick form. In each instance the cerium alloy was copper-plated, fastened to the end of a steel rod and plunged in the molten metal to the bottom of the ladle. This caused a violent ebullition and a slight increase of temperature.

Though many experiments were carried out with both cupola- and crucible-melted cast iron no beneficial effects could be traced to cerium when introduced in quantities up to 0.05 per cent.; with 0.10 per cent. a slight strengthening effect was found in two instances, but there was no increase in fluidity or decrease in shrinkage. In fact, there was every indication that the increased strength from the introduction of 0.10 per cent. Ce was a temperature rather than a cleansing effect.

Uranium.

This was introduced in the form of powdered ferro-uranium, containing 41 per cent. uranium, enclosed in a small sealed canister fastened to the bottom of the ladle, and the molten metal being tapped direct from the cupola.

Fluidity, shrinkage, tensile and transverse tests show uranium in quantities of under 0.20 per cent. to be without effect on the quality of ordinary cast iron.

Calcium.

These experiments were conducted on the same lines as adopted in the cerium experiments, using pure calcium in one series and ferro-calcium in another. No real benefit was found in any instance and no trace of calcium could be detected in the finished castings.

Vanadium.

Moldenke, in summarising his experiments, concludes that "to increase the breaking strength of grey cast iron a further investigation on the effect of vanadium is warranted on the part of every foundryman who has special problems in strength to master." Hatfield, after exhaustive investigation, does not attribute the slight beneficial effect of vanadium which he found in his experiments to be due to this element acting as a scavenger, but rather to its influence in preserving the carbon in the combined state.

In the author's experiments a 35 per cent. vanadium (ferro-vanadium) alloy was used, introducing in quantities up to 0.10 per cent. in the manner adopted with uranium. The test results obtained do not confirm Moldenke's assertion that small quantities of vanadium are beneficial to the production of a high-tenacity iron, whilst the hardening effect observed by Hatfield was not found; which suggests that Hatfield's results are more than probably accounted for by either a variation in the casting temperature or the initial temperature of the mould, factors which he does not appear to have taken into account.

Aluminium and Magnesium.

Extensive experiments have been conducted with these metals, introducing separately, alloyed with each other, and also alloyed with iron and copper.

The only direct and reproducible effect of aluminium found was to soften, whilst magnesium hardens. No improvement in the fluidity and physical tests could be detected by the introduction of either metals into normally-melted cupola iron.

The introduction of magnesium into cast iron is accompanied by a violent reaction, and great precautions are necessary.

Zirconium.

Moldenke* failed to find any beneficial effects from the use of zirconium if the iron is melted with the correct degree of heat. If, however, large amounts of steel scrap are used he states "it might be beneficial."

In the author's experiments he could detect no improvement from the introduction of zirconium in quantities of up to 0.20 per cent., whether steel was or was not melted with the iron, or whether a hot- or a cold-blast iron was used.

The collected tabulated physical test figures accompanying these experiments are excluded from this Paper on account of their bulkiness, but the comments summarise the results obtained and convey all that is necessary so far as "deoxidation of cast iron" is concerned. With reference to Moldenke's summing-up his results on the effect of zirconium, his comment as to "correctly melted" cast iron applies to practically all deoxidants, and, which is more important, to incorrectly melted iron, because no amount of doctoring will correct such iron and render it fit for use.

Casting Temperatures.

The initial melting- and casting-temperatures are two essential factors governing the successful production of clean, solid castings. If the metal is cold on leaving the cupola bad castings are inevitable, no matter what precautions are taken in other directions. On the other hand, if it contains the necessary degree of superheat and is cast at the right temperature, little or no trouble will be encountered as far as blowholes, scum and physical test results are concerned, assuming, of course, the correct mixture has been used in the first place.

During recent years many attempts have been made to measure and so control the degree of superheat in cupola-melted iron, but with little or no success, as the temperature figures quoted

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* American Foundrymen Association, Oct. 4-8, 1920.

TABLE I.—*Cooling Details of Cast Iron of Various Compositions.*

Mark	CC.	Gr.	Si.	Mn.	P.	S.	Incipient solidification. °C.	Main solidification. °C.	Latent heat of solidification in gramme calories.	Phosphide solidification. °C.	Latent heat value in gramme calories.	Carbide change °C.	Latent heat value in gramme calories.	Time taken in minutes to cool from immediate solidification to :			
														Final solidification.	End of phosphide change	End of carbide change	500 C.
1	0.66	2.74	1.03	0.63	0.09	.063	1243	1160	27.2	960	0.8	736	13.9	43	73	176	640
2	0.60	2.67	1.15	0.62	1.54	.086	1221	1125	21.7	957	9.4	738	11.1	34	80	167	605
3	0.73	2.15	1.27	0.55	0.47	.096	1232	1153	21.1	955	3.1	747	17.2	32	79	171	590
9	0.72	2.39	1.50	0.71	0.52	.097	1210	1142	26.7	955	3.3	738	12.2	37	72	155	570
Coe.	0.17	2.54	2.01	—	0.09	—	1212	1148	—	—	—	740	—	—	—	—	—
5	0.55	2.83	2.30	0.60	0.78	.063	1165	1149	23.6	956	6.7	749	10.5	28	61	150	650
6	0.21	2.88	2.49	0.52	1.28	.050	1160	1132	22.2	960	10.0	779	8.3	30	75	156	650

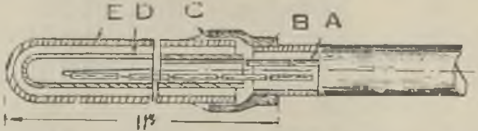
by recent investigators show, these ranging from 1,300 to 1,592 deg. C.

To measure accurately the temperature of molten cast iron in the foundry an actual immersion of a thermo-couple is the only satisfactory method. To be of practical utility the thermo-couple must be robust and reasonably fool-proof.

Thermo-Couples.

Of the numerous couples tried only two have been found worthy of consideration, the one, composed of Alumel (Ni 95, Mn 2 and Al 2)—Chromel (Ni. 89 Cr. 8 Mn. 1.5 Fe. 0.5), the other platinum and platinum+10 per cent. rhodium. The former has an advantage in that the first cost is low, whilst with the latter it is very high. Unfortunately, the life of the base metal couple at temperatures above 1,200 deg. C. is short, no matter what combination of protecting sheathes is used, that its use had to be subsequently abandoned.

Fig. 4 illustrates the rod finally designed with the rare-metal couple. Two of these rods were made fifteen months ago, and have been in daily use at temperatures ranging from 1,300 to 1,420 deg. C., with little or no change in the E.M.F. constants or depreciation in the value of the wire. The total upkeep has consisted of six new outer protecting sheathes.



A—Pt. + Pt. — 10 per cent. Rd. couple, both wires covered with silica beads. B, Screwed joint. C, Clay luting. D, Inside silica tube—one wire only covered with beads. E, Salamander tube.

FIG. 4.—RARE-METAL COUPLE AS FINALLY DESIGNED FOR ESTIMATING THE TEMPERATURE OF MOLTEN CAST IRON.

Warming the end of the rod over a coke fire or gas burner before immersing in the molten metal, although not essential, reduces the lag to under five minutes, and prolongs the life of the refractory protecting sheath. On withdrawing from the ladle of molten metal, adhering slag should be carefully removed and the rod stored in a warm place.

A mixture consisting of 5 parts china clay, 1 part alundum cement, and 4 parts graphite, made up to a cream consistency with a 5 per cent. aqueous solution of 70 deg. Twaddel sodium silicate, applied to end of the rod after use, materially prolongs the life of the refractory sheath.

By the aid of this pyrometer it has been possible to investigate many of the peculiarities of the cupola, standardise melting operations and control the casting temperature to a high degree of accuracy.

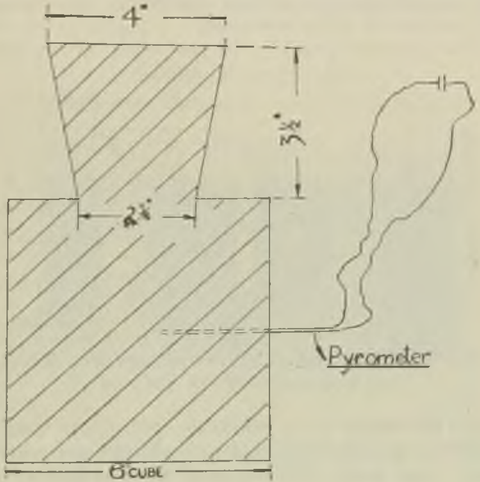


FIG. 5.—6-IN. CUBE USED FOR TEMPERATURE TESTS.

Casting Temperature v. Composition.

The effect of casting temperature was first demonstrated with crucible-melted cast iron by Longmuir in 1903. Since this investigation the importance of correct casting temperature has been recognised, although the author is not aware of any efforts to correlate casting temperature with composition.

The necessity of this may be gleaned from Table I., which sets forth the temperatures of incipient and final solidification of the irons commonly made in the cupola. These temperatures were obtained by means of platinum and platinum-rhodium thermo-couple cast just off the centre of a 6-in. cube made in dry sand, Fig. 5.

Whilst it is not possible to consider in this Paper all the factors governing the selection of the range of temperature within which any particular casting must be poured to obtain the best results, it is clearly evident that each iron must be considered on its own merits if any measure of success is to be obtained.

For general practice 10 per cent. of superheat may be taken as a working figure for castings made to specified physical test which must machine with clean faces. This means for hard irons containing a normal total carbon content, 1.0 per cent. Si. and low in P., the casting temperature should be round about 1,370 deg. C. In the presence of 1.5 per cent. P. incipient solidification falls 22 deg. C., so that the casting temperature is reduced to 1,343 deg. C. Iron No. 3, suitable for the manufacture of high-grade cylinders and cylinder liners and for castings to withstand superheated steam, casting temperature is 1,355 deg. C. For ordinary cylinder irons containing 1.5 per cent. Si and 0.50 per cent. P., 1,331 deg. C. A. 2 per cent. Si, iron low in P.* commences to

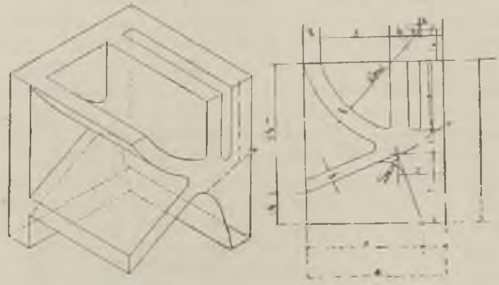


FIG. 6.—A CASTING MADE TO SHOW THE EFFECT OF COMPOSITION ON SOLIDITY.

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* Coe-Journal Iron and Steel Institute, 1913.

solidify at 1,212 deg. C., which brings the casting temperature to 1,333 deg. C. In the presence of 0.8 to 1.0 per cent. P. incipient solidification falls 47 deg. C., so that the casting temperature is correspondingly lowered; whilst for a soft-iron, high in silicon and phosphorus, it is 1,276 deg. C.

These figures, whilst amply demonstrating the correlation of composition and casting temperature, are by no means arbitrary. They are, in fact, only of practical value if considered alongside with the physical attributes of the irons melted, the range of temperature through which they solidify, mass effect and requirements of the finished casting.

Solidity of Cast Iron.

Grey cast iron does not possess true solidity as is understood to exist in pure alloys. The degree of solidity is a direct function of the quantity and form of the graphite present, everything else being equal. The quantity and form of the graphite being determined by chemical composition, cooling temperature, and the rate of cooling during solidification, solidity is a property under direct control. It is, of course, admitted that peculiarities are met with in the cupola-melted cast iron which are not easily explained; these, however, are the exception rather than the rule.

Fig. 7.—The First was Poured in at 1,370 and the Second at 1,280 Deg. C.

To exemplify the effect of composition on solidity in a practical way, a series of castings were made of the form shown by Fig. 6. This casting represents one of the most complicated sections with which the foundryman has to contend; one that is a constant source of trouble in all classes of cylinder castings, through porosity.

The castings were purposely made with the heavy section at the bottom and without risers.

The method of melting, casting temperature, head of metal, initial temperature of mould, etc., were carefully controlled throughout the experiments in order to eliminate as far as possible all variables except chemical composition.

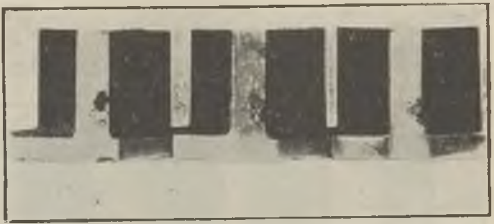


FIG. 8.—THE MIDDLE CASTING HAS SIMILAR COMPOSITION TO FIG. 7, BUT 0.25 PER CENT. MO. HAS BEEN ADDED. AT THE RIGHT HAND IS A HIGH SI AND P. IRON CASTING.

Each casting was sectioned through AB the position of drawing according to the isothermal lines of casting.

Nos. 1 and 2, Fig. 7, depict the drawing which has occurred with an ordinary soft grey iron of the following chemical composition:—TC., 3.27; Si., 2.20; Mn., 0.72; P., 0.91; and S., 0.096; an iron commonly used on account of its apparent non-shrinking qualities. Each was cast from the same ladle of metal, No. 1 being poured hot at a temperature of 1,370 deg. C., and No. 2 poured cold, 1,280 deg. C. No. 2, Fig. 8, represents a casting made from the same alloy to which 0.25 per cent. Mo. has been added, the casting temperature being 1,360 deg. C. This experiment suggests that molybdenum minimises the drawing defect common to ordinary soft grey iron, whilst No. 3 shows the result obtained with a high Si-high P iron of the following chemical composition: C.c., 0.50; Gr., 2.84; Si, 2.50; Mn, 0.56; P, 1.83; and S, 0.046; and although an improvement on No. 2, it is by no means solid. These experiments were confirmed and various grades of other soft irons tried, but with no better results.

Fig. 9 shows the results obtained from the harder series of irons. The chemical composition ot each is given in Table II. :—

Table II.—*Showing Compositions of the Castings Shown in Fig.* 9.

	c.c.	Gr.	Si.	Mn.	P.	S.	Mo.
1. ..	0.43	2.98	2.41	0.60	0.90	0.072	—
2. ..	0.63	2.86	1.25	0.68	0.20	0.089	—
3. ..	0.79	2.72	1.1	0.68	0.53	0.085	0.25

A material all-round improvement is evident, whilst No. 2 (Fig. 9), a low Si, low P iron, leaves little to be desired, the casting possessing a uniform solidity throughout.

Fig. 9.—Showing the Results Obtained from Harder Irons. (See Table II.)

The results of these experiments are contrary to what one would have expected from the ordinary accepted theories of the effect of silicon and phosphorus on the volume changes of cast iron during solidification, but they clearly demonstrate the effect of these two elements on solidity. These experiments are confirmed by the results of the K test bars, which have been made daily in the foundry over a period of years.

Effect of Mass on Solidity.

In the first series of experiments conducted on mass effect, a set of 6-in. cubes were cast in the irons shown in Table III.

TABLE III.—*Compositions Utilised for Showing Mass Effect.*

	c.c.	Gr.	Si.	Mn.	P.	S.
1. ..	0.55	2.83	2.3	0.60	0.78	0.063
2. ..	0.24	2.88	2.49	0.52	1.28	0.050
3. ..	0.66	2.74	1.20	0.63	0.09	0.066
4A. ..	0.73	2.15	1.47	0.55	0.50	0.096
5. ..	0.60	2.67	1.15	0.62	1.54	0.083

Each was poured with 10 per cent. superheat into dry-sand moulds, the initial temperature being controlled at 110 deg. F. (43 deg. C.).

Fig 10 illustrates each cube after sectioning vertically through the middle.

In principle, these experiments confirm the results obtained from the draw test experiments and are self-explanatory of relation between chemical composition and mass so far as solidity is concerned. It will be observed that alloy No. 3 containing 1.2 per cent. Si and 0.09 per cent. P. is equally solid throughout.

According to Turner ordinary grey iron expands on solidification, the higher the silicon and the phosphorus content the greater the expansion and the wider the range of temperature through which it operates. What do Turner's expansion figures mean? Do they infer that grey cast iron does not shrink during solidification? If so, why did the high-silicon irons in the draw test bars shrink at the thicker portions, which shrink hole or spongy place is nothing more nor less than a pipe due to there being no residual liquid left to fill the interstices of the primary skeleton arms of the crystals, a defect all too common in iron castings. Again, why did the low Si and low P. iron, pipe the least in the 6-in. blocks? Surely the experiments conducted by Turner on the volume or rather linear changes with the T. test bar do not in any way represent the effect of the elements quoted on the volume changes of cast iron on solidification.

An important factor controlling liquid shrinkage and one which the author has not been able to associate with chemical composition is the "Time taken during solidification," it being well known that the more rapidly molten iron solidifies the lower the liquid shrinkage and the higher the degree of solidity throughout.

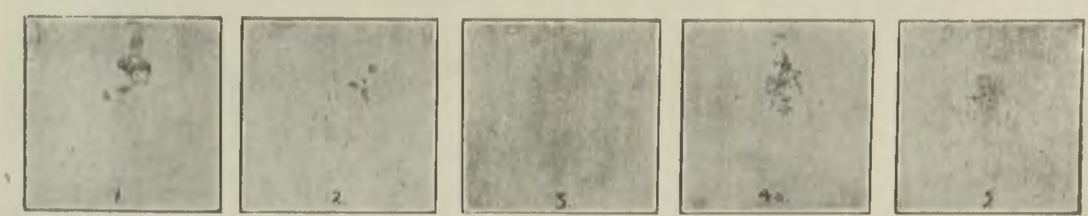


FIG. 10.—SHOWING 6-IN. CUBES OF VARIOUS COMPOSITIONS AFTER VERTICALLY SECTIONING.

Effect of Rate of Cooling on Solidity.

Fig. 11 represents three 6-in. blocks cast under identical conditions from the same ladle of metal, showing on analysis C. 3.28, Si 2.34, Mn 0.45, P 0.81, and S 0.066. No. 1 was cast into an exceptionally hard-rammed dry-sand mould having a temperature of 150 deg. F.; No. 2 in green-sand mould containing 6.78 per cent. H_2O at 70 deg. F. (21 deg. C.); and No. 3 in a sand mould lined with 1-in. steel plate at a temperature of 150 deg. F. (65 deg. C.).

These photographs typically portray the effect of "rate of cooling during solidification" on solidity of castings of large bulk. The explanation commonly accepted for this peculiar phenomenon is that the rigidity of the chill mould reverses the direction of the natural expansion of high silicon and high phosphorus irons whilst sand moulds give to it.

There are three poignant factors against this hypothesis :—

1. The volume change of hard grey irons with 1.3 to 1.5 per cent. Si, 0.30 to 0.70 per cent. P cast with the same degree of superheat is practically the same as that of soft grey irons, of from 2 to 3 per cent. Si and of high or low P content, so far as piping is concerned.

2. That all irons cast in green-sand moulds, which moulds possess an exceptionally low crushing strength, pipe less than dry-sand or loam-moulds which possess high crushing strength.

3. That the effect of temperature is more pronounced than chemical composition, *e.g.*, all irons pipe or draw if the metal is on the dull side, no matter the rigidity, temperature or form of the mould.

Solid Shrinkage.

By this is understood the contraction in cooling from immediate solidification to room temperature. During this period ordinary cast iron suffers from two stages of heat fragility, the one, at a comparatively high temperature when some liquid phase exists, the other at a low temperature ranging between 370 to 520 deg. F. (177 to 261 deg. C.).

If solidification of a casting be allowed to pro-

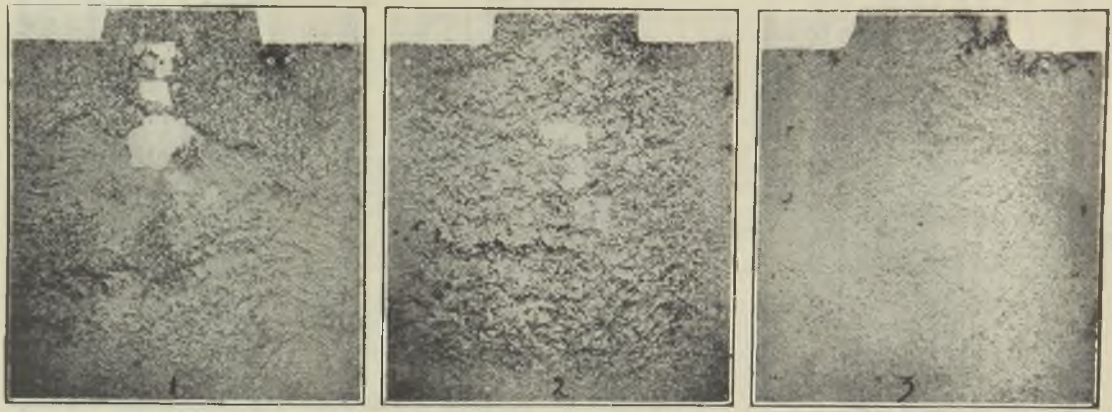


Fig. 11.—These are all Cast from the Same Ladle. No. 1 is Dry-Sand Moulded, No. 2 Green-Sand Moulded, and No. 3 Chilled by Denseners.

ceed uninterrupted little trouble is encountered with the high temperature fragility owing to the stretching capacity of cast-iron at these temperatures. In fact, this power to stretch is such that almost any iron casting may be made with rigid chills without any fear of cracking. On further cooling this stretch property falls and reaches a minimum at approximately 500 deg. F., the temperature at which cast iron suffers an appreciable loss in strength. This is shown graphically by Fig. 12. A represents an ordinary cylinder iron, B a 2 per cent. Si—low-P iron, and C, a high-Si—high-P iron.

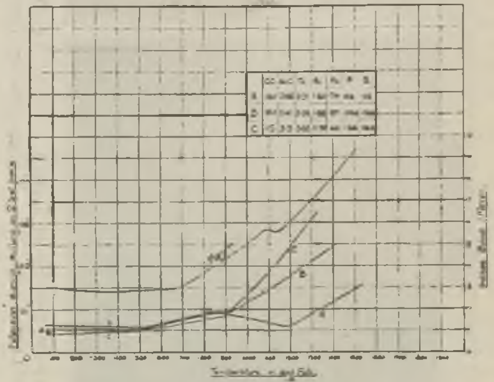


Fig. 12.—Shows the Extension found on Pulling 2-in. Test-Pieces at Various Temperatures.

From these curves it is obvious that although silicon and phosphorus do not affect the heat fragility of cast iron, as will be shown later, they have an appreciable influence on the extensibility (hot), and render the use of permanent cores as a practical proposition.

To demonstrate this in a more practical way a series of double "T" castings were made, fixing cast-iron bars 2-in. × 1½-in. section, in the mould, as shown by Fig. 13.

Table IV. shows the composition irons used, each of which were cast with 10 per cent. superheat.

TABLE IV.—*Composition of Irons Used to Demonstrate Peat Fragility.*

	C.C.	Gr.	Si.	Mn.	P.	S.
1 ..	0.65	2.60	1.43	0.72	0.42	0.108
2 ..	0.58	2.59	2.00	0.70	0.10	0.092
3 ..	0.46	2.78	2.00	0.60	0.80	0.092
4 ..	0.52	2.62	2.59	0.67	1.75	0.046

Alloy No. 1.—This was cupola melted, and in the first experiment it was cast in green-sand mould, and allowed to cool undisturbed, when it broke at 500 deg. F. (260 deg. C.).

In the second experiment it was again cast in a green-sand mould, but iron restricting-supports were removed at 1,100 deg. F. (590 deg. C.), and the casting allowed to cool slowly in a gas-heated muffle. This gave a sound casting.

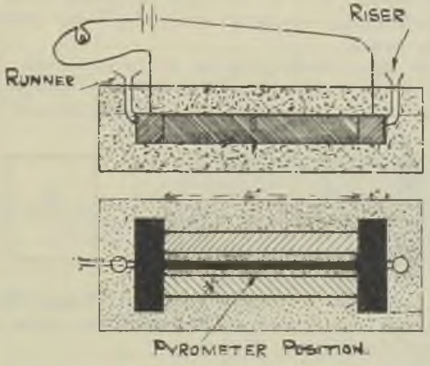


FIG. 13.—FORM OF MOULD USED TO DEMONSTRATE THE USE OF PERMANENT CORES.

Alloy No. 2.—In this case it was cast in a warm, dry-sand mould (150 deg. F.), and was allowed to cool undisturbed. It broke at approximately 530 deg. F. (275 deg. C.).

Alloy No. 3.—For the first experiment it was cast in green sand and allowed to cool undisturbed, when it broke at 570 deg. F. (290 deg. C.).

In the second test it was cast in warm, dry-sand mould, and allowed to cool undisturbed. This time it broke at 520 deg. F. (270 deg. C.).

The third test was carried out in a green sand, provided with iron restricting-supports which were removed at about 1,400 deg. F. (760 deg. C.), and the casting allowed to cool in the open, and it gave a sound casting.

The last experiment was cast in a warm, dry sand (70 deg. C.), in which the restricting supports were left in position, but was cooled slowly between two heavy iron blocks from 1,300 deg. F. (705 deg. C.). This, too, gave a sound casting.

Alloy No. 4.—Two experiments were made with this alloy, both giving sound castings. The first was cast in warm- dry-sand mould at 48 deg. C., and the restricting supports were left in position. In the second test it was cast in green sand and the restricting supports were left in position. Casting sound.

These experiments require little comment. They clearly indicate the relation between composition and casting strains in castings of complicated form and incidentally demonstrate that cracking in iron castings may be avoided by :—

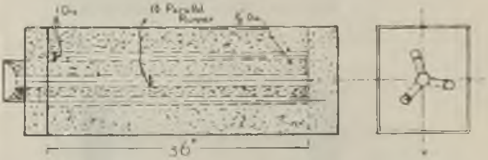


Fig. 14.—Mould used for Casting Three Test Pieces controlling Temperature both of the Mould and Metal.

(1) Releasing or removing restricting cores whilst the casting is at a dull red heat.

(2) By retarding the rate of cooling during the blue brittle range of temperature to a rate of approximately 10 deg. C. per hour.

(3) By accelerating cooling of heavier sections or retarding cooling of lighter sections, if conditions do not permit the selection of an iron of high-stretching capacity in the first place.

Effect of Composition on the Strength of Hot Cast Iron.

One naturally hesitates in showing any data concerning the effect of any single variable on the physical properties of cast iron, it being always problematic as to whether it is the effect of that variable or one of the many that inevitably creep in owing to the complications involved. At the best the results obtained from any investigation on cast iron can only be comparative. Particularly does this apply to the tensile test which is controlled primarily by the form of the graphite carbon.

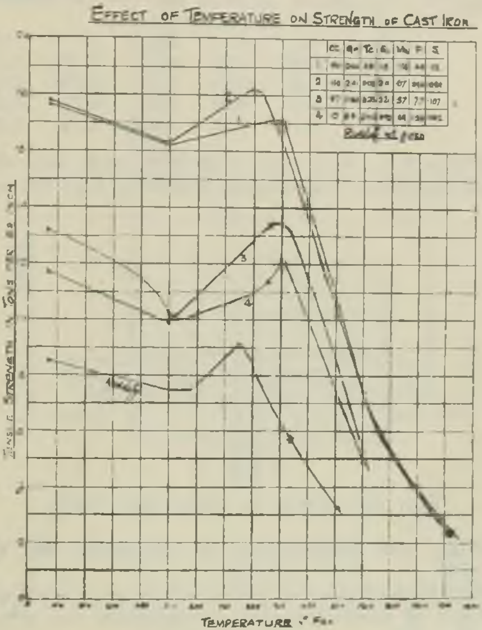


FIG. 16.—SHOWING THE EFFECT OF TEMPERATURE ON THE STRENGTH OF CAST IRON.

Again, owing to rapid deterioration of cast iron by heat and the lack of knowledge of the mechanism of this deterioration, the problem of temperature effect as associated with the chemical composition of the various grades of irons now made is peculiarly difficult, and one feels very reluctant to express any views on the subject at all.

At the same time there exists a long-felt want for some reliable working knowledge of the behavious of cast iron under conditions where well-known phenomena do not enter into consideration, and it is because of this that these experiments have been carried out. The irons selected are shown in Table V.

TABLE V.—*Composition of Iron Used for Mechanically Testing at Elevated Temperatures.*

	c.c.	Gr.	Si.	Mn.	P.	S.
1. ..	0.60	2.66	1.50	0.74	0.49	0.112
2. ..	0.60	2.41	2.00	0.57	0.096	0.089
3. ..	0.37	2.88	2.24	0.67	0.77	0.107
4. ..	0.15	3.5	2.92	0.49	1.26	0.620

Three 1-in. bars were cast from each into dry-sand moulds in the manner shown by Fig. 14, controlling both temperature of the metal and the mould.

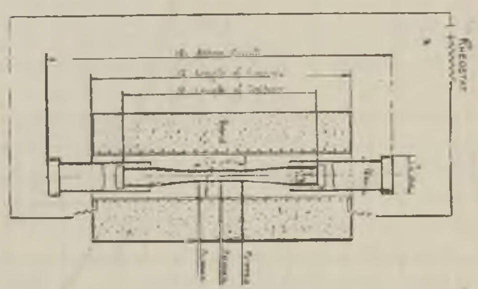


FIG. 15.—FORM OF TEST-PIECE USED.

The form of the test piece, the furnace used, and method of measuring the temperature are shown by Fig. 15.

Each test piece was heated to the specified temperature as quickly as possible, and retained at that temperature for exactly 1 hour before breaking.

The temperatures chosen were 70, 400, 500, 800, 860, 900, 1,200 and 1,530 deg. F. The lower temperatures 400-500 deg. F., to determine the loss in strength at the second period of heat fragility, the temperatures of 860 and 900 deg. F. were selected because of the distinct halt found in the

Table VI.—*The Tensile Strength of Cast Iron at Increasing Temperatures.*

	Tensile ton per square inch.							
Mark.	Room temp. 70°F.	400°F.	500°F.	800°F.	860°F.	900°F.	1,200°F	1,530°F.
1	17.75	16.5	16.2	—	—	17.1	7.00	2.44
2	17.8	—	16.3	18.2	—	15.8	6.9	2.41
3	13.2	11.5	10.2	—	13.6	—	5.2	—
4	12.0	—	9.9	—	11.2	12.4	4.96	—

cooling curve of the cast iron at about these temperatures; 1,200-1,530 deg. F. were chosen because of the remarkable ductility of cast iron when heated to a dull red.

The results of experiments are given in Table VI., and shown graphically by Fig. 16, together with the curve plotted from the figures published by Rudeloff.

It will be observed that there is a striking similarity between each iron whether a soft or high tenacity grade, or whether high or low in phosphorus, the strength falling from 200 to 500 deg. F., and rising to a maximum between 800-900 deg. F. Above 900 deg. F. the strength rapidly falls away, and is under 2½ tons sq. in. at 1,530 deg. F. (832 deg. C.), *i.e.*, between the carbide and phosphide change points even in the strongest and toughest irons.

These experiments, whilst by no means complete, enable a better understanding of the effect of temperature on the strength of cast irons. They show off the limitation of this material for internal combustion engine parts where high temperatures are encountered unless provided with a suitable arrangement for the dissipation of that heat. They explain the irregular behaviour of cast iron when used for press tool and die work, and the breaking down of furnace castings, firepans, stove grates, kiln-stirrer blades and ingot moulds. Together with a knowledge of the stretching capacity of cast iron they enable the designer and foundryman to predict the distribution and magnitude of the stress in a casting of complicated form, and furnish a working knowledge of the strength of any portion of a casting at the various stages during cooling in the mould, thereby enabling the necessary precautions to be taken in selecting the right time to release either mould or cores, and when to remove chills without endangering the casting in any way.

Sheffield Branch.

MECHANICAL PROPERTIES OF METAL.

By F. C. A. H. Lantsbury, M.Sc., F.I.C.

At the sixth meeting of the session Mr. F. C. A. H. Lantsbury, M.Sc., F.I.C., gave a lecture on "The Mechanical Properties of Metals." This was a joint meeting with the Society of Engineers and Metallurgists and the Institute of Metals.

Dealing first with mechanical tests, Mr. Lantsbury said this was the group of tests which was of the greatest interest to mechanical engineers, because, after all, the utility of all engineering structures was dependent almost wholly on their abilities to resist the action of stress. All engineers were familiar with the operations of making simple mechanical tests in tension, torsion, shear, compression and bending, with the object of obtaining values for the breakdown strengths and ductilities under these types of stress. The first point was the method involved in weighing the forces used in testing. Generally, this was effected by means of a jockey weight, which could be caused to move along the graduated lever of a steelyard, which lever might be simple or compound. This method of measurement was subject to a disadvantage which might give rise to serious discrepancies in the results obtained as a result of the inertia of the jockey weight. There was a very grave danger indeed that this defect might set up momentarily stresses in the test specimen which were greatly in excess of those recorded in the machine and give rise to results which were entirely misleading. This danger could be entirely eliminated by taking advantage of the hydraulic method of weighing largely developed by Martens. English testing machine makers had not taken the advantage they might have of this method of load measurement, but the Emery machine (U.S.A.) and the Amsler (Swiss) machine were excellent examples of the use of this principle.

For comparison it was important to use geometrically similar test pieces and conform to British standard specifications. The second point in the making of static tests was the extreme importance of true axial loading. A slight degree of eccentricity in loading was sufficient to give erroneous results, and this was particularly liable to occur during the use of wedge grips. Endeavours were made to obviate or minimise this trouble by the use of spherically seated grips, but even this precaution was not wholly sufficient to eliminate entirely the trouble. Quite early in the history of mechanical testing it was discovered that in actual use metals ultimately broke under stresses far lower than the maximum stress determined by the simple tensile test. This was first proved experimentally by the English engineer Fairburn, and his work was extended by the experiments of the German investigator Wöhler, whose results were published in 1871. As a result of this work it became generally recognised that neither the maximum stress nor the yield stress were any guide to the life of a material under repeated stresses. The object of his lecture was rather to consider results in a general way than to give details of the actual test. But reference to some of the outstanding tests must be made in order to get an adequate idea of results. Wöhler's test consisted in gripping the specimen in a rotating chuck suspending a weight from the free end.

The specimen was thus subjected to alternate bending stresses, the determination of which was a matter of simple calculation. The results were expressed as number of alternations to produce fracture under the outside fibre stresses involved. Although this was the oldest of the dynamic stress tests, it was still one of the simplest and best. As ordinarily carried out, it suffered from the defect that after the test had been running for some time the freely suspended weight acquired a certain periodicity of up-and-down movement, which made the fibre stresses of uncertain quantity. This defect could be removed by substituting for the suspended weight a fixture which could bend the specimen by a certain known amount and holding it rigidly in this position. Under these conditions there could be no question of periodicity. One of the objections which had been advanced against the Wohler test was that in the bending test the maximum stresses existed at the surface of the specimen only. The principle of subjecting specimens to alternating uniformly-distributed stresses was introduced by Prof. Osborne Reynolds, and developed by Dr. Stanton at the National Physical Laboratory. A still later machine was that of Prof. Smith, of Belfast, who utilised the centrifugal force of rotating masses to set up the stress in the test piece, and at the same time utilised a powerful spring to alter the stress range. One of the difficulties with regard to the carrying out of alternating stress tests was that although the limits of stress variation were defined there was in the methods described no knowledge as to how the variation occurred between two limits. The difficulty had been successfully surmounted in the arrangement introduced by Haigh. One end of the specimen was fixed to the frame of the machine, while the other end was attached to an armature situated between two electric magnets excited alternately by alternating currents. In this way there was produced in the specimen a stress variation which must follow the sine wave of the E.M.F. of the exciting current.

Although engineers were more or less familiar with the methods of making static tests, they were either ignorant of or showed remarkable contempt for the correct description of the tests. The terms stress and strain were more frequently misused than quoted properly, and before passing on to a consideration of the methods devised for the study of the elastic state of material it was necessary to have a clear conception as to the exact meanings of stress and strain. When a material was subjected to the action of a load or force it was said to be under stress, and stress was measured as load per unit area. The action of stress was to cause or tend to cause deformation or alteration in dimensions, and the alteration in dimensions of unit material was known as the strain. To speak, therefore, of a strain of so many tons or pounds per square inch was absurd.

It was the behaviour of the material in the elastic region which was of the greatest interest to the engineer, because the results of dynamic testing, which had been highly developed during the last few years, had proved conclusively that any stress in excess of the yield stress would ultimately lead to fracture. There was a general notion that the determination of the elastic properties were too difficult for commercial purposes, but since the ordinary commercial tests did not provide sufficient information to the engineer, there was no doubt that in time determinations of elastic constants would have to be made in lieu of the many imitative tests which had been introduced.

Mr. Lantsbury referred to a number of extensometers and the methods of using them, and remarked that in making the ordinary tensile tests all who had had experience of testing had observed that with materials like mild steel there was a distinct drop of the beam when the yield load was attained, whilst with other materials, like copper, no such drop of the beam occurred.

The lecturer referred to a number of tests which he described as obviously of great importance. When the results had been further studied, so that their real physical meanings could be thoroughly understood, they would undoubtedly have a great influence on the future of mechanical testing. At present the results obtained were bringing the tensile test to their notice, and only when they were thoroughly understood would the full value of this test be realised. If a specimen was stressed beyond its yield point and the stress removed they knew that one of the effects was permanent deformation, but another and more interesting effect had been produced. On immediate reloading, observations with the extensometer showed that the material began to yield immediately. In other words, its elastic limit was zero. But if the specimen was kept for a period of 24 hours or heated in boiling water for half an hour before re-testing, it was found that the elastic limit was raised to a point only just below the stress to which the material had previously been subjected. This process could be repeated until the elastic limit was practically coincident with the maximum stress of the material. The effect of mechanical work in "improving" the mechanical properties of a metal were, of course, well known in practice, and was made use of in the operation of cold rolling. They saw, therefore, that the determination of the elastic limit of a material was extremely liable to give misleading results if their object was to get an idea of the true properties of the material itself. Proceeding further with the inquiry, it was found that a specimen which had had its elastic limit increased by tensile work had had its elastic limit in compression lowered. Similarly, compressive work increased the elastic limit in compression and at the same time lowered the tensile elastic limit, and in every case the decrease in one value was equal to the increase in the other value. Or, in other words, the range of stress over which a material behaved elastically was constant for that particular material. Now the limiting range of stress for which a material would resist an infinite number of reversals was independent of small variations of the mean stress, and Stanton and Bairstow had shown that the true or natural elastic limit of a metal was equal to half the limiting range of stress, while the very essence of Bauschinger's theory of breakdown was that in its natural state the compression and tensile elastic limits of a metal were equal in value. The value of the elastic limit determined in the ordinary way had been callel the "primitive" elastic limit to distinguish it from the "natural" elastic limit determined by alternating stress tests. It would be observed that in every case the true elastic limits were lower than those determined by the ordinary static method, and this was, of course, of the utmost value to the designer.

But there was still a great deal of knowledge to be gained with regard to endurance tests, and in view of the enormous amount of time necessary for obtaining the results, endeavours had been made to find the limiting ranges in shorter time. The subject of hardness testing was one of extreme importance to the engineer, and yet it was of great difficulty, because of the confusion of ideas which existed as to the meaning of hardness. The mineralogical definition of hardness was resistance to abrasion, but even this is not a single property, but a combination of a number of properties. Therein lay the difficulty with regard to the subject of hardness, in that up to the present time the methods which had been introduced did not measure any particular property but a combination of properties, and the influence of each of the properties was different in each test. Nevertheless, the methods which had been introduced had undoubtedly been of great practical value in enabling the metallurgist and engineer to get greater uniformity of product. His work led him strongly to believe that there was a definite property of metal which would ultimately be recognised as true hardness. At the present time, however, the whole of their ideas on this subject were in the melting pot, and the work and discussions going on at the present time would consolidate and focus their ideas on the subject. At the present time three methods were in vogue for testing hardness, the method chosen depending upon the material to be tested and the knowledge required. These methods might be described as (1) scratch tests, (2) penetration tests, (3) abrasion or wearing tests.

So far, said Mr. Lantsbury, in conclusion, purely physical tests did not interest the mechanical engineer so much as the electrical engineer, but there were indications that in the very near future magnetic testing would be used very largely in testing, because there was undoubtedy a close relationship between the magnetic and mechanical properties of steels. There never was a time when the testing of metals was of such great importance to the engineering industry, and an adequate system of testing would only be realised by thorough discussion of the available methods and their indications by the engineer and physical metallurgists.

DISCUSSION.

Mr. Turner thanked Mr. Lantsbury for his lecture, and said that when they saw all the thought and energy that had been expended upon testing machines they realised that there was a good deal more than they thought in the production of models for ordinary serviceable use.

Mr. J. R. Hyde remarked that Mr. Lantsbury had offered a very clear explanation of many of the terms and machines of which they read and heard, but with which, in the foundryman's business, they did not actually get in touch. They could quite imagine that when engineers had tried most methods of testing steel and non-ferrous castings and found them wanting, they might turn to some of these more elaborate machines and see if they would help them still further. They laboured under a great disadvantage, for when they had cast their mould nobody seemed to have very much confidence in it, and it would be by careful investigation and with the clear guidance of such gentlemen as Mr. Lantsbury that they would possibly be enabled to improve their product. The many workers he had mentioned did not, of course, include all of them, because they had seen from time to time in Sheffield other machines to which Mr. Lantsbury had not referred. He would like to know whether the ones mentioned represented the most reliable and what might be called the standard machines of 1922. He was much more familiar with these things 10 years ago, and many that he knew then seemed to have entirely disappeared. Mr. Hyde went on to say that he was very much indebted for the stress-strain diagram and the description of the two terms. It was surprising how indistinct many of the leading chemists were when they were using the words stress and strain. Sometimes it seemed as though every man was a law unto himself, and until one got used to him it was extremely difficult to understand what he really meant.

Mr. J. Watson said the lecture had been particularly interesting to men like himself who were engaged in the foundry. They saw the test piece cut off from the casting, and knew nothing about it until they got the report. Very often they never saw the machines that broke it or the test piece afterwards.

A resolution of thanks was accorded Mr. Lantsbury for his lecture.

London Branch.

THE MAKING OF CASTINGS WITHOUT FEEDING HEADS.

By E. Ronceray, M.I.Mech.E.

An article which the author published in "La Fonderie Moderne" a little more than a year ago on "Castings Without Feeding Heads" has raised great interest in this country.

The translation appeared in abstracts in The Foundry Trade Journal, which raised discussions, some of which were getting rather controversial and to which the author finally discontinued to reply, thinking that correspondence of such a nature could not lead to any improvement in understanding. Some of the branches of the Institution of British Foundrymen have discussed the article, which proves the intense interest British foundrymen took in the subject, and the author has been frequently informed that many foundrymen have made more or less elaborate experiments to confirm or reject the results dealt with.

It is a generally accepted fact that metals, in solidifying, decrease in volume. The best authors accept this fact, and have demonstrated and built on it cooling theories, concluding that in the centre of a cooling metallic mass there must be a cavity.

It may be that this theory holds good for very large masses, but in most of the cases observed in foundry practice the cavities found in castings may be attributed to other causes which a better practice is likely to suppress.

In order to obtain sound castings it is common practice to put on the top of higher parts of them heavy feeding heads, and eventually to use the well-known action of pumping for adding new metal. It is not uncommon to find under feeding heads cavities and porosities. The empiricism of this method does not satisfy progressive men, and the author has some hope that if such men are willing to observe and experiment on the lines that will be outlined, there will be in the near future new laws governing the solidification of metal and the escape of mould-gas. which will result in considerable improvement, not only in foundry practice but also in other industries, for example, in ingot pouring.

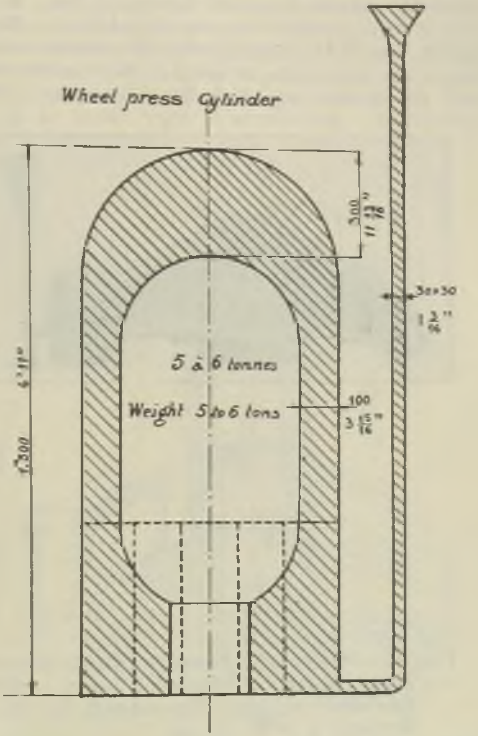


FIG. 1.—CYLINDER BOTTOM-CAST WITH THE HEAVY PART UPPERMOST BY MEANS OF SMALL RUNNERS.

The Origin of the System.

For the first time, a short history will be given of the way that the pouring of castings without feeding heads was originated. This will enable the author not to seem to usurp any longer a paternity which does not belong to him, and to put in its right place a great foundryman, Mr. E. Saillot, one of the managers at the author's works, who is the originator of most of the improvements that the author has had the honour to present during these past twenty years to the foundry world. Mr. Saillot is a man of perspicacity and observation—talents seldom developed in human beings, possessing as well an instinctive genius for engineering and foundry work.

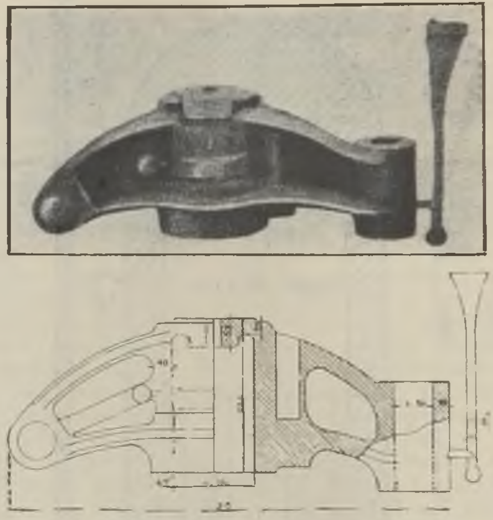


Fig. 2.—Moulding Machine Cross-Head. The Casting Weighs 3 cwt., the Runners 8 lbs. The Area of the Runner is 9/16 in. sq.

In about 1886 the foundry of the Western Railway Company of France was engaged in making white-metal brasses for carriage axle-boxes. In experimenting with various ways of pouring them it was found that for some reason, of little weight for the question under discussion, better results could be obtained with a small metal head than with heavy risers. This gave the idea to make tests on gun-metal railway castings in order to reduce feeding heads and risers. Step by step the reduction in bulk took place and pumping was done away with. However, risers plugged by sand still were used, and the runners, though not so large as usual, were of ample size. This went on for a few years.

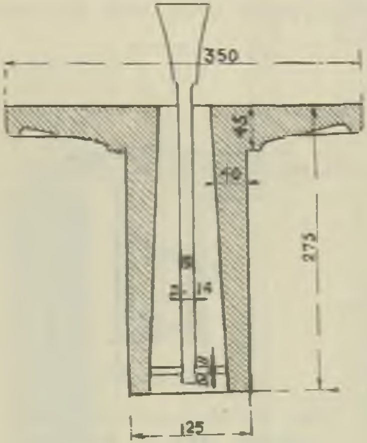


Fig. 3.—Moulding Machine Ramming Plate. Weight 81 lbs. Weight of Runner $2\frac{3}{4}$ lbs. Dia. of Vertical Runner 9/16 in. Dia. of Horizontal Runners 5/16 in.

One day, passing through the foundry while a Webb gun-metal locomotive safety-valve body weighing about 2 cwts. was being poured, Mr. Saillot, who was manager of the works, saw the men on the point of stopping pouring as the metal did not fill the mould as quickly as usual. One crucible was already poured, and a second one was ready. Mr. Saillot ordered it to be poured. There was not much risk. The mould was condemned and the metal could as well have been poured in it as in ingot moulds. Contrary to the usual practice, the riser plugs did not lift, and there remained in the pouring basin an amount of metal about equivalent to the volume of risers. A perfect casting was the result. It was found in fettling it that the runner was partly closed by a piece of slag which had fallen down from the crucible at the beginning of the pouring. The free section of clogged runner was about ½ in. sq.

Another mould was made without feeding heads, an ordinary pencil being used for making the runner. The result was perfect. The machining revealed no defect, and from this time these castings were made with runners of about ⅜ in. instead of ⅞ in. to 1 in. as before. The method was extended with success to locomotive slide-valves and axle-box bearings.

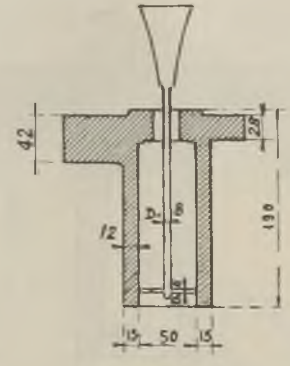


Fig. 4.—Moulding Machine 16 lbs. Dia. of Vertical Runner 5/16 in. Dia. of Horizontal Runners ¼ in.

Hot Pouring Essential

Machine moulding was becoming known at this time. Cliché tables were fitted with clichés where feeding heads, as used for hand moulding, were provided, and the moulds were poured on end.

During a whole month Mr. Saillot had the feeding heads put downwards. The loss was, if anything, less than before.

It must be mentioned that in this foundry moulds were dried and metal was very hot. Later on the adoption of an oil furnace gave trouble until it was found possible to get the same temperature as with clay crucible furnace. This hot

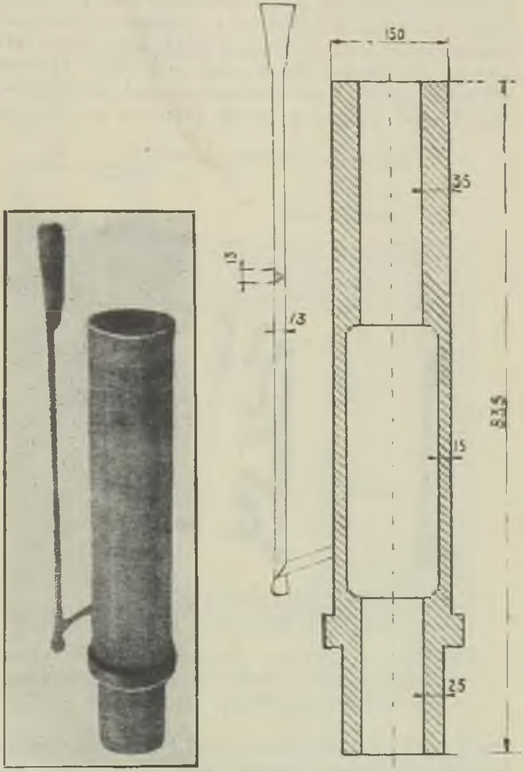


FIG. 5.—MOULDING MACHINE COLUMN. WEIGHT 117 LBS. WEIGHT OF RUNNERS 5 LBS. SECTION OF RUNNER ½ IN TRIANGLE.

pouring is most important, as it was proved in another case.

In the iron foundry of the same company brake blocks, oil boxes, and locomotive cylinders had always been poured without feeding heads—nobody knew why—but all other castings used to be made with heavy heads. The loco. cylinders were poured horizontally with a flow-off that was closed after having let pass 2 to 3 cwts. of iron. However, cylinder covers were poured on end with a large closed riser weighing about as much as the cover itself. The casting was sound, but in polishing it the metal looked darker near the riser, which can easily be explained by slower cooling at this place. No trouble was experienced by pouring this same casting on flat with a small gate in the centre and no riser.

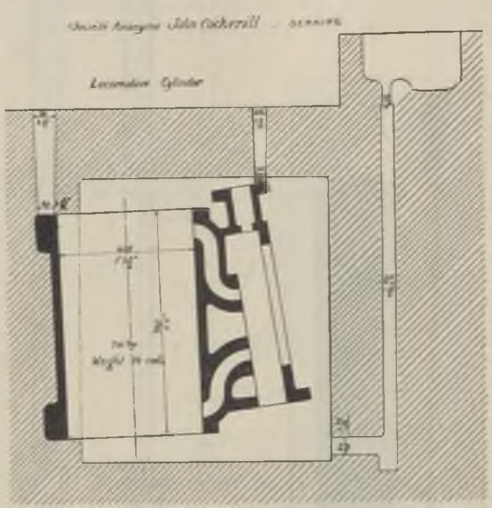


Fig. 6.—A 14-Cwt. Locomotive Cylinder Cast with a $1\frac{3}{8}$-in. Runner, Enlarged on Entering Mould to 1 15/16 in.

The resistance of staff and men to such methods increased when an order came for three wheel press cylinders, weighing from 5 to 6 tons. But

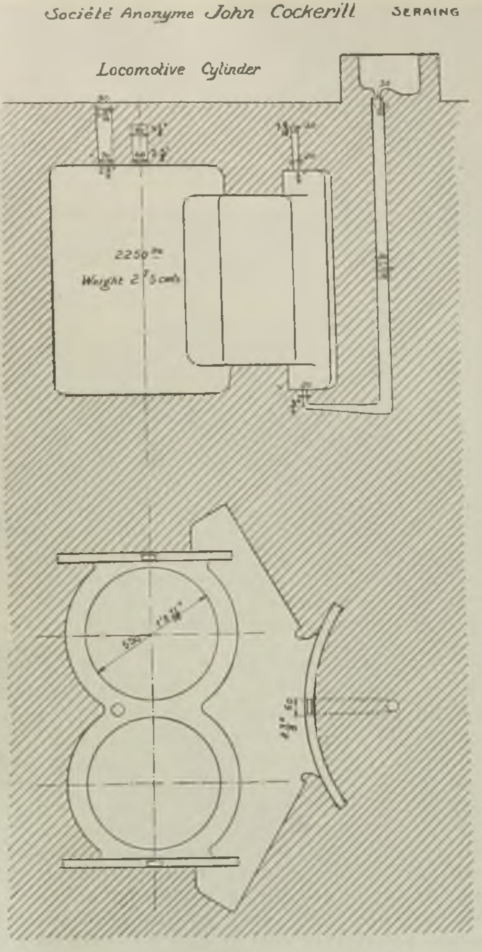


FIG. 7.—A 2-TON 5-CWT. LOCO. CYLINDER. CAST WITH 1 13/16 IN. RUNNER.

Mr. Saillot insisted, and the first one was poured, heavy part in top, as shown in Fig. 1. The runner was 40 × 40 m/m (about 1 9-16 in. sq.), and no risers or feeding heads were provided. The top came slightly flattened, but was put in regular service without any trouble. The two others were made same way, but with a runner only 30 × 30 m/m (1 3-16 in. sq.) and were perfect. Propellor screws of 9 ft. dia. were made similarly without trouble.

The author had frequent talks on such extraordinary facts with Mr Saillot, when for business we had opportunities of travelling together, but when in the office there was no time for such speculations, which, after all, were not directly related to the business of the firm.

At this time machine-moulding was principally confined to small castings which did not require feeding heads. Moreover, we had more or less to follow the customers' views as to the method of gating. We had not at this time obtained sufficient convincing power to impose our own views. The machine moulding was in its infancy, and as can be imagined, we had enough wheat to grind in our mill with what was related to direct opposition to new processes and not to divide our efforts in a side line and see the machine accused on account of all inside shop failures.

However, the opportunity arose during the war when it was necessary to make semi-steel shells with all speed. In order immediately to make shells on machines that were already installed in foundries, we devised a method of moulding on reversible split pattern-plates, and to pour them on end. We recommended doing away with feeding heads and to use for a 155 m/m (6 in.) shell weighing 1 cwt., a runner about ½ in. We, of course, met a considerable opposition from the War Office, and most foundrymen, but the scheme at last proved satisfactory. Had the moulds been dried no trouble whatever would have been experienced, but it was very advantageous to pour in green sand, and we strongly recommended it. Providing sufficient care was taken in sand-mixing and sand-ramming, perfect shells were obtained, and their cost was considerably reduced by the saving in handling coal and metal. However, in

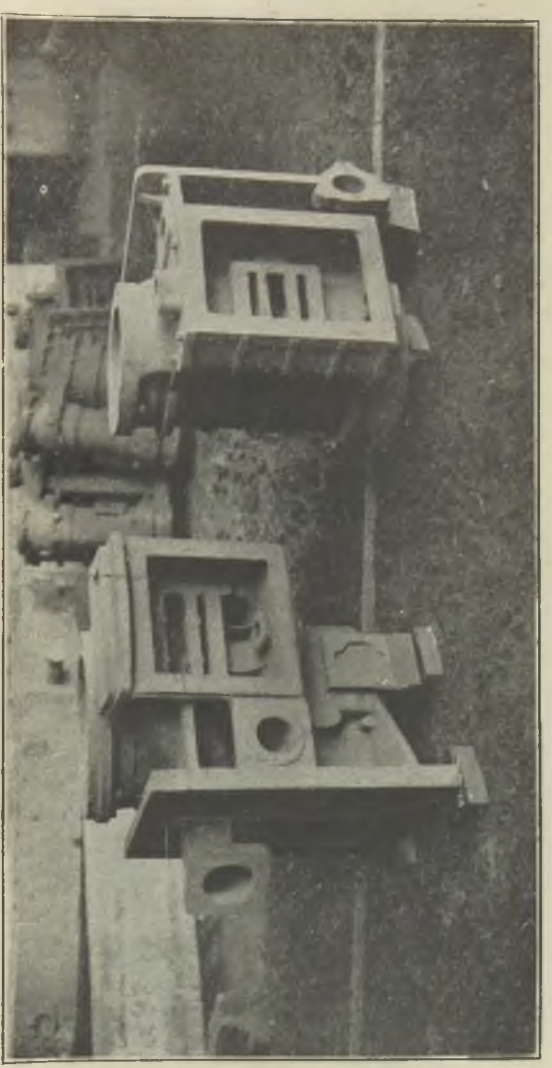


Fig. 8.—Loco. Cylinder Castings (14 cwt.), Made as is Shown in Fig. 6.

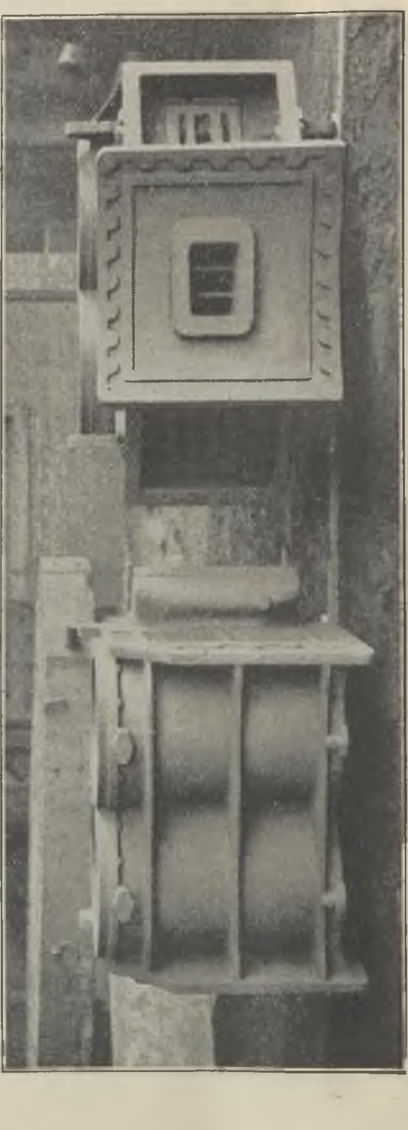


Fig. 9.—Loco. Cylinder Castings (2¼ Tons), Made by the Method Shown in Fig. 7.

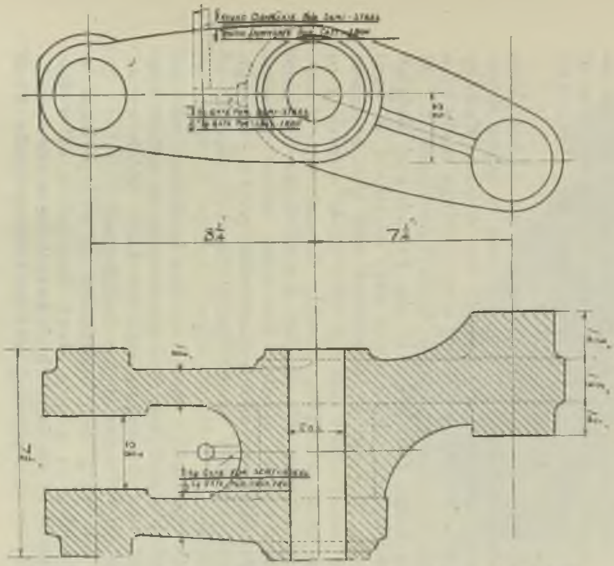


FIG. 10.—A SEMI-STEEL ROCKING LEVER. WEIGHT 1¼ CWTS. DIA. OF DOWN GATE ⅝ IN. AREA OF GATE ½ IN. SQ.

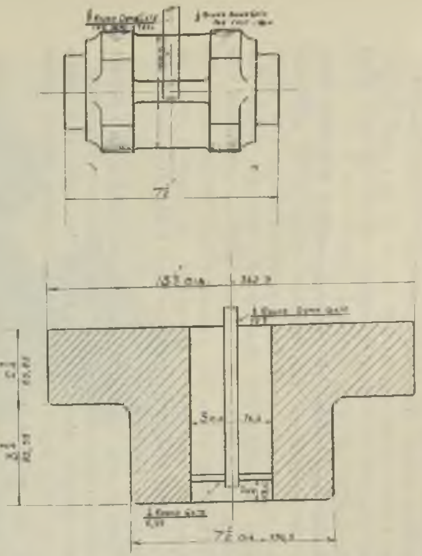


FIG. 13.—A FACE PLATE COUPLING WEIGHING 1 CWT. CAST WITH TWO ¼ DIA. RUNNERS.

the rush, this care was not always taken and troubles were thus experienced. Some foundrymen made shells up to 220 m/m (9 in.) and larger with success by this method, which proves that technically it was satisfactory.

Later on, when his demonstration foundry was put in operation the author tried with alternations of success and failure to produce the same results on different shapes of castings, with the view to determine the causes and obtain data for determining sizes of runners in proportion to weight of castings. However, it should not be considered that the author has fully succeeded to eliminate feeding in every case.

Then it was thought that in publishing the result of these experiments in "La Fonderie Moderne" other people could be induced to take the same course, and from combined experience obtain some increase in common knowledge.

The author wishes to emphasise that this system of slow pouring is not his invention; he has no desire to claim that it is his, though in spite of his efforts it is often called "Mr. Ronceray's System." It is not so.

Since investigating slow pouring it has been ascertained that it is partly used in many shops, though unsystematically. In the Western Railway Works Mr. Saillot found some castings made by a similar process, whilst he himself developed it. At the Liège Exhibition of the French and Belgian Associations, where visits were organised in local shops, the author discovered that loco cylinders and many other castings were made according to the same principles, possibly through some knowledge of what Mr. Saillot did at Gotteville some years before, possibly for some other reasons. Brunelli, years ago, recommended pouring through small runners about pencil size on the top of castings.

Consequently there is no invention on the author's part, but only an attempt to collect data and to find explanations for facts which are of the utmost interest for foundrymen.

This being well understood, it will perhaps be advisable to give a short description of a few samples of castings which have been made successfully by slow pouring and no feeding heads. First of all, the castings shown in the original article in "La Fonderie Moderne," which are shown in Figs. 2 to 5.

Some trouble is experienced with the castings shown in Figs. 2 and 3 when proper sand is not used for the cope; it is very liable to scabbing. Similar results are obtained by Brunelli runners used on top of casting.

The top of core, in Fig. 4, being heated inside and outside, is liable to evolve too much gas and produce a waster when the core is not perfectly vented. This casting is now poured on top with a round runner of ¼ in. section.

Fig. 11.—Actual Casting Made according to the Method Shown in Fig. 10.

The author pointed out in The Foundry Trade Journal the following conditions in which castings can be made without feeding heads:—(a) When the nature of the casting is such that the gating and cooling can be arranged so that solidification takes place at the same time throughout the casting. (b) That there will be no swelling of the sand, or if there is, it will not continue after pouring is completed.

Of course, small runners involve very hot metal. The runners must be kept filled during the pouring so that no air or slag enters into the mould. The slag must always be kept out of moulds if sound castings are to be expected. There are numerous ways to obtain this result, which too frequently are lost sight of.

Belgian Experiments.

In various papers, Mr. Leonard, confirming the results mentioned, says that slow pouring has the additional advantage of giving more time for the gas to escape. He gives very interesting examples and the author's practice confirms it. He also agrees that when risers are used they must be plugged or otherwise it is not infrequent to find them contaminated with blowholes.

FIG. 12.—THE CASTING SHOWN IN FIG. 11, BROKEN UP TO EXHIBIT THE SOLIDITY.

It has been remarked by some Belgian friends, especially Mr. Lamoureux, that their practice differs slightly from the author's sketches in that when they use small runners they manage to have the reduction far from the castings and increase the runner close to it, in order to reduce the speed of metal where it enters the mould. This is quite reasonable, especially when the stream is striking a core or a part of sand. It can then cause scabbing and it is advisable to follow this suggestion.

Figs. 6 and 7 refer to locomotive cylinders cast vertically at Cockerill Works, Seraing, near Liège.

It can be seen that the runner is choked close to the basin and that afterwards the runners are increased. The risers are there for washing the mould. Their section is too small to consider them as feeding heads. This practice is quite common in the Liège district, and this discovery was a great satisfaction to the author. The actual castings are shown in Figs. 8 and 9.

British Experiments.

Amongst other confirmations of satisfactory results from Great Britain the author has received from Messrs. John Musgrave & Sons, Limited, Bolton, the details of a rocking lever which are shown in Figs. 10 and 11.

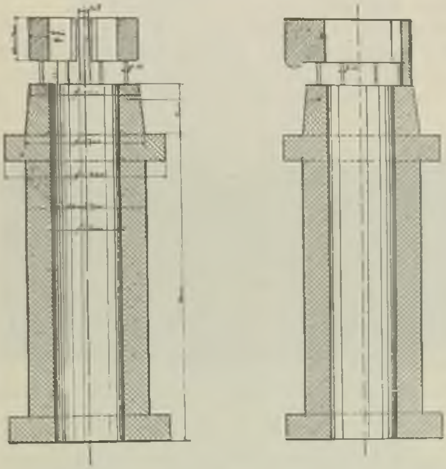


Fig. 14.—Two Sections through a 10-Ton H.P. Hydraulic Cylinder Cast with Eight $\frac{5}{8}$-in. Dia. Runners.

It is said that previous to adopting this system they were obliged to have a large riser over each of the bosses, also on the body. This meant 4 risers to be fed and cut off by machine. The casting made of cast iron was broken up and found to be absolutely solid and without any signs of sinking on the outside.

A semi-steel mixture with 35 per cent. of steel with the gates slightly enlarged gave the same good results. Fig. 12 shows the casting after breaking. Another casting made by the same firm is shown in Fig. 13. It is a face-plate coupling, weighing 1 cwt. The diameter of vertical runner is $\frac{1}{2}$ in., and that of the two horizontal runners $\frac{1}{4}$ in.

It is said that previously this casting had to be fed to be solid. No sign of sinking was found; broken, it was perfectly solid and even in texture, and the machine-shop foreman stated it was the cleanest casting he ever had to machine.

When visiting works around Liège, whilst the author's attention was already taken up with some interesting castings poured in unusual ways, he was struck at Esperance-Longdoz foundry by a heavy roll lying on the floor, on which traces of only a few small, very thin gates were noticeable. The casting weighed about 10 tons and apparently had no feeding head. Moreover, after inquiry, it was ascertained that the part of the casting where the gates were apparent had to be cut out, and a satisfactory reply could not be obtained as to why this part was added to the pattern. The author was informed that the idea was to have more pressure on the casting. It was more likely, however, that it was put there more for safety than for anything else.

Fig. 15.—Fractured Head of the Casting Shown in Fig. 15.

The 10 tons of iron were poured through 8 round gates $\frac{5}{8}$ in. dia. Thinking that it would be most interesting to find out whether the head was sound, the author asked the foundry manager, M. Varlet, to split it after having cut it, and to send him a photograph of the section. He was good enough, with the permission of his managing director, M. Stoultz, not only to do this, but also they sacrificed the casting. This casting is shown in Figs. 14, 15, and 16. It undoubtedly is a most remarkable job.

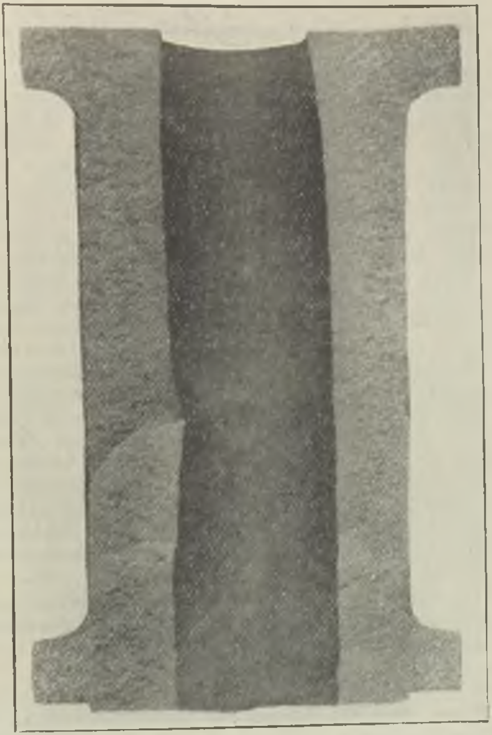


Fig. 16.—Fractured Hydraulic Cylinder Made as Shown in Fig. 14.

Experiments with Non-Ferrous Metals.

M. Saillot's attention, as previously stated, was first called to this subject by an incident during the pouring of a gunmetal casting. It may be of interest, therefore, to finish this Paper by recounting how a brassfounder, M. Fariner, who visited the author's foundry, having read the original article, carried out some experiments on castings that had previously given trouble. He used small gates with complete success. Mr. Fariner was kind enough to send the author the drawing giving details of their manufacture. The first one was a plain cylinder made of 88-10-2 metal of 13 ins. outside dia. × 6 in. deep × $1\frac{3}{8}$ thick, weighing 77 lbs. It was bottom cast, with two $\frac{3}{4}$ in. × $\frac{1}{8}$ in. runner. The second was a bearing casting made in 86-12-2 metal, and weighed 42 lbs. It was bottom cast by two runners of 19/32 in. × 3/32 in. Both castings were in every way satisfactory.

Many reports of successful experiments have been received from different parts of Europe, but the object of this Paper was to mention some typical ones, with names of works, so that the facts could be indisputable. No doubt British foundrymen will succeed in many cases if they try for themselves.

The underlying scientific principles are not dealt with in detail because the author is not certain that his hypotheses are right. Suffice to say for the present that it is possible to pour successfully without feeding heads a great number of castings that have been considered impossible to do by this method up to now, and to get them sounder than with the use of feeding heads.

Obviously it is desirable that scientists and practical men should set to work and try to determine causes for such results, which will probably result in the discovery of unknown laws.

In conclusion, the author desires to thank Mr. Greiner, General Manager of Cockerill Works; Mr. Droyart, Superintendent of the Foundries; Mr. Stoultz, Managing Director, and Mr. Varlet, foundry manager, of Esperance-Longdoz Works, for having had the kindness to supply photographs and drawings showing their practice. The author is further indebted to Messrs. John Musgrave & Sons and Mr. L. A. Bentley, their foundry manager, and Mr. Fariner, for having experimented on the lines indicated, and for giving permission to use the documents they so kindly had prepared.

DISCUSSION.

Favourable Experiments Detailed

The Branch-President (Mr. H. O. Slater) opened the discussion by stating that M. Ronceray had served the foundry world to great purpose, in that he had not only lectured to them in a most fluent manner, in a language not his own, but he had explained some fundamental principles in connection with moulding. He himself, like M. Ronceray, had carried out a number of experiments of the particular nature referred to in the lecture. Mr. Stone, a member. like many other foundrymen, could not accept the theory, but was convinced by practical experiments. The method was later extended to include gunmetal and other alloys. No doubt many of them were aware that malleable iron was something of a " hungry " metal, similar to manganese bronze and steel. One experiment was made—a spring bracket on a motor lorry, with a section of ½-in., with ribs leading to bosses of 3 in. dia. x 2¼ in. It was necessary, in order to get a sound casting, to have a feeding head on each boss, there being two bosses on the casting. The difficulty was not so much that of getting the metal sound underneath the risers, as in getting the risers off without knocking a piece out of the casting owing to design and the larger risers used. Necessity drove them to invention, and they cast these brackets with just a small riser, with about the same dimensions as mentioned by M. Ronceray, namely, 3-16th in. by ½ in. To make up for the feeding heads, they put 6, 9 and 12 ins. of extra height of runner on to these particular castings. The theory at that time was that the pressure would have some compensating effect for the risers. They had found that that was not altogether satisfactory in this particular case, owing to greatly unequal section, and there was difficulty with regard to the regular solidification of the metal. Having an advantage which in malleable iron they did not have to the same extent in cast iron work, owing to annealing, they put a chill on the bosses. The calculation they used was to have a chill half the size of the thickness of the boss to save the fusion of the chill and at the same time densening the bosses, and it was found that that regulated the solidification of the metal, and they obtained a perfect casting. They extended the method until they saved something like 20 to 25 per cent. of the melting charges on the shop as a whole. With regard to M. Ronceray's 6-in. shell, did he cast that shell with a core, and, if so, what did he allow for machining?

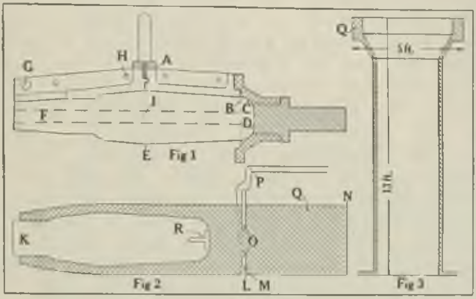
M. Ronceray said it was cast with a core, and he had allowed 4 or 5 mm. on the radius.

The Branch-President said that was $\frac{3}{8}$-in. a side for machining, and M. Ronceray had achieved something great. He had saved something like 20 to 30 per cent. on the machining charges of a shell. There was one thing which had come to his mind, and that was as to whether the secret of small gates and no risers lay in the use of hot metal. He was pleased to note, from the lecture, that the French moulder was like the English moulder, in that he followed out instructions as far as he could when being watched. It gave them satisfaction to know that they could not altogether denounce the English moulder any more than any other.

Casting Shells.

Mr. A. R. Bartlett, speaking in connection with the shell which M. Ronceray had mentioned, said that his firm had made many shells during the war, but he was sorry to have to admit that they had to cast them all with feeding heads. Their method of gating was certainly not that described by M. Ronceray, and he gave an example of their method of gating by means of a sketch. The shells were cast vertically and moulded vertically. They were made on a stripping plate machine, and possibly the way they were moulded had some effect upon the castings. They were moulded six in a box, which was round, and there was a core in each, as shown in Fig. 1. The core box is swung from the perpendicular for running to the horizontal for lifting from the box, when lifted out. It is then dipped into a blacking bin and hung on bars ready for stoving.

The reason for making heads such as are shown was that they had a moulding machine converted to this particular use, and as it was the only machine which they thought would make them economically and quickly, they adopted that method. They had never had a reject, but they always had to break off the heads. He believed the general practice in England was to cast them, sometimes singly, in a box, but he understood many firms cast them two in a box, but with feeding heads on them. The runners were generally much smaller, when compared with what was generally accepted for a casting of that size. The castings weighed 49 lbs. each, and were for 4.5 gas shells. Six-in. shells were necessarily longer, and weighed little under 1 cwt., but they were run in the same manner, with a 9-in. head. He had had no experience of anything which was run in the manner M. Ronceray had spoken of.



A=Steel band with handle each side to act as trunnions. B=Rammed first to this level with protecting cap in position. C=This cap then placed on top and rammed. Three brads put it and wire withdrawn. D=Top plug then driven in to give finished shape and length. E=Split here for ease of machining. F=Print. G=Adjustable pin holes across corner, ¾ in. diameter. H=Bolt holes for fastening when machining, ⅜ in. diameter. I=Core bar with vent wires placed in position first. K=Core print. L=Joint of mould. M=Core head broken off here with hammer. N=Top. O=Core. P=Runner. Q=Head. R=Chill.

M. Ronceray asked whether the feeding heads were broken.

Mr. Bartlett illustrated the feeding head, and how it was broken, by means of a sketch, reproduced in Fig. 2.

Mr. Bartlett then instanced the case of another casting, weight 8 tons 10 cwts., with a flange top and bottom, the casting being tapered. It was rather difficult to make, as will be appreciated from Fig. 3.

M. Ronceray asked whether the head was sound.

Mr. Bartlett said that when cut off it was perfectly sound.

M. Ronceray: And the top?

Mr. Bartlett: That was also perfectly sound. Continuing, he said he had illustrated a small and a large casting, which more or less carried out what M. Ronceray had said. There were several small things such as machine-moulded castings which we in England would never think of putting a riser on, and M. Ronceray's theory was carried out by his own experience of a good many small things. The fact which had interested him most was the coupling run through the centre, which M. Ronceray had mentioned. He had never seen such a thing done. He was not upholding all M. Ronceray's theories, but was just giving facts as he had found them in his own experience. He would like to know whether M. Ronceray found that he obtained a different result with a different chemical analysis of his iron. Did he find it essential to have a very high phosphoric iron for running castings with fairly thin section, and with such a small runner, or could he advocate any particular chemical analysis to be successful under his system?

Mr. Hall expressed his pleasure at having heard a lecture by M. Ronceray. About June last year the lecturer had written an article in "La Fonderie Moderne," which had been translated by his (Mr. Hall's) employer and himself, and they carried out certain experiments, which were afterwards described in the Foundry Trade Journal. One question arose out of those experiments, and that was with regard to the casting of shells. M. Ronceray, he believed, had cast shells, or had had them cast in France, the big side up. Was that correct?

M. Ronceray said it was.

Mr. Hall said Mr. Bartlett was casting shells with the thick side up, with a feeding head on top. Was that correct?

Mr. Bartlett agreed.

Mr. Hall said that during the war he had been taken to Woolwich Arsenal to see some of these shells cast. They weighed about 10 lbs., and at Woolwich Arsenal they were casting them with the heavy side up; there was about 1⅛-in. of metal on the thick side, and there was a runner all the way round about 1-16th-in. thick, with one down-stick. As soon as the shell was cool enough, they hit it, and it dropped out of the runner, but when put up for test the shells used to leak. His firm had taken on a contract for those shells. They at once commenced to cast them the thick side down, and had a 1-in. down-stick, which poured four shells. They would understand that there were four in one box, against Mr. Bartlett's six. They had the 1-in. down-stick to take all four, with a small runner in the bottom, and no riser. He was not going to say they had success every time, but under the hydraulic test they never lost more than 1 per cent., and there were never any wasters. They rammed very hard. The trouble in England seemed to be that we must not ram very hard, because if we did we should get scabs. Was it a question of the sand more than anything else? They knew the iron entered into it to some extent, but he wanted to find out what effect the sand had. He was still experimenting on these lines with different sizes of runner

Applicability to Steel.

Mr. F. Darley (Messrs. Firth, Sheffield) said he had not had much experience with cast iron, but he was very much struck with M. Ronceray's method of slow running and cooling in order to get a solid casting, although personally he had very little faith in it. In his opinion they must have very hot metal to do that, and the hotter the metal the greater the contraction. In steel, with which he was concerned, it would be of no use at all, for the simple reason that they could not run a 1-cwt. casting with less than a 1-inch runner, and further, unless the steel were very fluid, *i.e.*, very hot, they would not get an intricate thin casting 1 in. thick and 5 ft. long with a runner of less than 1¼ in. He had also found that it was an utter impossibility to make a steel casting perfectly, where they had to feed a thick part through a thin wall. The contraction of steel was 7/32nd of an inch to a foot, whereas in the case of iron it was only 1/10th of an inch. He was rather surprised that brass and phosphor bronze was successful for the purpose as the contraction was about 3/16ths. of an inch, nearly as much as steel. He had come to the meeting because it had been announced that the question of making castings without heads would be discussed, but he was afraid there was no chance of being able to make steel castings without heads, simply on account of the excessive contraction, and the difficulty of keeping the steel sufficiently fluid to run with a small runner.

Sand Experiments.

Mr. E. H. Brown said that he had been present last September at the conference of the Association Technique de Fonderie, at Liege, and he had had the pleasure of visiting both Messrs. John Cockerill's works, and also those of the Esperance Longdoz, and he would like to point out two or three fundamental factors in which their methods differed from those of the majority of foundries in England. First, with regard to Belgian sands, they were totally different from our own. They were produced from sands which were found, he believed, either on the outskirts of Belgium, or in Luxembourg, and sometimes, perhaps, in Germany, but the Belgians were producing a casting with a finer skin than we could produce, while that particular sand was far more porous. When he came back he had brought with him a box of sand from one of the foundries at Liege, passed it through a series of sieves, and compared it with an average sand in his firm's works at Newcastle. Whereas their own sand would barely pass through a 60 mesh sieve, he could pass practically the whole of the Belgian sand right through that, and about 45 per cent. of it through an 80 mesh sieve. That was considerably finer than most of them in England could use. Similar samples of sands, 3-in. square, were rammed under a Brinell testing machine, to get the same pressure on the two. He put through a constant flow of air, and for the purpose of the experiment he was using a carbon dioxide diffuser. The Belgian sand passed practically 25 per cent. more gas than the English, at the same pressure. With regard to the composition of the metal, the composition of the cylinders mentioned in the lecture was nothing like that of the cylinders he had seen made here and in Holland. He quoted an instance of some cylinders of very similar construction, which he had seen made during the five weeks he spent at a works in Amsterdam. They were making practically a similar type of casting with a head somewhere about 9 in. in height, tapering from about 3 in. at the top, to, roughly, 1½ in. at the bottom. The metal was nearly 0.5 per cent. lower in phosphorus than that which he understood was being used in Belgium, and the sulphur was considerably higher, certainly up to 0.15 per cent. almost every time. That necessitated a manganese content of well over 0.44 per cent., otherwise they would get sulphur blowholes. The manager of this particular foundry had told him that they could cast the same cylinder in what he said was identically the same composition of metal as used in Belgium, without heads, but when they tried their own metal, which, due to the sulphur content, was considerably thicker, and was impossible.

High Temperature Tests.

There was another point, with regard to temperatures of casting. When speaking of casting with hot metal, they must remember that hot metal did not mean the same to one foundryman as to another. He was astounded in the particular foundry he had mentioned, in Holland, to see the metal they were running through a cupola with a receiver. He had never previously, in this country, seen metal anything like so hot, and it had taken him nearly nine months' experimenting to get anything like it. He had ascertained, by the use of a pyrometer, that the temperature was somewhere in the region of 1,500 deg. C. With regard to the whole of the castings cast in Belgium, there was in Belgium practically nothing else than intensely high phosphorous iron. Iron was coming from Belgium and Luxembourg containing phosphorus up to 2.6 per cent. Was that the metal which M. Ronceray was putting into some of the castings he had mentioned? Because if so, the average Englishman would not look at it.

M. Ronceray said it was impossible.

Semi-Steel Considered.

Mr. Brown, continuing, and dealing with the question of semi-steel, said he believed it was generally accepted now that semi-steel differed from cast iron only in the very slightly lower carbon content; the diminution was in the vicinity of 0.1 per cent., and there was also a somewhat lower manganese content. If they had to have a thicker runner for the semi-steel, did not that mean that with any thick metal the same would be necessitated? During the course of the last two years he had been casting some cylinder liners for a marine engine. The sulphur content was over 0.2 per cent., and it was deliberately kept at that high value. In the past there had been an enormous amount of trouble with the porosity in the top of those cylinders, and they had had some very big heads cast on them. With a 72-in. liner it was the usual practice to cast with an 18- to 21-in. head. He illustrated his remark by means of a sketch of a half-section of the liner.

Such a casting would show a depth of anything up to 72 in., and a thickness of metal of about 1¼ to 1½ in. except in one place, where it would be about 2½ in. After a good deal of experimenting he had found that the shorter tapered head was considerably better than a long narrow one. The runners for these liners were cast on the top of the head; there were four runners, about 1½ ins. long by, roughly, ½-in. wide. As to the sulphur content, high-sulphur metal had advantages over low-sulphur metal in some ways. In dealing with a cylinder liner they were endeavouring to obtain a casting with a hard skin, resistant to wear, and also, when dealing with superheated steam, it had to withstand a fairly high temperature and still be resistant. Sulphur hardness maintained that resistance to wear considerably better under increased temperature than silicon. The average percentage of silicon in these liners was between 0.9 and 1.2, depending actually on the size of the liner. Manganese, of course, was higher still, about 1.54. He would like to know if M. Ronceray could suggest any method of running that particular type of casting with the same composition metal, and without the enormous head, because it ran into considerable cost both in melting the metal and in cutting off the head.

Gas Engine Liners.

Mr. J. Longden said there was in this country a good deal of practice on the lines which M. Ronceray had laid down. The difficulty was that foundrymen, and perhaps English foundrymen especially, needed more courage. As M. Ronceray had pointed out, the principle was to keep the metal entering the mould at the thinnest possible part of the casting, in order to enable all the metal in the mould to set as nearly as possible simultaneously. He did not claim that he had tried the small section runner, but he had proved the validity of the principle of putting the metal into the mould at the thinnest place, so that the metal finally reached the heavy part when it was cooler, it being the last place reached by the metal, so that there was more chance of even cooling. Some years ago he had experience of casting gas engine liners, having sections pretty much as those outlined by Mr. Brown. The weight varied from about 14 cwt. downwards, the bigger ones having a section of about 2 ins., being about 4 ft. 6 ins. long, and cast on end. There was no big head cast on the end; there was a head of about 1½ ins., but it could not be claimed that that was a feeding head. Its function, he believed, was to receive gas holes or any scum that might have arisen through the operation of casting, and he was surprised to notice that no bad results accrued, such as one might have expected. In this case there were hundreds of liners cast perfectly sound, with perhaps three small runners on the top, each about 1 in. round. Mr. Brown had referred to the difference in the metal used here and on the Continent. He had said that the Belgian metal was higher in phosphorus and lower in carbon. He (Mr. Longden) was rather of the opinion that that told in favour of M. Ronceray, because if on the Continent they could get sound castings with a lower carbon content and a higher phosphorus content, that seemed to help to prove their case. He believed he was right in saying that the phosphide eutectic was the last to set in the casting, and that the contraction was greater than that of the pure iron. Consequently, there was a greater tendency for the production of the holes. Similarly, the absence of sufficient carbon would also tend to make for increased liquid shrinkage, because if the carbon were low there was less to precipitate, and when the carbon had been precipitated it took up a larger space than when it was in its combined form, thus helping to prevent shrinkage holes. He believed there was a great field for investigation in this particular matter, and there was no doubt that it needed courage, but he was quite satisfied that a great deal was to be expected of it, and a great deal of economy would result.

Pans made without Heads.

Some time ago he was responsible for the making of a number of pans weighing about 30 cwts. each. They were 4 ft. 6 ins. in diameter and 5 ft. deep, and he was staggered when he discovered that it was necessary to make them with a machining allowance on the top flange of ¼-in., and with no head. These were cast with three rectangular sectioned runners, each runner being about ½ in. by 1 in., and cast perfectly successfully, and perfectly clean on the top flange. That was something he did not expect, but it was being done, and there seemed to him to be great room for investigation.

Successful Experiments.

Mr. Creek said he would like to give the author a word of encouragement. He had been up against something which had given him a lot of trouble; he had tried all methods, and could not get a sound casting in one particular case. After reading the article in The Foundry Trade Journal, however, it had given him an idea. He went down from a 1¾-in. runner to a ½-in. down runner, and a very much smaller runner into the work itself. The first casting was absolutely sound, and from that day to the present he had had no further trouble with this particular casting. He had tried many other types with the same sort of metal, and it had been the greatest success in the foundry that he had ever had. He was convinced that there was a very great deal in this method of running if they could only experiment a little further. So far as the runners themselves were concerned, he had not quite followed the lines which M. Ronceray had indicated. Instead of having a down runner direct into the work, he had had a down runner and a cross runner, and a smaller one underneath that leading into the work. The result was, as he had said, a perfectly sound casting, and he had produced a great many of them. So far as iron was concerned, he had not had the same success, largely because he had not had the metal as hot as had been mentioned that evening. He would continue his experiments on iron, however, and believed he would get some good results.

THE AUTHOR'S REPLY.

M. Ronceray, replying to the discussion, dealt first with hot metal. Of course, if they were going to use small gates they would have to use hot metal, and he believed they all knew that it was absolutely necessary to use hot metal to have sound castings. If they had not hot metal they would get slag mixed with the metal, and if they had large gates the slag would get inside with the metal, so that there were many reasons for having hot metal and smaller gates. He was rather surprised to hear that there was some iron containing 2.6 per cent. phosphorus; he had never seen it, the common iron used on the Continent contains 1.6 to 0.27 per cent. phosphorus. In Belgium the phosphoric iron was made from the French ore, because they had no ore in Belgium. Discussing the casting of shells, during the war it was not a question of making shells with the phosphoric iron made in France; they obtained hematite iron from England. But that was not the best, he could assure them. Irons of different analyses behave differently, but when the castings shown were made in different shops it would be understood that the analyses were very different. Sometimes they used high phosphorus iron, sometimes low, sometimes low silicon, and sometimes low sulphur, and some of the castings he made himself with only 15 per cent. pig-iron, and with a high phosphorus content. One, he believed, contained 0.26 per cent. sulphur, so that this proves that it was possible to make castings without feeding heads with both high and low sulphur or phosphorus. It seemed to be a matter of adaptation in each case. The brass experiments gave the same results. He could not give his experience with steel, because he had had none, and he did not wish to mention anything he was not sure of. He had heard that if they wanted to get ingots with small pipes they had to resort to slow pouring, and he asked Mr. Darley whether that was so.

Mr. Darley said it was possible to make an ingot to run on somewhat similar lines from the bottom. His firm made them in their works, ingots of about 2 tons, and there was probably about 4 ins. of pipe in the top only. On the other hand, he had seen the pipe fully half the way down, but by slow running, with a smaller runner, it was possible to run steel with a pipe of only about 4 ins. His firm had a Research Department, and they continued casting ingots and other castings and indexing them, with a view to trying to get over these difficulties. He believed they had made the casting of ingots as nearly as possible with a minimum of piping, but that was done by having a refractory top pipe. These did not act as chills, because they were put in hot and acted as feeders.

M. Ronceray said he had no personal experience of steel, but he believed that something could be gained in this connection, by experimenting on the same lines. It was probably more difficult, because the metal solidifies more quickly; however, the results mentioned by Mr. Creek on chrome nickel steel were striking. With regard to contraction, it seemed that there had been a confusion between what he would call solid contraction and liquid contraction. If they poured metal into a casting and obtained by some way solidification of the mass as a whole, the casting would be sound, but they did not know up to now what was happening before solidification. Solid contraction had nothing to do with the piping. The moment the metal was solid there was no possibility of liquid contraction, and liquid contraction was what made piping. Replying to Mr. Hall, he said that shells had been made in many ways in France, good and bad. The regulation method before the war, was to pour with the heavy part down, and with the feeding head on the top. It was common practice, when this method was adopted, to find a hole in the thick part.

Mr. Hall said that was the way he had cast them, and they were all right, but at Woolwich the heavy side was cast up in the particular case he had mentioned.

M. **Ronceray** said that was right, and that his opinion was that shells could be made good either way, and had been, in fact, providing good practice was followed. There were many troubles that arose in casting, so that in experimenting they must not expect good results every time, but they must try to change only one thing at a time, in order to avoid assigning the wrong reason to a particular trouble. With regard to the sand Mr. Brown mentioned that in Belgium, France and Germany, sand was more permeable than in England, and at the same time, it was finer, and he (M. Ronceray) could not understand how that could be. Mr. Brown had said that the skin of the castings made in Belgium was smoother. The castings he had spoken about were dry sand castings, and the skin of such castings was produced by the blacking, and consequently has no relation to size of sand. Mr. Melmoth had said he had made the very same casting, *i.e.*, a cylinder liner with success with English sand and English iron. He did not think the English sand was bad, the success of the workers in many different foundries on many different castings was clear proof of it, but if it were bad, why did not they make it good? If it were not permeable, he suggested putting some silica sand in when milling it. Referring to sulphur segregation and blow holes that Mr. Brown obtained, he thought that the reasons given were altogether wrong.

Sulphur Blow Holes.

Custer made experiments on the influence of occluded air on the soundness of castings, and he found that if, when pouring a casting, the air was trapped with the iron, blow holes were found. There was a combination of the sulphur with the oxygen of the air, producing sulphur dioxide. The same results were found when experimenting in sand and in chills. M. Ronceray again pointed out that the system which was referred to as his system was not his invention, his only aim was to try to throw light on the subject, which was of great interest. He would be proud of the fact that he had lectured to the London Branch if he had been able to interest them sufficiently for them to continue experimenting on the lines he had suggested. It was clearly proved by several experimenters who tried his suggestions, that it was possible to make, under certain conditions, castings without feeding heads, and if it were possible to make some castings, it might be that once they had found the reason for it, it would be possible to make them all in that way.

Votes of Thanks.

Mr. Melmoth proposed a vote of thanks to Mr. Ronceray for his lecture. In doing so, he stated that the subject of the lecture was of infinite interest to him and others interested in the production of steel castings. Mr. Darley had said that he could not see this method being applied to steel, but in his (Mr. Melmoth's) opinion, that was not the attitude to take. He had been connected with the carrying out of an extensive range of experiments on the speed of running steel ingots, and although they were made in chill moulds as against sand moulds in the case of castings, yet they were run from the bottom with a small runner in proportion to the size of the ingot, and his firm had succeeded in dropping their percentage of wasters from these ingots from 25 to 30 per cent., down to 8 to 10 per cent. during the war. A previous contributor to the discussion had referred to the temperature of cast iron. He had never heard of such temperatures as 1,560 deg. C. in cast iron, and he did not see what practical purpose would be served if it were obtained. Also, according to some metallurgical opinion, excessive heat in any metal in the liquid state was liable to leave behind after ill-effects. As to the use of the optical pyrometer, he had not a half-penny worth of faith in any optical pyrometer on the market for judging the temperature of a stream of molten metal. He commented on the fact that the industrial people in this country, who, after all, did count for something, were discussing the technical and industrial problems, whilst the politicians were dealing with more or less abstract and unproductive political questions, and also on a gratifying fact, that it was one of our French allies in the recent War who was teaching them the possibility of this particular method of casting. He himself was going to try to make certain types of steel castings on the lines suggested, and believed one person had already had some success in doing so. He had the greatest pleasure in proposing the vote of thanks to M. Ronceray for his excellent lecture, and the extremely genial way in which he had dealt with the discussion.

Mr. Faulkner, seconding the vote of thanks, said he was rather proud of the fact that he had started the ball rolling. He had given a short account of M. Ronceray's work in the Foundry Trade Journal, and it gave him a feeling of satisfaction to know that one member had derived practical benefit from it.

The vote of thanks was accorded with acclamation.

M. Ronceray, in a brief reply, said he was proud to have received such a warm reception, and emphasised the importance of the exchange of ideas.

Joint East Midlands and Sheffield Branches.

Held in Sheffield.

CUPOLA FACTS, FACTORS AND FANCIES.

By A. Poole.

A joint meeting of the East Midlands and Sheffield Branches of the Institution of British Foundrymen, held in Sheffield, took the form of a visit to the Brown-Firth Research Laboratory, where the visitors were received by Dr. W. H. Hatfield.

At a meeting in the Cutlers' Hall at night **Mr. A. Poole**, of Stoke-on-Trent, gave a lecture on "Cupola Facts, Factors, and Fancies." When one considered the many varieties of cast iron which were required from the foundrymen of to-day, said Mr. Poole, and the important part the cupola played in their production, the need for a standard type of cupola, with standard practice, embodying the maximum of efficiency and economy, became apparent. It had been said that the standardisation of cupola practice was an impossibility. With so many types of cupolas in existence this might be true, and would probably remain so until the best features of these numerous types were embodied in one perfect apparatus. The attention of those engaged in research work was, no doubt, focussed on these important matters. Experiments under laboratory conditions, however, were not quite satisfactory. To be of the utmost value they should be carried out under practical working conditions, and the responsibility for the erection of the finger posts to perfection lay with the foundryman himself.

One of the most important factors for good cupola practice was the quality of the fuel. The demands of foundrymen for a standard foundry coke of definite chemical and physical qualities from the manufacturers did not appear to be an unreasonable one. The qualities required might be summarised as follows:—

Chemical:—The maximum percentage of fixed carbon associated with a minimum percentage of sulphur, ash, and moisture.

Physical:—Strength combined with porosity, high calorific power, and more important still, high calorific intensity.

Coke of the following composition might be taken as a good average standard which would meet the requirements of most foundrymen if they could secure consistent and regular supplies:—Carbon 90, sulphur 0.5, ash 7 per cent., and the rest water and other impurities.

Coke Ratio.

After discussing a coke of this quality with regard to melting ratios, Mr. Poole said the principal source of loss was the incomplete combustion of the fuel in the charge. From analyses of the waste gases taken just below the top of a cupola charge it had been estimated that only 52 per cent. of the carbon in the fuel was completely burned to CO_2, the remaining 48 per cent. being burned to CO in the charge, changing to CO_2 above the charge. This represented a loss of about 34 per cent. of the potential heat contained in the carbon which formed 9/10th of the coke, or approximately 37 per cent. from the total weight of fuel.

The question naturally arose as to whether some method could be devised for utilising the surplus and potential heat contained in the gaseous products issuing from the charge. A modern blast furnace had many points in common with the cupola, and there was no apparent reason why some of the methods which had resulted in so much greater efficiency and economy with regard to blast-furnace practice should not be applied to the cupola. The adoption of the closed top with the cup and cone charging arrangement, or some modification of it, and the utilisation of the waste gases for pre-heating the blast, drying ladles, cores, etc., should not present any insurmountable obstacles, and the advantages were evident, especially with large cupolas running long heats. The cup and cone method of charging ensured a practically perfect distribution of the charges, an essential factor for perfect working, and if the temperature of the blast was raised only a few hundred degrees Cent., the results should justify the initial expense. Another source of loss in cupolas where the molten metal was collected in the hearth was the excessive amount of coke necessary to form the bed.

Is Wet Coke Advantageous?

The idea of saturating coke with water before charging was open to criticism. It was claimed that this treatment had the effect of keeping the upper part of the charge comparatively cool, thus concentrating heat in the melting zone, with consequent quicker melting and less combined carbon in the metal by the time it reached the melting zone. The temperature of a cupola at the charging door was high enough to evaporate the moisture in the coke in a very short time, probably before the charge had descended more than a foot. It was difficult to see how any appreciable cooling effect could be exercised by the relatively small amount of water absorbed by the coke, even in the proportion of 2½ cwts. to one ton of iron. Dealing with the question of air supply, Mr. Poole said that for the greatest efficiency it was necessary to supply to the cupola an adequate volume of dry air, pre-heated if possible, delivered at sufficient speed and pressure to ensure its even distribution over the whole of the cupola area, and to obtain the maximum calorific value and intensity from the fuel. The question of blast pressure was intimately connected with the quality of the fuel. The most important characteristic of foundry coke was its calorific intensity when burned in air. The temperature factor in cupola practice could not be emphasised too strongly. It was also of vital importance for the efficient and regular production of semi-steel. The generally accepted theory with regard to the melting of steel was that the steel absorbed carbon from the coke, thereby lowering its melting point sufficiently to melt at cupola temperatures, the implied assumption being that the cupola does not attain to temperatures sufficiently high to melt steel without this action taking place. This appeared to be fallacious, and in his opinion it might be definitely asserted that good semi-steel of regular composition could not be produced from a cupola unless the temperature of the melting zone was above the melting point of the steel.

Temperature of Melting Zone.

The temperature of the melting zone of a cupola working normally was easily high enough to melt mild steel. In a Paper read before the Institution at the Blackpool Annual Conference, Mr. G. K. Elliott said, "There is good authority for assuming that the temperature of the hottest part of the melting zone is about 2,200 deg. C." This was probably an over-estimate, said Mr. Poole. No firebrick or fettling would stand up to anything approaching this temperature under cupola conditions; but it was practically certain that temperatures of 1,600 deg. C. and even higher were nothing out of the ordinary for a cupola working at its best. Having no means of taking the temperature of the melting zone while the cupola was in operation, he recently took a series of tests of the coke from the melting zone when discharged from the furnace ten minutes after the blast had been shut off. The average temperature of the coke was just over 1,350 C. It was reasonable to assume that these temperatures, taken outside the cupola, would be at least 250 deg. C. below those inside the cupola at full blast. Nearly all the carbon absorbed by steely mixtures, or any cast iron, was taken from the coke bed after the metal was melted. The number, disposition, and dimensions of the tuyeres were governed by the size of the cupola, and the blast pressure. The tuyeres were better kept at one level. The effect of an upper row was to raise the melting zone, and consequently the coke bed, which led to increased coke consumption. If the air supply was insufficient more tuyeres should be added at the same level, or the capacity increased.

Internal Form of Cupola Important.

Another factor which had an appreciable effect on the melting efficiency was the internal shape of the cupola. A lining which tapered outwards slightly from just above the tuyeres appeared to give the best results. The height of the charging door from the cupola bottom was a factor which deserved more attention than it usually received. In many cases the height had been fixed so that the least labour and expense might be involved in lifting the materials to the charging platform. Modern mechanical appliances, however, had rendered this consideration a comparatively unimportant one. Any increase in the charge depth would have the obvious effect of utilising a greater proportion of heat, with a corresponding increase in the temperature of the charges before reaching the melting zone.

The weight of each charge of iron which could be efficiently melted was governed principally by the fuel ratio, and the capacity of the melting zone. The amount of slag-forming material charged into a cupola had an appreciable effect both on fuel economy and loss of iron. This material consisted chiefly of the ash in the fuel, and the sand and oxide of iron attached to the pig iron and scrap. The average loss of heat due to the formation and melting of the slag had been estimated at about 8 per cent., producing 65 lbs. of slag per ton of iron melted. Obviously, any reduction in the amount of slag-forming material charged led to further economy. Most of the pig iron cast in Great Britain was cast on sand-beds, and the presence of sand on pigs cast in this manner was unavoidable. Whether it would be a paying proposition or not to remove the sand by sand-blasting the pigs, he was not prepared to say. The onus, however, should not be on the users of pig iron, but on the makers, and the solution lay in following the American practice of casting the pigs in cast-iron moulds. Pig iron cast in this manner would be chilled to a greater or lesser degree, but the composition remained practically unaltered, and when re-melted in a cupola, the resultant metal would have approximately the same qualities as a similar pig cast on a sand bed.

Sand v. Chill-Cast Pig.

A further important consideration was that the thermal resistance of a chill-cast pig was far less than one cast on a sand bed. An appreciable amount of heat was required to break down the thermal resistance of the thin skin of sand attached to a sand-cast pig. The weight of sand charged per ton of pig iron averaged about 20 lbs. This value could be ascertained from any brand of pig iron by weighing a few samples of the pig and noting the decrease in weight after sand-blasting. Assuming that coke was used containing 6 per cent. ash and that the melting ratio is 2 cwts. per ton of iron, the amount of slag-forming material in the coke equalled 12 lbs., which, with the sand adherent to the pig iron, using half pig and half scrap, gave a total of, say, 20 lbs. of slag-forming material to be fluxed per ton of iron. Assuming this to be silica (SiO_2) and that all of it was fluxed by lime (CaO) to form the silicate $CaO.SiO_2$, the amount of limestone to be added could be easily calculated from the formula:—Sixty lbs. of silica requires 56 lbs. of lime, which are contained in 100 lbs. of limestone. Twenty lbs. of silica would therefore require $33\frac{1}{3}$ lbs. of limestone. As the ash of the coke was to some extent self-fluxing, and as a proportion of the silica was fluxed by oxide of iron, the amount of limestone added was usually less than the proportion given.

Influence of Atmospheric Conditions Inside Cupola.

The atmosphere of a cupola in good working order might be taken as practically neutral, or only slightly oxidising. Very little, if any, of the oxide of iron charged was reduced to metallic iron. The greater proportion of it found its way into the slag, either by combination with the sand and ash, or with the silica in the lining materials. On the other hand, the only appreciable oxidation of iron which took place in a cupola running normally appeared to occur in the vicinity of the tuyeres after the metal was melted. The molten metal collected in the hearth was protected from the oxidising action of the blast by the slag which floated on its surface. The amount of iron in the slag was mainly dependent on the amount of oxide of iron charged, and it would be more accurate to describe "loss of iron" as loss of sand and rust. It might also be safely assumed that the removal of silicon and manganese occurred principally after the metal was melted, and was largely due to the presence of oxide of iron in the slag and oxide of iron occluded by the metal itself, although it was probable that some manganese was removed by combination with sulphur. The conditions were very similar to those which prevailed during the manufacture of malleable iron by the "wet" puddling process, where molten metal was subjected to the influence of a slag, rich in oxide of iron.

The life of a lining was adversely affected by the presence of iron oxide, which attacked the silica in the fire bricks or fettling, with the formation, in many instances, of appreciable quantities of quite unnecessary slag. The reduction in the slag output when using pig iron and scrap, free from rust and sand, was very noticeable. Two trial heats recently melted, one of $5\frac{1}{4}$ tons and one of 6 tons, using pig-iron previously sand-blasted, and scrap shell-plugs with an anti-corrosive coating, resulted in a total output of slag and refuse averaging just over 30 lbs. per ton of iron melted.

Silica Cupola Linings.

It was a mistake to use inferior fire-bricks for a lining, which should consist of the best silica brick available with the joints as close and tight as is practicable. The cement and fettling used should be as nearly as possible of the same composition as the brickwork. Given normally good bricks it would be found in most cases that the joints and the jointing materials were the principal sources of weakness. If a silica brick was used in conjunction with a cement or fettling containing much alumina or oxide of iron, chemical action was nearly certain to take place between these compounds and the silica of the brickwork, with the result that the life of the lining was considerably shortened. Three per cent. of iron oxide in a silica brick was stated to be sufficient to make it fusible. At high temperatures silica caused expansion, and provision should be made for this when lining a cupola with high silica materials. In some cases a small space was left between the shell and the lining, which was filled in with a refractory sand. When associated with silica the tendency of alumina was to cause contraction. The acid silicates of alumina are stated to be more fusible than the basic. The melting point of pure alumina is given as 2,050 deg. C., and that of pure silica as 1,750 deg. C. to 1,800 deg. C., although the latter was open to criticism as to whether it was the true melting point or not.

In conclusion, said Mr. Poole, the point should not be forgotten that low coke consumption was not the only end to be attained. Hot and rapid melting was of equal, if not greater, importance, and good castings could not be produced unless the metal had the proper amount of superheat. The true melting ratio was not the weight of coke per ton of iron produced from the cupola, but the weight of coke per ton of good castings.

A resolution of thanks was accorded Mr. Poole for his lecture, this being proposed by Mr. John Watson, the President of the Sheffield Branch. Mr. Evans, the President of the Derby Branch, seconded, and referring to the Paper, suggested that if they could get the makers of pig iron to come more into line, he thought the majority of their troubles would be overcome.

Sheffield Branch.

SOME PERPLEXING FOUNDRY PROBLEMS.

Discussion on Paper by J. Shaw.

"Some Perplexing Foundry Problems" was the title of a Paper read by MR. J. SHAW, of the Brightside Foundry and Engineering Company, Sheffield, before the March meeting. Mr. John Watson presided.

The Paper was originally read by Mr. Shaw at the Blackpool Conference, and a report of it has already appeared in the Proceedings for 1922.

THE DISCUSSION.

THE CHAIRMAN said they had listened with pleasure to Mr. Shaw's remarks, and he would be very glad to hear the views of the members on the points he had raised.

Oxides may be Present in Cast Iron.

DR. SWINDEN said he desired to congratulate Mr. Shaw on the extremely interesting way in which he had asked his questions, but at the same time he hoped it would be realised that it was much easier to ask questions than to answer them. He would not like to attempt to answer completely any of the four questions. In regard to "oxygen" mentioned in the synopsis of the Paper circularised, he thought it was generally agreed that there was no evidence whatever that oxygen as such was present in either iron or steel, but that iron oxide existed most probably in the form of a solid solution was he thought definitely proved. He had not studied the data in regard to iron particularly, but in regard to steel that view was now generally accepted. He was not present at the function at which Dr. Hatfield made the statement referred to by Mr. Shaw, and if it was made without any qualification he (Dr. Swinden) was rather surprised, because he saw no reason whatever why oxide of iron should not exist in the presence of 1.3 per cent. of silicon. Oxide of iron would be formed on high temperatures. It was well known that where iron and steel contained considerable proportions of manganese and silicon the Fe Mn and Si would be oxidised in certain ratio according to the temperature and to the supply of oxygen. He thought it was safe to state that iron oxide could be formed and remain in the metal without assuming the complete prior oxidation of silicon. In the case of manganese it was quite definitely proved that the reduction of iron oxide by manganese is a balanced reaction and that it was impossible to completely de-oxidise with manganese. The problem was difficult, because of the difficulties in the way of an accurate method of estimating oxygen in its several states of combination in the metal. The work of Pickard and others had been very carefully carried out, but he still thought that the Ledebur method did not give results of practical value in attempting to determine the effect of oxygen or oxides on either iron or steel. He did not think that anyone would suggest that the analysis shown by Mr. Shaw was complete, because it ignored the oxides. Then there was the important question of nitrides. He accepted Mr. Shaw's statement that the quality of a casting depended upon the quality of the iron and that re-melting did not necessarily put all iron into a uniform condition. To explain exactly why this was was a matter of extreme difficulty. One met with exactly the same thing in regard to Swedish iron. If the possibilities of explaining that difference are traced out, taking the case of Walloon and Lancashire bar iron, it is found that one essential point of difference is that the Walloon blown with a cold blast and the Lancashire iron was blown in a pre-heated blast. He (Dr. Swinden) had previously mentioned at these meetings that in Sweden a blast furnace working under certain conditions had given iron which was quite satisfactory as regards analysis, but the resulting steel in the open-hearth process was not so good as when the iron was made with cooler and lower pressure blast. One feature that might explain that was the possibility of the influence of the nitrides and also possibly the influence of hydrogen. There had been practically no work done in hydrogen. That hydrogen could be occluded in very large quantities had been proved, and it was still an open question what effect ordinary deoxidisers had upon hydrogen. In regard to nitrogen there was a difference of opinion as to how it exists, but there is good evidence to show that nitrides are formed which are stable. He suggested to Mr. Shaw that the content of nitrides, oxides, and possibly even hydrides would have a bearing on that difference in results quoted. In the case of nitrides it was quite possible that even re-melting would not eliminate their influence. He would not attempt to discuss the question of test bars, but it seemed obvious that more work was required in that direction. With regard to the British Standard specifications, his experience was that they were most reliable and workable, and the Committee were always anxious to receive suggestions to improve them and make them what they should be—that was a series of reliable tests to control the quality of the articles which were ordered to these specifications.

The Shape of Test Bars.

Mr. John R. Hyde said he was very pleased indeed with the way Mr. Shaw had dealt with the subject. As a foundryman, however, he could only say that when doctors differed it was a very awkward position for the patient to be in. After the discussion on oxygen and the whole question of analysis, they were absolutely in a fog. It was interesting, however, to see the effects on the two series of iron that Mr. Shaw had published and to know that they were not by any means freak irons. They had been manipulated by the same people over 60 consecutive days. When they obtained results like that one had to look round for some other condition than analysis. Dr. Swinden had told them they had to look for other things. As foundrymen they had made tremendous strides in foundry practice, and had induced men to take an interest in analysis, but when it came to nitrides and the like he was prepared to leave that to the Research Association and let them explain some of the differences.

With regard to test bars, he supposed they would have to put up with them more in the future than in the past, but they had always the idea that cast iron was distinctly erratic on test. With the tensile test they had been able to work with reasonable consistency, and if they machined the transverse tests the results were also reasonably consistent. But then was introduced the whole question of variation in casting temperature and in the type of mould. He would support the round bar machine as a distinct advance in consistency. But no one was going to disregard altogether the tensile bar. Any of these suggestions that were put forward were really in the interests of both sides of the question. They would be a help to the inspectors, most of whom admitted that cast iron was a difficult subject, and it would be a help to the foundryman.

Tensile Tests Preferable.

ENGINEER-CAPTAIN MOORSHEAD said he was prepared to take exception to what Mr. Shaw had said about the lax manner of stating the results of tests. As far as the Admiralty were concerned they were particularly definite in the qualities required in the case of cast iron under test. The British standards laid down three distinct areas for test, and presumably they were so arranged as to be the most applicable to the job as long as the necessary 11 tons tensile was obtained the Admiralty were satisfied with the metal. He did not know whether in cast iron everybody's wishes could be met, and he considered Mr. Shaw was too sweeping in his statements. Mr. Shaw apparently wanted to wipe out the tensile test. That was destructive criticism, because he thought the tensile test was a very useful one. If the designer of, say, a steam cylinder was deprived of his tensile test and had to rely entirely on another—presumably more of a shock test than anything else—he did not know where he was. All steam cylinders should have the tensile test, and to suggest wiping it out was a retrograde movement. If he (the Captain) could get 11 tons on the tensile he would be satisfied. He was inclined to believe Mr. Shaw had a little bit up his sleeve, and would perhaps give further information on tests.

Satisfactory Puddled Bars Contain Oxygen.

Mr. T. D. Robertson, of Sydney, Australia, said he regretted he was not able to be present at the meeting at Blackpool at which Mr. Shaw's Paper was read, and therefore he welcomed that opportunity of being present to hear the subject. When the question of oxygen was introduced to him some time ago he had an idea which he had never had a chance of proving by actual experience. But the idea he had got hold of was that the bad effect of oxygen in iron or steel was largely a question of temperature at which that iron or steel was exposed to the oxygen. If they took, for example, the making of rod iron which was made under extremely oxidising conditions at a very low temperature—it was really below its melting point—oxidising conditions did not appear to have any bad effect. With regard to the testing of cast iron, he noticed that the subject of temperature had not been referred to at all.

Does Oxygen Close Grain of Pig-Iron.

Mr. E. Adamson said it was well known in blast-furnace practice that certain forms of iron oxide were more refractory than others. He thought it was possible that iron oxide could exist in pig-iron, and did not think it was wise for anyone to say that simply because there was a certain small percentage of silicon present in pig-iron that oxide of iron, if present in pig-iron in that form, could not therefore exist. He thought, moreover, before it could be definitely settled whether the increased strength of pig-iron was due to the presence of oxygen a very great deal of further investigation was necessary, because increased percentages of oxygen appeared to coincide with closeness of fracture, which in itself denoted strength. It was yet to be proved that the presence of oxygen or oxide of iron caused this closeness of grain, and in his opinion this closeness of grain was due to thermal conditions in smelting. Too many conclusions have been drawn in the past from varying percentages of one impurity. What applied in the laboratory did not always apply in works practice, and when both chemical and physical conditions were disclosed other conclusions could be drawn than variations of one impurity. It was not one thing which had to be taken into account, but a whole series of influences—for instance, Cook's two tests referred to by Mr Shaw of 9.1 tons and 18 tons from the same analysis was one of the proofs of this.

He agreed that oxygen was difficult to analyse and he thought the presence of oxygen or oxide of iron and its influence, and also the difference between Numbers 1, 3, 4 and other fractures of pig-iron was subject-matter which was well worth serious research and very stringent investigation. In 1910 he was showing the late Mr. Hailstone a piece of a 2 in. × 1 in. transverse test bar which was very close grained, and asked him to give his opinion of the silicon contents; the reply was about 1.50 per cent., and he would not credit the statement that it was 3.00 per cent., consequently he wished to investigate. From Mr. Hailstone's letter, dated May 11, 1910, he gives Si, 3.051; S, 0.042; P, 1.098; and Mn, 0.688. This test-bar gave 32½ cwts. and 0.60 in. deflection on 3 ft. centres—hardly a test which would have been expected from such a high silicon bar, and it was no isolated instance of this test from similar analyses, but one regularly obtained.

Cold Blast and Refined Irons are Strong.

With regard to the physical properties of iron, they spoke only of facts when it was stated that cold-blast iron and that refined in the Siemens furnace were stronger physically than hot-blast irons, not because of the analyses, but for some other reason outside of this. He thought there could be no cause of dispute about this. Dr. Swinden had referred to the statement that the present method of analyses was incomplete and that differences in tests would be explained by taking a complete analysis. In his (Mr. Adamson's) opinion, this suggestion was merely talking round the subject, and he did not think Dr. Swinden would accept this position when he himself spoke of the differences in physical properties of pig-iron from Swedish charcoal furnaces merely by changing the method of working; therefore if such a physical difference is possible in what might be termed a "baby" blast furnace, how much more will it apply to the more modern furnaces producing 20 or 30 times as much pig-iron—or possibly even more—per day.

Low Silicon Grey Iron.

Mr. Shaw had referred to his (Mr. Adamson's) sample of pig-iron with silicon 0.35 per cent. and a perfectly grey fracture, as those present had seen when the sample was passed round. The accuracy of the analyses had been questioned, because it did not conform to the established theory which assumes that the iron should have been white, but such an objection is no argument. The sample and analyses were given to him in 1905 through the kindness of Sir Robert A. Hadfield, and they would agree that those in his laboratory responsible for the analyses would not allow an improper one to be issued.

Chemical Analysis Less Important than Physical Properties.

The emphasis of these physical differences in cast iron, as Mr. Shaw pointed out, is not an attack on the chemist, although it has been continually taken as such. Unfortunately, many chemists who have been trained to make analyses —which did not control iron foundry metallurgy— have begun their works experience with the idea that it did, and many Papers have been given on that score. The physical properties of pig-iron. however, are due to other causes primarily, and are only modified by chemical composition. In a recent issue of the "Chemical Trades Journal" (dated October 31, 1921) was given an extract from Vol. 41, pp. 1285-1293, of "Stahl und Eisen" for 1921 as follows:—

> "The physical properties of the pig-irons are more important for successful working of the Thomas process than the chemical properties."

It is a fact that certain basic irons are preferred to others, not on the grounds of analyses, but on the results obtained.

With regard to the machining of test-bars, he was glad this had been mentioned, as he had shown in a Paper published before the Iron and Steel Institute in 1910 that machined bars gave fully 10 to 15 per cent better results than those tested as cast—taking into account the exact section of the bar. He believed in the transverse bar because it gave three different kinds of tests, tensile, transverse and deflection; and if these were worked out to the moment of resistance, as shown in the Paper just referred to, the engineer knew exactly what was desired just as well as the tensile would disclose.

In 1910 he remembered seeing the results, before publication, of an investigation by Meyer, of Wintertour, on different sized test-bars, published before the International Testing Association at the Copenhagen Congress of 1910. but he felt then there was much more work required before it could be definitely decided which shape and size of bar was the best for *British* practice, as it did not follow that what suited American conditions suited ours, and he thought they themselves should undertake on a very serious scale the duty of deciding what test-bar would be best for British requirements.

THE AUTHOR'S REPLY.

Mr. Shaw, in his reply, said he was pleased to hear that Dr. Swinden agreed that it was possible both oxygen and probably other occluded gases might have serious effects on the structure of cast iron. In this respect he was at one with the present Director of Research (J. E. Fletcher). Mr. Adamson, in his remarks, confirmed a theory long held by Dr. Moldenke, namely, that the effect of oxygen on cast iron might not be a direct one, but by its influence on the carbon. causing the balling up of the graphitic portion into fine particles instead of the usual plates. Personally, he thought, if the conclusions of Cain and Pettijohn were correct, there was only one thing to do, namely, to devote all energies to finding a more simple and correct method of determination than any at present in use. It seemed useless to form any opinions if the analysis was open to suspicion. Coming to the question of variation of strength in cast iron of the same composition, he was sorry no one had taken this point up more strongly, because it was a vital one. After allowing for all cooling effects and the minute variations in some of the elements, would anyone venture to say that these were the cause of a 50 per cent. increase of strength for 60 consecutive days. After eliminating all other factors, the only variation they knew of. was the fact that on the day one iron ran out, and was replaced by a new one to give the same ultimate analysis, the strength went up from 10.7 tons to 15.8 tons, and maintained that for the remaining 60 days. He had also submitted to them actual samples, showing the great variation between analysis and structure. It was open to any member to take two of these samples away with him and remelt them in any way they liked, providing they were not melted above cupola temperatures and also not held at a high temperature for a long time, but when melted cast into a sand mould, as the iron would be in the foundry. If these conditions were observed there would be no recovery of structure, and an iron containing T.C. 3.24 per cent., C.C. 0.25 per cent., Si 2.89 per cent., Mn 0.95 per cent., S 0.027 per cent., P 1.31 per cent., would still have the close fracture as at present, and would not recover when remelted to the open-crystal fracture of a No. 1 that would be expected from the analysis above. Nor would the 0.35 per cent. and 0.18 per cent. silicon irons on remelting under the same conditions show the mottled or white fracture expected, but still remain grey. There can be no outside element not accounted for in two of these samples, because we are using irons at the moment from the same furnace and ores, which are normal in all respects. Chemical analysis is not at fault, but the lack of knowledge of temperature effects in the blast furnace, due to irregular working, etc.; facts well-known to blast furnace managers. He would have been pleased if more expression of opinion had been voiced as to the advisability of using one size test-bar with varying loads for different thickness of castings or three different size bars, the latter to bear some relation to the thickness of castings they represented. Like himself, Mr. Hyde was in favour of the latter method. Captain Moorshead, in his spirited criticism, preferred the tensile bar. No foundryman would quarrel with him on that point, as it was more easily made than the transverse. In reply to Mr. Robertson's question as to the temperature at which the 60 bars were cast at, no actual tests were taken. In every case it was good hot metal. If he would consider that little variation in the results of the tests during the first 60 days, and it was only on changing the iron in the last 60 days' test that the large increase in strength took place, he would realise that temperature was not the dominating feature.

West Riding of Yorkshire Branch.

THE TRAINING OF FOUNDRYMEN.

By A. A. Liardet.

Modern Conditions.

It is an indisputable fact that at the present moment the very greatest difficulty is experienced in finding boys willing to be apprenticed to the art of moulding.

If this state of things continues—Necessity being the mother of invention—moulding will cease to be an art, and will degenerate into a mere mechanical process, carried out by workers depending on the brains of the pattern-maker and the mechanic.

The average boy is almost invariably interested in all things mechanical, but is rarely attracted by the outwardly drab occupation of playing with dirty sand, which is how the moulder's occupation is looked upon by the outsider, all ignorant of the skill and experience necessary to become a proficient foundryman.

This being the case, it becomes almost the foremost duty of an organisation such as the Institution of British Foundrymen to consider, and, if possible, recommend for adoption, means by which foundry work and its various branches can be made more attractive to the average boy just ready to leave school.

We should go a long way towards accomplishing this if we could adopt in our foundries in conjunction with the local Technical Institutions, a system of training which would afford equal facilities to every class of boy entering a foundry, to attain before the completion of his actual apprenticeship—by his own exertions and proficiency—a knowledge of the higher branches of foundry work, such as metallurgy and the selection of materials.

Co-operation of Technical Schools.

In the past, technical schools have not catered for the training of the foundryman, but of more recent years several of the larger establishments have been running a course in this branch of engineering, and it is now the wish and intention of the Bradford Technical College to inaugurate such a course in conjunction with the foundries of the district.

When considering the question of any sort of training the first point to make clear in one's mind is the final result we wish to achieve. What is the object of the training? What are we aiming at to produce?

The Raw Material.

Training is a process of evolution, the shaping of raw material into some desired finished product, by means of carefully planned out progressive steps, very similar to any process of manufacture from the raw material to the finished article.

The materials upon which we have to work in this case are human beings—material sometimes presumed to be of a standard specification, but when subjected to analysis, of widely varying qualities, both physical and mental.

Any scheme therefore, which we may suggest, while keeping the ultimate desired result always in view, must provide for dropping unsuitable material into its proper grade, after having given it repeated opportunity to take the polish necessary for the next step in the evolution of the desired finished article.

It is useless to continue work on material, when that material is incapable of taking the preliminary polish.

Our system therefore, must also include an examination of this material, at a very early period of its evolution, to avoid the danger of throwing on to the scrap heap material which might have been suitable for some other purpose, but rendered useless owing to the fruitless work that has been done upon it.

Having determined these points as axioms in the problem of the training of foundrymen, our next task is to decide on the final result we wish to achieve, and the various gradings into which we shall have ultimately to consign our raw material, according to its capabilities of absorbing the training we are going to impart to it.

The diagram indicates the author's idea of the grading of the finished product, together with suggestions for the necessary training to produce it.

Doubtlessly many will recognise a similarity between this diagram and one that was published by the Engineers' Advisory Committee to the Bradford Technical College for the training of civil, electrical and mechanical engineers. This latter scheme has been adopted in a modified form, by most of the engineering shops in Bradford, and the experience gained from its adoption enables me to put forward this present scheme avoiding many of the difficulties which arose with the original.

Probationary Period.

Adopting the principle of grading, or more correctly, selection, we start by bringing a boy into the foundry between the ages of fourteen and sixteen, telling him that he is on probation until he reaches the age of sixteen, that until then, he will only be called upon to do light work, will have every opportunity of making himself familiar with foundry work, learning the routine, and observing the conditions under which the foundryman spends the greater part of his day. We further tell him that at the age of sixteen he will have to pass a simple test examination in mathematics, engineering science, and engineering drawing, which he must study at the branch schools evening classes.

We also make it quite clear that he is under no obligation to enter on a trade apprenticeship, nor do we bind ourselves to take him as an apprentice if he is not fit physically or otherwise, to follow the calling of a foundryman.

Here we have our preliminary grading or selection. If a boy fails to show a sufficient knowledge of the elementary subjects mentioned above, or is unsuitable for foundry work, he has to choose some other trade. At the early age of sixteen no harm is done, he still has ample time to take up and learn some other subject.

Ability to Read Drawings Essential.

At this point the author cannot emphasise too strongly the absolute necessity for all foundrymen to have some knowledge of engineering principles. How many otherwise most excellent foundrymen of to-day are hampered by their inability to read a drawing? How often does it happen that it is only when the pattern is in the foundry, or worse still, when the casting is made, that the foundryman can point out obvious errors in design leading to cracked or drawn castings?

On many occasions since the formation of this Branch has the opinion been expressed, that half of the foundry wasters are made in the drawing office. This is only too true, and implies a lack of co-operation between the designer and the foundryman, or more often, because the foundryman has not thoroughly understood the drawing when it was shown him.

It is for this reason that it is desirable to include a knowledge of engineering drawing, or at any rate an ability to read simple drawings, as a necessary qualification of the would-be foundry apprentice, and advocate continued instruction in this subject during at least the first two years of apprenticeship.

Trade Apprenticeship.

This preliminary grading having demonstrated that the boy is satisfactory, he commences his trade apprenticeship approximately at the age of sixteen.

Nothing definite can be said at the moment on the advantages or disadvantages of apprentice indentures, or what is often termed the binding of apprentices. It is only reasonable that if employers agree to give facilities to boys to take such a course of training as is laid down here, they should ask for some form of assurance that the young man will not run away before they have obtained any real benefit from his services, as soon as an opportunity presents itself for him to improve his position.

On the other hand, if the training is attractive enough and the youth really in earnest, no such temptation should ever arise.

From 16 to 17 the practical work in the foundry would consist of light sand core-making, and light bench moulding.

In many foundries it is the custom to put the apprentice with one or more experienced moulders as a helper, often working on heavy and intricate moulds. This appears to me a case of trying to make him run before he can walk.

Age	14 15 16	17	18
Practical Training	Boy can Start any time between the ages of 14 & 16. Employed in Foundry on Light Work, handling of Patterns, with every opportunity to see Pattern Shop work. Not finally Apprenticed until age of 16.	Commences Trade Apprenticeship Moulding and Core-making. Light Sand Core and Moulding Work.	Continuation of Trade Apprenship. Advanced Core-making and Moulding Work in Sand.
Technical Training.	Mathematics. Engineering Science Engineering Drawing. At Branch Schools. Evening Classes. Test Examination for Fitness to enter Technical College on Apprenticeship.	Mathematics. Engineering Drawing. Chemistry. Two Nights a Week at Evening Classes, or on One Half Day per Week.	Theory of Pattern Making from Drawings. Simple Metallurgy. Chemistry. Two Nights a Week at Evening Classes or on One Half Day per Week.
	Probationary Period.	Trade. Apprenticeship.	Trade. Apprenticeship.

Suggested Scheme for

During the probationary period he will have had sufficient opportunity to learn the root principles and methods of moulding, so that when given a small pattern or core box he should know, at least, what he is expected to produce from it.

Every foundry foreman should select one of his assistants, either an under-foreman or charge hand, whose especial care it should be to supervise generally the work of all apprentices. In large foundries, where many apprentices are employed,

	19	20	21
Continuation of Trade Appren-ship. Heavy Sand Moulding. Loam Moulding.	HIGHER GRADE. Moulding Six months. Furnace Work. Metal and Sand Mixing.	HIGHER GRADE. Moulding Six months. Laboratory and Research Work.	Progress made in Shop Work will be taken into consideration in conjunction with result of yearly examinations for decision as to subsequent disposal.
	LOWER GRADE. Continuation of Trade Apprenticeship to Moulding or Coremaking.	LOWER GRADE. Continuation of Trade Apprenticeship to Moulding or Coremaking.	
The Blast Furnace Grades of Ore and Pig Iron. The Iron Foundry Cupola. Steel Making Plant. Refractory Materials. Moulding Sands. Metallurgy. Chemistry. Two Nights a Week at Evening Classes, or on One Half Day per Week.	HIGHER GRADE. Steel Making Processes. Microstructures. Annealing. Metallurgy. Equivalent one half day per week.	HIGHER GRADE. Advanced Metallurgy. Heat. Treatment. Alloy Steels. Equivalent one day per week.	Annual Examinations corresponding as near as possible to the completion of each year of Apprenticeship will be held, to decide subsequent Technical Training. Failures relegate to lower grade or, if repeated, disqualification.
	LOWER GRADE. Continuation of Simple Course in Foundry Metallurgy and Chemistry. Equivalent One Half Day per Week.	LOWER GRADE.	
Trade.	Lower Grade.		RESEARCH WORK. ASSISTANT FOUNDRY MANAGER. ASSISTANT METALLURGIST. FOUNDRY CHARGE HAND. SKILLED MOULDER OR COREMAKER.
Apprenticeship.	Continues Trade Apprenticeship.		

THE TRAINING OF FOUNDRYMEN.

it would be quite reasonable to appoint a thoroughly skilled practical moulder whose sole duty would be the supervision of apprentices' work.

The art of founding is one of the most ancient.

its secrets and mysteries have been handed down from generation to generation. In a constructive art of such antiquity there must of necessity exist many traditions—not only many traditions, but many conflicting traditions. The present-day student of the art is likely therefore, if not supervised by one selected workman, to be at the mercy of many conflicting and erroneous traditions, gathered from the many instructors with whom he would otherwise come into contact.

Naturally, the descipline of the foundry would have to be maintained, and any such supervisor would not control what the apprentice should do, but only how he should do it.

During this period the technical training would consist of mathematics, engineering drawing and chemistry. By mathematics it is not intended to convey that instruction would be given in analytical or geometrical conics, integral calculus and all the other advanced subjects covered by this term, but rather plain applied arithmetic, simple algebra and geometry, all to enable the student to understand engineering drawing and the simple calculations entailed in chemistry. The statement is advisedly made that this instruction should be taken at evening classes (or on one half-day per week), because at this juncture it would be going too far in saying that we recommend day classes without having consulted employers on their views on the subject.

Day Classes Preferable.

It should be stated, however, that the day class is more satisfactory in every respect. Not only has the employer a definite control over the attendances, as he can insist on the apprentice attending, and call for reports of his work, which he cannot do in the case of voluntary evening classes, but also it is far more likely that the boy will derive greater benefit and learn more, from instruction given to him after only having done a few hours' manual work, than he would at the end of a full day's work.

During this period it is considered inadvisable to include any subject touching on actual foundry work, as the apprentice will have quite sufficient new ideas to absorb regarding foundry practice during the day. Chemistry only is introduced, additional to the engineering drawing and mathematics, a knowledge of which is so essential to the foundryman.

The chemistry would be of such an order as to serve as introductory teaching to metallurgy, which appears later in the course.

Practical Side the Most Important.

From the diagram it will be seen that no further definite selection takes place until the age of 19. A process of automatic grading, however, is taking place. From 16 to 19 a steady progressive course is recommended, the apprentice being gradually advanced on to more important and intricate moulding, while his technical instruction carries him up to simple metallurgy with a knowledge of the various melting and refining processes.

Examinations would be held at the end of each session, and reports furnished on the progress made in the foundry.

Failures at examinations would necessitate the student continuing instruction in the subjects he has failed in, instead of progressing to the more advanced work of the next year.

This would constitute the grading, but would give boys who develop late, a chance of reinstating themselves at the next examination, and enabling them to continue with the others on the progressive course.

A second failure would naturally point out the inability of the boy to absorb technical instruction, but even this would not debar him from continuing on a lower grade course, or if he preferred, from dropping class work altogether.

Our system is such, that during the whole of this period he is learning the trade of a skilled moulder, so that his failure in technical work, and his decision to drop it, would not prevent him from completing his trade apprenticeship.

We must not lose sight of the fact that a man may be a thoroughly competent skilled moulder with very little technical knowledge beyond that which he can learn from actual experience in the foundry, although the more instruction he receives in subjects concerned in his work, the more intelligently and satisfactorily will he accomplish it.

Knowledge of Pattern-Making Included.

The theory of pattern-making and moulding referred to in the technical training between 17 and 18, will constitute a link between the knowledge of engineering drawing already gained and the principles of pattern-making and moulding.

If a boy wishes to become a pattern-maker, the author would endeavour to teach practical pattern-making and moulding. Not even a moderate degree of skill can be imparted to a student in either of these subjects in the relatively short time which is at his disposal.

If the boy wishes to become a pattern-maker, he must be apprenticed to a pattern shop and learn to make patterns; if he wishes to become a moulder then he must be apprenticed to a foundry and learn to mould. There is no need for the moulder to try to make patterns, nor for the pattern-maker to try to make moulds, but there is *every* reason for the moulder to know how patterns are made, and the pattern-maker to know how moulds are made.

This, then, must be the function of technical institutions with relation to the training of foundrymen: to impart to the student a knowledge as to how patterns should be made from engineering drawings, to show by means of actual patterns the meaning of prints, cores, loose pieces, draw-backs, turn-over boards, skeleton patterns, struck-up patterns, etc., etc., bearing in mind that there is no logical reason for a moulder to know how even to sharpen a chisel or set a plane iron.

College Foundries Criticised.

A foundry department in a technical institute for the purpose of preparing moulds and running castings is a waste of money, and no exceptions are made for those establishments running a diploma or degree course for mechanical engineering, including foundry work.

The theory of moulding, however, should be taught, the theory underlying contraction, the effect of risers, chills, the difference between dry and green sand moulding, etc., etc. A small cast-iron melting plant should be available for making test pieces from various mixtures, carrying out experiments in shrinkage and other more scientific investigations in connection with castings other than the actual making of the castings themselves.

The simple metallurgy referred to would not at this period include any practical analysis; in fact, practical analytical work is not advocated until after the age of 19, and then only to those apprentices who have qualified for the higher grade course and whose attainments appear to indicate that they are ultimately fitted for occupations in which a practical knowledge of analysis as applied to foundry work, is essential.

Lectures would be given dealing with the properties of metals, the theory of the blast furnace, grading of pig-iron, the iron foundry cupola, steel-making plant, and the alloys of copper, zinc and tin.

Necessary Apparatus Defined.

Practical work would be confined to experiments such as the reduction of ores, the examination of the physical properties of various metals and mixtures of metals, as revealed by the recognised mechanical testing appliances, and possibly a few simple laboratory experiments showing how to detect the presence of certain elements in various alloys.

At the age of 19, the most important grading or selection in the whole course takes place. It is at this point that we determine by examination the progress made by the apprentice in the shop, whether he should follow, for the last two years of his training, an advanced course which would fit him, at the expiration of his apprenticeship, for the positions of responsibility in a foundry, or continue his trade apprenticeship, with such additional technical instruction as he can absorb, ultimately becoming a skilled moulder or coremaker.

Training Raises Status.

However democratic our scheme may be, offering as it does equal opportunities to all, a few only will rise, whilst others less favoured with the necessary talents will remain on the lower level, but at a level considerably higher than they would have attained without the opportunities of gaining the knowledge and experience which such a scheme as this affords.

This last consideration is perhaps one of the most important in the whole scheme. We mislead no apprentice as to what position he will be fit for on completion of his time. We continue to instil into him the fact that he is apprenticed to the trade of a moulder or coremaker, with opportunities to rise. Even if he is not successful, the existence of these opportunities must lead him to absorb a large quantity of the instruction offered for his consumption, so that he finishes his apprenticeship as a skilled craftsman, with an intelligent knowledge of the technicalities of the materials with which he works.

The higher grade training in the works for apprentices who attain the necessary standard at the age of nineteen, would consist for the first year of furnace work and practical experience in the mixing of metals and preparing refractory materials.

In the iron foundry they should be actually employed on the cupola, in the brass foundry on the mixing and melting of the various alloys, and in the steel foundry on the furnaces and annealing stoves.

Moulding of Primary Importance.

It is suggested that for approximately six months in each of the last two years, the apprentice following the higher grade should return to moulding.

In some of the projected training schemes for foundrymen, and one of the conditions laid down by the proposers, is, that the co-operation of employers should be enlisted to find employment for the highly-trained product. This, of course. is a highly impractical suggestion. A demand for such men cannot be created.

It is for this reason that the author suggests the six-months' moulding during each of the last two years, so that in the event of the apprentice passing successfully through the higher course, but not being able to find on the completion of his apprenticeship a vacancy in a position of responsibility in a foundry to which the knowledge he has acquired fits him, he will not have lost touch with practical moulding, and can take work as a moulder until a more favourable opportunity occurs for his advancement.

Works Laboratory Practice.

The last year of practical training includes laboratory and research work. A laboratory is not found in every foundry. Where such a department exists, it is undoubtedly better for the apprentice to study practical laboratory work there than in an academic institution of a similar kind, provided that, as our scheme provides, he has had instruction in chemistry and metallurgy at an institution where it is the business to teach. The average works metallurgist is far too busy a man to afford time to instruct young men in the rudiments of chemistry. In a foundry laboratory they would learn the routine of foundry analysis and its application to practice.

Apprentices in foundries not having laboratories would perforce have to be drafted as whole-time students to a technical institution having facilities for teaching practical laboratory work, and ample opportunity afforded them for visiting the laboratories of other foundries in the district.

The technical training during the last two years would consist of theoretical work in connection with the advanced practical work referred to above. Several of the subjects are enumerated on the diagram, but they are only meant to serve as an indication of the standard of work undertaken, and by no means limit the instruction to the actual subjects mentioned.

Foundry Research Workers.

In the last year a longer weekly period for theoretical work is advocated, and in exceptional cases the desirability of liberating the young man from apprenticeship and allowing him to enter some establishment where foundry research work and metallurgy are solely carried out should be considered.

It will be noticed at the foot of the last column of the diagram a suggestion for the final grading of the finished product. The type of positions which the fully-trained young foundryman ought to be able to fill. The author realises that he will incur the criticism of many of the more scientific fraternity by recommending that the training for the foundry research worker and metallurgist should be based on an apprenticeship to foundry moulding. Possibly for pure research work and metallurgy such training is not necessary, but when these have to be applied to practice, the only way the metallurgist can learn how it should be applied is by studying the methods and operations to which he has to apply it. A knowledge of the theory of music is essential to make an accomplished pianist, but he would have no use for an instructor in this subject who could not play the piano. Abstract scientific metallurgy is of little use in a foundry.

The practical foundryman of to-day is groping in a fog—not a fog of his own making—as no one can dispute the fact that British foundries have turned out castings which are second to none in the world.

It is a fog set up by the conflicting theories and dogmas of scientific advisers, who, from the mentality developed from an abstract academic training, are unable to examine the many foundry problems with that broader outlook which a partially practical training imparts.

On the other hand, we must admit that very valuable work has been carried out by scientific research, and that practical scientific control carried out by the right type of man is an absolute essential to the successful operation of a foundry. We should regard the present relation it bears to practical problems as being in the process of evolution.

Whilst the practical foundryman is dropping many of his erroneous traditions by rubbing shoulders with scientific control, scientific control is dropping many of its unappliable scientific investigations by rubbing shoulders with the practical foundryman.

Conclusions.

The scheme elaborated is meant to illustrate in principle only a proposal for the training of foundrymen. It is incomplete in many details.

The actual number of hours to be devoted each week to technical instruction would have to be decided by those accustomed to drawing up a syllabus of instruction. Whether this instruction should be given in the daytime or at evening classes would be a matter for the employer to decide, as also whether the apprentices should receive wages for the time spent at day classes, if these were adopted. Very little mention has been made of malleable and non-ferrous foundries, but the principle of training would remain the same.

It should be stated that those responsible for the organisation and control of this technical institution are willing and anxious to co-operate in a scheme of this kind, and are prepared to recommend the establishment of plant, laboratories, and syllabus to provide for a course of training similar to the one here laid down. Additionally, it would have the whole-hearted support of the Engineering Advisory Committee to the Bradford Technical College.

The author wishes to acknowledge his indebtedness to the Principal, Professor Richardson, and to Professor Charnock, for enabling him to state with confidence that such a course could be readily put into operation at this college provided certain additional plant and apparatus were installed.

If a recommendation for some such scheme—after it has been duly criticised—were made by local foundrymen, the attention of those able to put it into operation would be forced as to the desirability and necessity of its adoption.

What more fitting body is there than the Institution of British Foundrymen, to discuss, to decide and recommend, what is the best scheme for the training of foundrymen?

DISCUSSION.

Mr. Bullock, supporting the scheme, said that it would be necessary to advertise it very widely, to let boys know what training and chances they would get if they decided to learn the art of moulding. This would be necessary, as otherwise the putting into operation of such a scheme would not attract more boys to the foundry.

Mr. Slingsby generally approved of the scheme, and emphasised the point brought out by Mr. Bullock. He had had some experience with instruction in practical founding as given at a technical institution, and knew the difficulties entailed. He was strongly opposed to any endeavour to teach practical founding in such an institute.

Mr. W. H. Poole said that although a metallurgist and engaged almost entirely on research work, he was strongly in favour of the works metallurgist receiving a partial training in the foundry. He was of the opinion that this would lead to what everyone wished for—the best type of practical scientific co-operation.

Mr. Smith, whilst generally approving the scheme, foresaw great difficulties in putting it into operation, especially in small foundries where employers depended in a large measure on the apprentices to get the output. Such foundries could not spare apprentices to attend technical classes, and had very little facilities for affording experience in any work other than the actual moulding. He strongly advocated the day class instead of the evening, as he knew the tendency for boys to go to sleep in the evening classes after a day's hard work. He was of opinion that no practical moulding should be carried out at technical institutes, boys only spent their time throwing sand at each other in such classes.

Mr. Watson, in supporting the scheme, said he had had actual experience in giving instruction in foundry practice, and knew the great benefit which apprentices derived from gaining some technical knowledge of the work they were engaged upon.

Mr. Parker thought the scheme would break down with apprentices working in highly specialised foundries, where they would have no chance to learn other moulding than the special work upon which the foundry was engaged.

Mr. Groves was of the opinion that the time suggested per week for technical instruction was far too short. There was so much to teach that one half-day or two evenings per week would be quite inadequate.

Mr. Thornton generally approved of the principle of the scheme, but thought there was so much in it that wanted careful consideration, that it ought to be printed and sent to all members and interested parties for their written criticisms.

Mr. Love thought that one of the chief difficulties in obtaining apprentices to foundry work was the low wages paid. Parents could not afford to keep their boys at a trade, even with special opportunities for learning and advancement, if the wage they earned was so small.

Mr. Robinson thought the chief objection to the scheme was that employers generally would not welcome it. Not only would it be a source of expense, but it would lead to disorganisation of the foundries, if boys were allowed to go to classes during working hours, and be moved to other jobs just at an age when they were really becoming useful.

THE AUTHOR'S REPLY.

The Author (Branch-President) replying to the various points raised in the discussion, said that he entirely agreed on the necessity of advertisement, but submitted that this would be accomplished through the branch schools. Headmasters of schools would be enlightened on the necessary qualifications for, and advantages offered to, boys who decided to learn foundry work. They would have to guide their early education to enable them to pass the preliminary qualifying examination to the Technical Institute at the age of 16. He reminded those who spoke against practical foundry teaching at a technical school that he had made it very clear in his paper that he was absolutely opposed to it. He acknowledged the difficulties of the small foundry and the specialised foundry, saying that this had been recognised with reference to the training of engineering apprentices now in operation in Bradford. A suggestion had been made for an exchange of apprentices between different works, to enable all to obtain equal experience, but after consideration, this idea was not adopted. At the present moment he could only say that if such a scheme were adopted, these foundries would find a difficulty in obtaining apprentices, as they would naturally wish to go to those offering the best facilities for gaining an all-round experience. In replying to the difficulty of low wages paid to foundry apprentices, the President said that if we were considering a scheme for the betterment generally of foundrymen of the future, some sacrifices would have to be made. The employer, who would ultimately reap the benefit of a supply of better trained and more intelligent workmen, would have to put up with the inconveniences and expense of allowing apprentices to take up such a course, while the parents would have to be satisfied with the boy's reduced breadwinning capacity in order that their son might benefit by it in the future. He submitted that boys whose sole immediate object was to earn as much money as they could, were not likely to make efficient foundrymen. Whilst acknowledging the fact that the inauguration of such a scheme entirely depended upon the co-operation and willingness of the employers, he did not agree that there was likely to be any opposition from them. He felt sure that employers would recognise that it was about time that something should be done for foundrymen. Every employer realised the difficulty of obtaining apprentices to foundry work.

After the discussion, on the proposition of Mr. Robinson, seconded by Mr. Johnson, the following resolution was unanimously adopted:—

> "That this general meeting of the West Riding of Yorkshire Branch of the Institution of British Foundrymen heartily approves of the scheme of training for foundrymen detailed in the paper given by the Branch President, and recommends the foundry employers in the area to give it their serious consideration as a means of ensuring a better supply of foundry apprentices and generally improving the status of the foundryman of the future."

Lancashire Branch.

Burnley Section.

MELTING STEEL AND CAST IRON IN THE CUPOLA

By J. Hogg.

Much experimenting with steel and iron mixings has been carried out by experienced foundrymen, both at home and abroad, and many of them have been extremely successful, chiefly with amounts of steel varying from 10 to 40 per cent.

It has been the practice to refer to cupola melted mixtures of steel and iron as semi-steel. Many ironfounders and engineers have unbounded faith in, and enthusiasm for semi-steel mixtures, for without doubt, such mixtures are extremely useful for certain classes of work. The writer has cast piston rings in large quantities, which have given satisfaction, using a 20 per cent. addition of steel, and has preference for the mixture because of its fine wearing surface.

The writer's first experience in putting steel in the cupola with iron took place about eight or nine years ago. He had to deal with an order for six rollers, about 2 ft. 6 in. dia. with a 12 in. face, and with the order came a request that the castings should be made of a good wearing metal, as those previously supplied were of soft grey-iron and had worn away very rapidly. At the same time the castings had not to be too hard to machine, and had to be dense in character. One of the old hands in the shop advised the putting of a few old files in the ladle and tapping the iron on to them. This method did not appeal to the writer, as he had seen it done in his apprentice days with very indifferent results, and had often heard the method criticised. It was decided to adopt the method recommended by various lecturers at that time and put the steel in the cupola with the iron. Twenty per cent. was charged in small punchings of mild steel, and good risers were made on the castings. The moulds were skin dried, and the results were satisfactory, although the castings were harder than the usual grey-iron mixture, but they machined up very well.

These mixtures have been used very often since that time and have been quite satisfactory.

Steel Turnings Used.

During the latter part of the war, when C.I. shells were being made in large quantities, and a high tensile-test had to be furnished, many foundrymen used steel and iron mixtures, among them was included the writer. Fairly high combined carbon helped to provide a satisfactory tensile test, and the use of steel provided the necessary combined C. without resorting to white iron, which would not be satisfactory for machining purposes. It also helped to provide a good sound casting. On a charge of 10 cwts., 5 cwts. of good scrap were used, 3½ cwts. of pig-iron of two brands which were considered suitable, and 1½ cwts. of steel. Owing to the great amount of steel required each day, punchings could not be obtained, so steel shavings from the shell turning department were substituted, the method proved successful. The shells were clean, dense and machineable, the tensile test which was taken from the body of a shell, chosen by the inspector, varied from 12.1 to 14 tons. After a few days' continuous progress, a difficulty arose. The castings began to harden up, and this was soon traced to the re-melt among the scrap, which was used in the proportion of 20 per cent. Reference is made, of course, to runner heads, risers, and gates. It was necessary to reduce the steel to 1 cwt. per charge for a few days, and this method helped us to soften the castings a little, without affecting greatly the density or the tensile result. The hardness and tensile strength were tested daily, in the morning, and the proportion of steel varied accordingly.

One test gave the following result :—The analysis of one test, which gave tensile 13 tons and machined easily, was Gr.C., 2.70; C.C., 0.65; Si., 1.8; S., 0.11; Mn., 0.34; and P., 0.59 per cent.

It was thought that the Mn. ought to be higher, perhaps double the quantity, and eventually a brand of pig-iron was chosen that was thought would give a reasonable amount, but after ordering it the firm was unable to obtain delivery at that period, so no change could be made.

The writer often uses steel now in amounts of 15 per cent., and it is fairly satisfactory, and always so if the metal is poured hot. Small pieces of plate or cuttings of mild steel bars seem to be best for the purpose.

Practical Details.

A good bed of coke is used of good quality. The pig-iron is placed on the coke and limestone, then the steel, and last of all the scrap. No receiver is attached, but effort is made to get the charge melted completely before tapping into the ladle, because it is presumed that the charge must be well mixed.

A very high temperature is favoured, as the metal had to be very hot when poured, because of the danger of hard spots. If the mould is a green sand one it is best to have it on the dry side if possible. A dry sand mould would be better still for the purpose. If the metal is at all "dull," blow-holes are almost certain to appear when machining the castings, or if the metal is not well mixed, or the mould damp, hard places will appear, causing the casting to be rejected. It is advisable to have the metal analysed at intervals, or at least to test for combined carbon, which must not get above 0.85 per cent., if the castings require machining.

A Simple Hardness Test.

A test the writer has had strongly recommended to him for testing the percentage of combined carbon is to polish a small sample of the iron and then boil it for a few moments in sodium picrate. The combined carbon will assume a rich brown colour, and there is not much difficulty in judging its amount from day to day. This is a special test for hardness, and can be carried out by means of a low power microscope.

Applicability of Semi-steel.

Steel additions are also useful for getting a good transverse strength, and it is particularly applicable for beams, girders, pipes which may have to hang over a large span, without much support and even light section castings which do not require much machining, such as levers for valve work. Ten per cent. of steel added to 40 per cent. pig and 50 per cent. good scrap will give good results if mixed properly and melted at a fairly high temperature. Common iron with steel added are often made to fill the place of higher-priced irons. Personally the writer would not eliminate the better class iron entirely, but reduce the quantity, say, from 20 to 10 per cent., or in such proportion as may be considered necessary. Of course, these mixtures will not take the place of steel itself. It has been found that firms which were having castings made in steel, and after hearing of the so-called semi-steel, decided to change over to this product because of the price. They have made the mistake of expecting semi-steel to replace steel, but needless to say it will not do that. For improving grey cast iron it is eminently suitable when used with discretion.

Order of Charging.

In a jobbing foundry where different mixings of metal are required, and some of them are to be steel mixtures, it is suggested that about two tons of grey cast iron be melted first, so that the cupola may have a chance of becoming heated to a high temperature before starting to charge the iron and steel mixtures. An extra layer of coke may be placed above the last grey-iron charge, so that the grey-iron charge may have time to be removed before the steel mixture begins to melt and fall into the bottom of the cupola. The lighter cast scrap will, of course, be put on the last of each charge.

The coke should not be used too sparingly with an iron and steel mixture. Of course, it is not meant that it should be wasted, but sufficient should be used to ensure hot melting. If possible the metal should come down the spout bright white in appearance, or even dazzling white, if it has any distance to be carried. The writer would say that he has found Pouilett's table, published in Professor Rhead's book on iron founding, a useful method of judging the temperature of molten metal without a pyrometer.

An excess of limestone should be guarded against, as owing to the high temperature used in the cupola it may result in destroying the cupola lining and the face of the bricks.

The lecturer hopes the remarks made are as plain and as practical as he had hoped they would be. Perhaps more details about the structure of the mixtures might have been given and also of the method of melting the steel, and of the steel taking up its carbon from the coke, etc., before becoming fusible, but he felt that first of all interest must be aroused, and then one would be able to take up the study of the subject more deeply afterwards.

He is not prepared to recommend the addition of steel to the metal in the ladles, because of one vital point. It lowers the temperature of the metal in the ladle, and this is vital. A foundry foreman had better not use steel at all and keep to his grey iron mixtures rather than attempt to cast steel mixtures at a low temperature. Keep to high temperatures if success is to be obtained, and also remember that the following rule applies:—

Softness to hardness.
Weakness to strength (Tensile).

For transverse strength aim at a lower total carbon with just sufficient Si to keep the combined C. below 0.75 per cent.; if this proportion is increased machining difficulties will arise.

If steel turnings are to be used, it can be done successfully if one charges by weight and sees that the light shavings of steel are kept from blowing up the cupola chimney.

DISCUSSION.

Semi-Steel Firebars.

Mr. Cooper asked whether more coke was required for melting the mixture of steel and cast iron than was usual in ordinary foundry practice. Was that an item of extra cost to be taken into consideration? Was the mixture suitable for heat-resisting castings, such as annealing pots, furnace frames or firebars? Was it worth while to put steel into castings of that description in order to get a superior firebar which would last longer? Could not the quantity of Scotch iron be reduced by substituting No. 1 for No. 3, and would the difference in price be justified?

Mr. Hogg replied that extra coke would certainly be required. He had heard it claimed that textile castings could be produced using 1½ cwt. of coke to the ton, but he had not been able to do that satisfactorily himself. He thought it would take 2¼ cwt. per ton to melt iron and steel effectively. A lesser quantity might suffice, but he had seen iron coming down perfectly melted, but with very thin steel shavings imbedded in it, and that was due, he thought, to an insufficient quantity of coke. Before steel could be melted it had to take up a certain quantity of carbon, and it took that up from the coke and the iron in the cupola. If there was not enough coke it did not get the requisite amount of carbon and would not melt.

A mixture of steel and iron he should consider ideal for firebars, because they would have a longer life than the ordinary soft grey iron bars. He had himself cast quite a number.

No. 1 or No. 3 Pig?

He hesitated to say whether there would be economy in substituting No. 1 for No. 3 Scotch iron; it depended on the price. With a reduction of 14 lbs. the same chemical analysis would be obtained associated with the same result.

Mr. Cooper: In my opinion it is more economical to buy No. 1 Scotch than No. 3, not for semi-steel alone, but at all times.

Mr. Miles pointed out that when starting with No. 1 they commenced with a low percentage of combined carbon. What would Mr. Hogg do with scrap that was left over?

Mr. Hogg stated that he would use it for bars and for heavier work such as brackets and pillars. He would mix with it a small percentage of ordinary common iron. It would be satisfactory when it was not intended to machine the casting.

Mr. Miles remarked that very good results were obtained for light machinery castings, with the following mixing: Semi-steel shell scrap, 50 per cent.; 4½ per cent. silicon pig-iron, 20 per cent.; ordinary shop scrap, 30 per cent. But care must be taken that the shop scrap did not unduly increase the amount of combined carbon.

Size of Heads.

Mr. Layfield asked whether it was necessary to have a bigger head with a semi-steel casting than with an ordinary grey iron casting.

Mr. Hogg replied that if a casting was required to be very dense, it should be furnished with a good head. He would not say that with semi-steel a bigger head was required than with soft grey iron, but he would certainly advise putting a good riser and a good head.

Temperature Considerations.

Mr. Hogg gave the following figures (degrees Centigrade) as showing the appearance of liquid iron: Deep orange, 1,100; clear, 1,200; white, 1,300; bright white, 1,400; dazzling white, 1,500.

Mr. Hogg, replying to Mr. Barnes, said the colour was due to the very high temperature. By putting on a large quantity of coke for a small percentage of iron they would get the metal melted dazzlingly white. He did not advocate pouring into the mould dazzling white, but by the time it got to the mould the temperature would have fallen somewhat.

Mr. Barnes suggested that dazzling white when poured into the mould would result in a sand-burnt casting.

Mr. Hogg agreed, but said the sand should be on the dry side. For a heavy casting the sand should be at least skin-dried. Sand does not penetrate deep into the casting. It would be pitted about the face of the casting. For instance, if a flat plate ¼ in. thick is cast, there would be seams all over on both sides, top and bottom. If the sand found its way into the metal it would make dirty castings. Semi-steel was not suitable for ornamental work which did not require any strength. For work of that class he would use the commonest high-phosphorus iron.

Mr. Miles said he thought it had not been made quite clear about the use of scrap. It had been proved when using a mixture of 40 per cent. steel that all the returns could not be used. In one foundry where 35 tons per day were melted, including risers and runners, 12 tons out of the 35 had to be re-melted. After several days it was found to be impossible to use that 12 tons with the

40 per cent. steel, so that it was cut down to 10 per cent. in order to enable all the returns to be used each day.

Mr. Hogg said he used exactly the same mixture. If at the same time he had had orders for ordinary work he could have got rid of the returns. He did not advocate using a high percentage of steel with a high-phosphorus iron.

Mr. Miles: I should say it was satisfactory if the percentage of phosphorus was not above 1.2 per cent. It is being used extensively with pig-iron containing 4 to 5 per cent. silicon.

Mr. Hogg, answering Mr. Barnes, said he thought a ratio of 1½ tons of coke to the ton of iron could be used with a cupola 2 ft. 8 in. dia. melting 10 tons a day. He had himself often melted with 2 cwt. His full blow was 10 or 11 tons, but it depended upon the nature of the work. With very light casting the iron could not be melted satisfactorily with 1½ cwt. to the ton.

Mr. Barnes, referring to a blow of 5 to 6 tons a day, said that before the war his cupola used to average 2½ to 3 cwt. of coke to a ton of metal, exclusive of bed, but now it has risen to 4 cwt.

Mr. Cooper said his work was fairly heavy work, and he used 3¾ cwt. to the ton.

Contraction of Semi-Steel.

Replying to a question as to the effect upon the allowance for contraction, Mr. Hogg said that depended upon the type of casting. With a long pipe, 9 to 10 ft. long, where the combined carbon was very high, there would be a considerable contraction, but in the case of a square or round block with a semi-steel mixture there was no need to make any difference in the allowance for contraction.

Mr. Beecroft suggested that the amount of carbon would be the same whatever the shape.

Mr. Hogg explained that the total amount of carbon would be the same, but because of the difference in the rate of cooling the proportion of combined carbon would vary. It was difficult to speak dogmatically on these points, for in some cases the contraction might be greater than in other cases. Differences occurred even when the same mixture was used.

Mr. Harwood, speaking on behalf of the engineering students, said the lecture had been exceedingly instructive. In the past the foundry side of the industry had been neglected in technical schools, and he was glad that in Burnley, which they were disposed to regard as a pioneer town, steps had been taken to encourage the education of foundrymen. At all times it was a pleasure to meet a practical man who understood his trade and could explain it, and more could be learned from him than from a purely academic man. The College had a good 25-ton testing machine, and if the engineering department could render assistance in regard to any phase of the craft they would be very pleased to give it. They felt that the foundry people could also teach them something.

The Chairman (Mr. R. Place) said during the war his firm, like most of the others in the town, were engaged upon munitions, and it was absolutely essential for them to experiment with the use of mild steel. Before the war they used to introduce a little hematite into the mixture when the tests of tensile strength were low. The castings were very light. During the munitions period they were not allowed to use hematite for that purpose; therefore they had recourse to mild steel. He regretted that they did not keep records of their experiences, because they would now have been very interesting, but at the time all their energy was given to getting out the work. In the past there had been a lot of secrecy among foundrymen, but the wiser policy was to make known anything that would help the trade as a whole. In that way they would bring back prosperity to the country.

A vote of thanks was accorded to Mr. Hogg, on the motion of Mr. Pell, seconded by Mr. Miles.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

LIST OF MEMBERS.

September, 1923.

B.—Birmingham Branch.
E.M.—East Midland Branch.
Lncs.—Lancashire Branch.
C.—Coventry Branch.
L.—London Branch.
N.—Newcastle-on-Tyne Branch.
S.—Sheffield Branch.
Sc.—Scottish Branch.
— General or unattached to a Branch.

B'nch.	Year of Election.	MEMBERS.
L.	1922.	Abaza, M. N., B.A., Vickers, Petter, Ltd., Ipswich.
N.	1921.	Adam, F., 25, Mitchell Avenue, Jesmond, Newcastle-on-Tyne.
B.	1919.	Adams, E., " Arclid," Vicarage Road, Blackheath, nr. Birmingham.
Sc.	1920.	Aitkenhead, R. W., Blacktoun House, Carron, N.B.
E.M.	1908.	Aiton, J. A. (Aiton & Company), Derby.
S.	1918.	Allan, J. M., Cyclops Works, Sheffield.
B.	1906.	Allbut, J. E. H., " Woodcote," Bourne Street, Dudley, Staffs.
S.	1906.	Allen & Company, Edgar (Subscribing Firm), Imperial Steel Works, Sheffield.
L.	1922.	Allum, A. W., 41, Devonshire Road, Greenwich, S.E.10.
Sc.	1920.	Anderson, Alex., Roebuck Park, Carron, Falkirk, N.B.
Sc.	1919.	Anderson, E. W., 46, Inverleith Row, Edinburgh.
Sc.	1920.	Andrew, J. H., D.Sc., Royal Technical College, Glasgow.

B'cnh.	Year of Election.	MEMBERS.
Lncs.	1919.	Andrew, J. W., 71, Middleton Road, Oldham.
L.	1918.	Armstrong, H., 108, Baldock Road, Letchworth.
N.	1921.	Armstrong-Whitworth & Co., Ltd., Sir W. G. (Subscribing Firm), Close Works, Gateshead-on-Tyne.
N.	1920.	Arrowsmith, J. K., 4, Dean Road, South Shields.
L.	1911.	Aston, W. H., 46, Eagle Wharf Road, London, N.
L.	1917.	Aynsley, J. M. V. (Miss), 4, Elsworthy Terrace, Primrose Hill, London, N.W.3.
N.	1918.	Aynesley, W. B., 62, Bath Lane, Newcastle-on-Tyne.
B.	1920.	Ball, F. A., c/o Ball Bros., Stratford-on-Avon.
—	1923.	Bargellesi, G., Casella Postale, 458 Milano.
B.	1922.	Barnsley, W. G., The Limes, Church Road, Netherton, nr. Dudley.
L.	1917.	Barraball, F. J., 181, Queen Victoria Street, London, E.C.4.
L.	1912.	Barrett, G. H., 14, Britannia Road, Bedford.
L.	1911.	Bartlett, A. R., 1, Lower Park Road, Belvedere, S.E.
L.	1923.	Bartram, J., 369, Grove Green Road, Leytonstone, E.1.
E.M.	1921.	Bates, W. R., United Steel Companies, Limited, Irthlingboro' Iron Works, Wellingboro'.
B.	1922.	Bayley, J. P., "Ty-gwyn," Clytha Park, Newport, Mon.
Lncs.	1919.	Beanland, A. E., 4, Oldfield Road, Sale, Cheshire.
L.	1920.	Beech, A. S., 97, Queen Victoria Street, London, E.C.
L.	1911.	Beere, H. O., 11, Lindon Grove, Peckham, London, S.E.
S.	1922.	Bell, G. S., 7, South Park, Lincoln,
Sc.	1910.	Bell, W., 336, Pollokshaws Road, Glasgow.

B'nch.	Year of Election.	MEMBERS.
—	1922.	Bell, Wm. Dixon, 72, Avenue Road, Itchen, Southampton.
B.	1923.	Bell, W. J., "Glenfyne," Pembroke Street, Gloucester.
Sc.	1919.	Bellis H., 12, Regent Street, Paisley.
L.	1919.	Benbow, M., "Ombersley," Carrington Road, Dartford, Kent.
S.	1920.	Benson, E. C., 303, Fulwood Road, Sheffield.
W.R. of Y.	1922.	Bentley, J. N., 6, Cocklington Terrace, Hull Road, York.
Lncs.	1922.	Bentley, L. A., Wood End, Bromley Cross, Bolton.
S.	1918.	Biggin, Frank, 19, Rupert Road, Nether Edge, Sheffield.
S.	1921.	Birchall, T., Latebrook House, Goldenhill, Stoke-on-Trent.
C.	1920.	Birkett, W., 11, Raleigh Road, Coventry.
N.	1921.	Birtley Iron Company (Subscribing Firm), Birtley Co., Durham.
—	1919.	Blair, A., 7, Derryvolgie Avenue, Belfast.
C.	1912.	Boote, E. M., 11, Lydgate Road, Coventry.
L.	1912.	Booth, C. C., Mildmay Works, Burnham-on-Crouch.
E.M.	1919.	Booth, J. H., Fletton Spring House, Peterborough.
L.	1920.	Booth, P. M. 4, Erchingham Park Road, Church End, Finchley, N.3.
Lncs.	1920.	Boswell, A., Premier Brass Works, Burnley, Lancs.
W.R. of Y.	1922.	Boyle, J., "Westroyd," Bramley, Leeds.
L.	1918.	Bradley, P. L., 55, Jerningham Road, New Cross, S.E.14.
N.	1922.	Brailsford, A., 18, Elswick Row, Newcastle-on-Tyne.
B.	1922.	Brandon, C., 62, Norman Road, Northfield, Birmingham.
S.	1921.	Breakey, J. E., 20, St. Andrew's Road, Sharrow, Sheffield.
Lncs.	1914.	Bridge, W., 199, Drake Street, Rochdale, Lancs.

B'nch.	Year of Election.	MEMBERS.
S.	1922.	Brightside Foundry Engineering Co., Ltd. (Subscribing Firm), Wicker Works, Sheffield.
Lncs.	1919.	Broad, W., 230, Dumers Lane, Radcliffe, Lancs.
Sc.	1919.	Brook, G. B., British Aluminium Company, Kinlochleven, N.B.
C.	1904.	Broughall, E. H., Alfred Herbert. Ltd., Edgwick Works, Foleshill, Coventry.
S.	1922.	Brown, E. J., 11, Newlyn Place, Woodseats, Sheffield.
L.	1921.	Brown, E. R. 136, Eglinton Road, Plumstead, S.E.
Sc.	1918.	Brown, N. M., Bogston, Greenock, N.B.
W.R. of Y.	1917.	Brown, P., Park Works, Lockwood, Huddersfield.
S.	1919.	Brown, P. B., 12, Gladstone Road, Sheffield.
W.R. of Y.	1922.	Brown, S. E., 12, Gledlow Wood Avenue, Roundhay, Leeds.
E.M.	1918.	Bryant, C. W., C.B.E., Westwood House, Thorp Road, Peterborough.
B.	1904.	Buchanan, R., F.R.S.A., 35, Thornhill Road, Handsworth, Birmingham.
—	1922.	Bull, R. A., 639, Diversey Parkway, Chicago, Ill., U.S.A.
E.M.	1910.	Bunting, H., 17, Marcus Street, Derby.
E.M.	1905.	Burder, K. M., "Clavering," Ashby Road, Loughboro'.
B.	1922.	Burn, A. J. H., 34, Old Road, Llanelly, S. Wales.
W.R. of Y.	1922.	Burnley, H., 59, Plaintrees Road, Bradford, Yorks.
N.	1915.	Burrows, Lyc., 36, Southwark Bridge Road, London, S.E.1.
S.	1923.	Butler, J., 63, Deepdale Road, Rotherham.
Lncs.	1918.	Butler, W., Borough Brass & Iron Works, Dukinfield, Manchester.
W.R. of Y.	1921.	Butterfield, P., 10, Eastfield Place, Sutton-in-Craven, Keighley, Yorks.

B'nch.	Year of Election.	MEMBERS.
N.	1914.	Buxton, W. B., "Westwood," Beechfield Road, Gosforth, Newcastle.
—	1909.	Caddick, A. J., Minas de Rio Tinto, Huelva, Spain.
N.	1919.	Calderbank, T. H., 75, Meldon Terrace, Heaton, Newcastle-on-Tyne.
Sc.	1917.	Cameron, J. (Cameron & Roberton, Limited), Kirkintilloch, N.B.
Sc.	1919.	Cameron, T. P., South Bank Ironworks, Kirkintilloch, N.B.
S.	1922.	Cammell Laird & Co., Ltd. (Subscribing Firm), Cyclops Steel and Iron Works, Sheffield.
Sc.	1911.	Campion, A. (Honorary Life), 3, Strathview Gardens, Bearsden, Glasgow.
N.	1912.	Carmichael, J. D. (Life), 10, Sydenham Terrace, South Shields.
N.	1912.	Carmichael, J. D., Jun. (Life), 9, Belgrave Gardens, Harton, South Shields.
S.	1918.	Carnegie, W., Firs Hill House, Pitsmoor, Sheffield.
L.	1919.	Carpenter, H. C. H., Prof. (Hon. Life), 30, Murray Road, Wimbledon, S.W.19.
S.	1921.	Castle, Geo. Cyril, "Lindeth," Victoria Park, Wavertree, Liverpool.
Lncs.	1905.	Chadwick, J. (Life), 12, Nuttall Terrace, Bolton.
Lncs.	1919.	Chadwick, J. N. (Life member), School Hill Ironworks, Bolton.
L.	1919.	Cheesewright, W. F. (Col.), D.S.O., 5, Duke Street, Adelphi, W.C.2.
Lncs.	1918.	Clark, A., 133, Denton Road, Audenshaw, Manchester.
S.	1922.	Clark, G., 61, Westbourne Road, Sheffield.
L.	1915.	Clark, H. S., 17, Filey Avenue, Stoke Newington, London, N.
N.	1917.	Clark, W. H., 152, Newport Road, Middlesbrough.
Lncs.	1919.	Clayton, T., 14, Stansfield Street, Rose Grove, Burnley, Lancs.

B'nch.	Year of Election.	MEMBERS.
L.	1917.	Cleaver, C., 10, Ringcroft Street, Holloway, N.1.
—	1917.	Clement, W. E., Morfa Foundry, New Dock, Llanelly.
L.	1913.	Coan, R., Aluminium Foundry, Goswell Road, E.C.
Sc.	1917.	Cockburn, N., 48, Murrayfield Gardens, Edinburgh.
L.	1922.	Coll, J., Comandancia General de Ingenieros, Sevilla, Spain.
N.	1912.	Collin, J. J., 19, Ingleby Terrace, Sunderland.
N.	1916.	Collin, T. S., 4, Argyle Square, Sunderland.
N.	1922.	Consett Iron Co., Ltd. (Subscribing Firm), Consett, Co. Durham.
B.	1904.	Cook, F. J., 139, Poplar Avenue, Edgbaston, Birmingham.
Lncs.	1918.	Cook, W. H. "Staveleigh," 434, Wellington Road, Heaton Chapel, Stockport.
N.	1921.	Cooke, W. W., 40, Sefton Avenue, Heaton, Newcastle-on-Tyne.
L.	1919.	Cooper, B. W., 13, York Road, Leyton, E.10.
N.	1921.	Cooper, J. H., 16, Cleasby Terrace, Corporation Road, Darlington.
L.	1919.	Corby, S. F., (R. B. Doulton, Ltd.), Lambeth Sanitary Engineering Works, Albert Embankment, London, S.E.1.
Sc.	1922.	Couper, J. C., Milton House, Dunnipace, Denny, N.B.
Lncs.	1922.	Cowell, A., 259, Manchester Road, Burnley.
B.	1920.	Cowper, W. J., Ivy Bank, Clive Road, Bromsgrove, Birmingham.
C.	1917.	Cox, E., 123, Hearsall Lane, Coventry.
E.M.	1914.	Cox, J. E. (The Rutland Foundry Company, Limited), Ilkeston.
C.	1919.	Craig, A., Earlsdon House, Earlsdon, Coventry.
B.	1922.	Cramb, F. M., 5, Triangle Villas, Oldfield Park, Bath.

B'nch.	Year of Election.	MEMBERS.
L.	1920.	Creek, W., 2, Eleanor Road, Stratford, E.
L.	1911.	Creighton, T. R., The Foundry, Stepney Causeway, E.
W.R. of Y.	1922.	Croft, Frank, 52, Pollard Lane, Bradford.
L.	1919.	Crosby, W. R.
B.	1920.	Cross, John K., 32, Park Hill, Moseley, Birmingham.
S.	1907.	Crowther, J. G., 5, Sharrow Mount, Psalter Lane, Sheffield.
Lncs.	1920.	Crowder, T. C., 92, Brewerton Road, Oldham.
E.M.	1919.	Culley, W., 6 Doncaster Road, Leicester.
Sc.	1906.	Cummings, W., "Hollybank," Keir Street, Dunblane, N.B.
L.	1923.	Curtis, A. L., 39, London Road, Chatteris, Cambs.
B.	1921.	Danks, A., "Northfield," Hucclecote, Gloucester.
Lncs.	1918.	Davies, H., 92, Hope Street, Dukinfield.
—	1919.	Davis, P. N., 29, Brunswick Road, Brunswick, Melbourne, Victoria, Australia.
L.	1923.	Dawes, C. E., 26, Keston Road, West Green, N.15.
S.	1916.	Dawson, W. J., 220, Newhall Road, Sheffield.
B.	1918.	Deakin, W., Thornleigh, Oakfield Road, Selly Park, Birmingham.
N.	1919.	Deas, P., 4, Blenheim Terrace, Coatham, Redcar.
S.	1917.	Desch, C. H., Ph.D., D.Sc., F.I.C., The University, Sheffield.
C.	1921.	Dicken, Charles, 2, Ash Street, Daisy Bank, Bilston.
L.	1922.	Dickson, J. (Herring & Son), Ironfounders, Chertsey.
Lncs.	1920.	Dixon, L., 252, Audenshaw Road, Audenshaw, Manchester.
L.	1914.	Dobson, W. E., "Newlyn," Grand Drive, Raynes Park, S.W.

B'nch.	Year of Election.	MEMBERS.
L.	1919.	Dodwell, A. E., 54, Rectory Road, Barnes, S.W.
Lncs.	1918.	Doughty, E., 54, St. Mary's Road, Moston, Manchester.
Sc.	1911.	Doulton, B. (Life), Doulton Ironworks, Hawkshead, Paisley.
B.	1920.	Dowell, P., 255, Long Lane, Halesowen.
L.	1923.	Downing, D., Britannia House, Titaghur, India.
S.	1921.	Duckenfield, W., 47, Dunkeld Road, Ecclesall, Sheffield.
W.R. of Y.	1922.	Duckham, W. J., 4, Oxford Villas, Guiseley, Leeds.
B.	1920.	Dudley, Wm. E., 5, Cobham Road, Halesowen.
S.	1921.	Edginton, G., 30, Springbank Road, Chesterfield.
B.	1922.	Edwards, A., "Dunbar," Old Bath Road, Cheltenham.
N.	1921.	Eldred, E. J., 21, Ford Street, Gateshead-on-Tyne.
L.	1909.	Elliot, A., Ingate Ironworks, Beccles.
L.	1904.	Ellis, J., 6, Eckstein Road, Clapham Junction, London, S.W.11.
S.	1918.	Elliss, J. A., 217, Middlewood Road, Sheffield.
L.	1919.	Estep, H. Cole, 2–3, Caxton House, Westminster, London, S.W.
E.M.	1918.	Evans, W. T., Mount Pleasant, Sunny Hill, Normanton.
S.	1920.	Fairholme, F. C., Churchdale Hall, nr. Bakewell, Derbyshire.
L.	1915.	Faulkner, V. C., Bessemer House, 6, Duke Street, Adelphi, W.C.2.
W.R. of Y.	1922.	Fawcett, Jos., 25, Ellesmere Terrace, Lidget Green Bradford, Yorks.
S.	1910.	Feasey, J., 192, West Parade, Lincoln.
N.	1918.	Fender, B., 15, Kenilworth Road, Monkseaton, Northumberland.
B.	1914.	Field, H., 12, Bayswater Road, Handsworth, Birmingham.
B.	1914.	Fielding, G., 15, Paget Road, Wolverhampton.

B'nch.	Year of Election.	MEMBERS.
B	1904.	Finch, F. W. (Honorary), 52, Denmark Road, Gloucester.
S.	1914.	Firth, A., junr., Prior Bank, Cherry Tree Road, Sheffield.
S.	1914.	Firth, F. W., "Storth Oaks," Ranmoor, Sheffield.
S.	1909.	Firth, T. H., Prior Bank, Cherry Tree Road, Sheffield.
—	1907.	Flagg, S. G. (Honorary), 1,407, Morris Buildings, Philadelphia, Penn., U.S.A.
B.	1922.	Fletcher, J. E., 8, St. James Road, Dudley, Staffs.
S.	1921.	Flower, J. A., 147, Middlewood Road, Sheffield.
Sc.	1917.	Forbes, J. T., 176, West George Street, Glasgow.
N.	1919.	Fortune, T. C., 76, Falmouth Road, Heaton, Newcastle-on-Tyne.
B.	1919.	Fosseprez, G., 3, Rue du Grand Jour, Mons, Belgium.
C.	1920.	Foston, G. H., Ivy Bank, Balsall Common, Berkswell, nr. Coventry.
Lncs.	1909.	Fowler, W. H., 53, New Bailey Street, Manchester.
L.	1920.	Frank, A. C., "Rozel," Knatchbull Road, Harlesden, N.W.
Sc.	1920.	Fraser A. R., Craigard, Bearsden, N.B.
Sc.	1920.	Fulton, David, 5, Brighton Place, Govan, Glasgow.
L.	1919.	Furmston, A. C., Hope Cottage, 211, Neville Road, Letchworth.
N.	1912.	Gallon, M. E., c/o Younger & Gallon, Atlas Foundry, Dunston-on-Tyne.
N.	1921.	Gardiner, E. T., Hoppyland House, Albert Hill, Bishop Auckland.
Sc.	1919.	Gardner, J. A., 24, South Hamilton Street, Kilmarnock, N.B.
L.	1922.	Gardom, J. W., 235, Park Road, Luton, Beds.
W.R. of Y.	1922.	Garforth, E. P., 48, Haslingden Drive, Toller Lane, Bradford.

B'nch.	Year of Election.	MEMBERS.
B.	1922.	Garland, F. W., "Homeleigh," Albany Road, Stratford-on-Avon.
Lncs.	1922.	Garner & Sons, Limited (Subscribing Firm), Victoria Street, Openshaw, Manchester.
Lncs.	1922.	Garnett, N., Bury New Road, Kersal, Manchester.
Lncs.	1919.	Gartside, F., 18, George Street, Chadderton, Lancs.
Sc.	1920.	George, John, Rosepark, Falkirk, N.B.
L.	1922.	Gibbs, A. F., 55, Gordon Road, Wanstead, E.11.
L.	1920.	Gillespie, H. J. W., 7, Tyson Road, Forest Hill, S.E.23.
Sc.	1920.	Gillespie, P., "Glenora," Falkirk Road, Bonnybridge, N.B.
E.M.	1915.	Gimson, H., White House, Clarendon Park, Leicester.
E.M.	1906.	Gimson, S. A., 20, Glebe Street, Leicester.
C.	1920.	Glover, S., Rookery Farm, Keresley, nr. Coventry.
S.	1905.	Goodwin, J. T., Red House, Old Whittington, Chesterfield.
N.	1922.	Gordon-Luhrs, Herman, 52, Moorside, Fenham, Newcastle-on-Tyne.
L.	1920.	Gower, A. B., 34, Sugden Road, Lavender Hill, S.W.
Sc.	1921.	Graham J., 27, Onslow Drive, Dennistoun, Glasgow.
Lncs.	1922.	Grandison, W. H., 113, Albert Avenue, Sedgley Park, Prestwich, Manchester.
Lncs.	1920.	Grant, G. C. (Sir W. G. Armstrong, Whitworth & Company, Limited), Ashton Road, Openshaw, Manchester.
N.	1921.	Gray, C. R., 14, Latimer Street, Tynemouth.
L.	1920.	Gray, S., 29, Crescent Road, Plumstead, London, S.E.
S.	1920.	Green, H., Ingleside, Clifton Lane, Rotherham.

B'nch.	Year of Election.	MEMBERS.
N.	1912.	Greensitt, R. H., 24, Stuart Terrace, Felling-on-Tyne.
E.M.	1920.	Greenwood, R., The International Combustion Engineering Co., Derby.
—	1906.	Griffiths, H., 70, Partridge Road, Cardiff.
Lncs.	1923.	Grundy, Ltd., John (Subscribing Firm), Tyldesley, Lancs.
S.	1920.	Gummer, G., junr., 1, Moorgate Terrace, Rotherham.
S.	1910.	Hadfield, Sir R. A. (Hon.), Hadfields, Limited, Hecla Works, Sheffield.
Lncs.	1906.	Haigh, J., 9, Bradford Road, Wakefield.
W.R. of Y.	1919.	Haley, G. H., "Longfield," Clayton, nr. Bradford, Yorks.
Lncs.	1911.	Hall, H. P. (Platt Brothers, Limited), Hartford Works, Oldham.
L.	1913.	Hall, J., 37, Melbourne Grove, East Dulwich, S.E.
—	1912.	Hamilton, A., Victoria Foundry, East Moors, Cardiff.
N.	1922.	Hamilton, C. J., 30, Malvern Street, Newcastle-on-Tyne.
E.M.	1914.	Hammond, Wm., Samson Foundry, Syston, Leicester.
Lncs.	1904.	Hampson, F. R. (J. Evans & Company), Britannia Works, Cross Street, Blackfriars, Manchester.
N.	1920.	Hands, J., 7, Ward Avenue, Rowlands Gill, Durham.
L.	1921.	Harford, A. E., Capt., 85, Sumatra Road, West Hampstead, N.W.6.
C.	1910.	Harley, A., Ashlea, Stoke Park, Coventry.
L.	1918.	Harris, A. J. A. (Capt.), 41, High Road, Balby, Doncaster, Yorks.
Lncs.	1918.	Hartley, Wm. Alexr., Stonebridge Foundry Company, Limited, Colne.
—	1922.	Harvey, André, 193, Castle Street, Bedford.
S.	1909.	Hatfield, W. H., D.Met., The Brown Firth Research Laboratory, Princess Street, Sheffield.

B'nch.	Year of Election.	MEMBERS.
N.	1921.	Hawthorn, Leslie & Company, R. W. (Subscribing Firm), St. Peter's Works, Newcastle-on-Tyne.
B.	1906.	Heggie, C., 79, Holly Lane, Erdington, Birmingham.
Lncs.	1918.	Helm, R. W., Cragside, Padiham, Lancs.
N.	1910.	Henderson, W., 6, Rosewood Crescent, Walkerville, Newcastle-on-Tyne.
Lncs.	1923.	Hensman, A. R., 121, Plymouth Grove, Charlton-on-Medlock, Manchester.
C.	1921.	Herbert, Ltd., Alfred (Subscribing Firm), Queen's Road, Coventry.
N.	1913.	Herbst, M. B., Saxby House, Corbridge-on-Tyne.
Sc.	1917.	Hetherington, R., 19, St. Vincent Place, Glasgow.
C.	1919.	Hill, Eustace Carey, c/o Rowland Hill & Sons, Limited, King Street, Coventry.
C.	1919.	Hill, Percy Rowland, Kynston, Stoneleigh, Kenilworth.
B.	1918.	Hill, Sydney Ashton (John Tickle & Company, Limited), West Bromwich.
Sc.	1919.	Hodgart, H. M., Vulcan Works, Paisley, N.B.
Lncs.	1923.	Hodgkinson, A., Ford Lane Works, Pendleton, Manchester.
Lncs.	1914.	Hodgson, A., 14, Park Range, Victoria Park, Manchester.
N.	1922.	Hodgson, G. W., 2, Beechwood Terrace, Sunderland.
Lncs.	1912.	Hogg, J., 365, Manchester Road, Burnley, Lancs.
S.	1914.	Holden, S. M., c/o 99, Plantation Street, Accrington.
W.R. of Y.	1922.	Holehouse, T. R., 14, Tower Road, Saltaire, Yorks.
S.	1920.	Holland, R., Boythorpe Cottage, Chesterfield.
N.	1919.	Holmes, C. W. H., D.Met., c/o Birtley Iron Co., Birtley, Co. Durham.

B'nch.	Year of Election.	MEMBERS.
Sc.	1914.	Hood, Jas. McLay (Life), 54, Maxwell Drive, Pollokshields, Glasgow.
Lncs.	1919.	Horrocks, B., 1, Jersey Street, Ashton, under-Lyne.
L.	1920.	Housby, I., 345, Norwich Road, Ipswich.
Lncs.	1922.	Howard & Bullough, Ltd. (Subscribing Firm), Accrington, Lancs.
C.	1923.	Howl, Clifford (Major), "Norland," Tettenhall Road, Tipton.
S.	1918.	Hoyle, J. R. (Thos. Firth & Sons, Limited), Norfolk Works, Sheffield.
Sc.	1913.	Hudson, W., Lion Foundry, Kirkintilloch, N.B.
W.R. of Y.	1922.	Hull, T. E., 26, Macaulay Road, Birkby, Huddersfield.
C.	1922.	Humber, Ltd. (Subscribing Firm), Coventry.
L.	1920.	Hunt, R. J., "Greenhithe," Earls Colne, Essex.
N.	1920.	Hunter, Hy., 1, Manor Terrace, Tynemouth.
Lncs.	1917.	Hunter, H. E., Barton Hall Engine Works, Partricroft, Manchester.
N.	1919.	Hunter, Summers, 1, Manor Terrace, Tynemouth.
C.	1907.	Hurren, F. H. (The Rover Company, Limited), Meteor Works, Coventry.
S.	1920.	Hurst, F. A., Woofindin Avenue, Ranmoor, Sheffield.
S.	1911.	Hyde, J. R., 27, Hastings Road, Millhouses, Sheffield.
S.	1922.	Hyde, Robert, & Son, Ltd. (Subscribing Firm), Abbeydale Foundry, Woodseats, Sheffield.
N.	1914.	Ireland, W. S., 9, Park Terrace, Gateshead-on-Tyne.
Lncs.	1920.	Jackson, J., 33, Burns Street, Bradford, Manchester.
S.	1915.	Jackson, L., 2, Richmond Avenue, Park Lane, Sheffield.
L.	1911.	Jarmy, J. R., "Rosslyn," 197, Cliffe Road, Strood, Kent.

B'nch.	Year of Election.	MEMBERS.
—	1912.	Jenkins, I. O., c/o Philip Jenkins' Sons, Limited, Excelsior Works, Riverside, Neath, Glamorgan.
S.	1917.	Jenkinson, S. D., Cromwell House, Wincobank, Sheffield.
Lncs.	1920.	Jennings J., 215, Booth Street, Tottington, nr. Bury.
L.	1904.	Jewson, H., East Dereham, Norfolk.
L.	1921.	Jewson, K. S., 4, Coopers Terrace, Scarning Road, Dereham, Norfolk.
E.M.	1909.	Jobson, V., The Derwent Foundry Company, Derby.
B.	1919.	Johnson, F., "Enderley," Kineton Road, Olton, nr. Birmingham.
W.R. of Y.	1918.	Johnson, T. H. F., 32, Wensleydale Road, Thornbury, Bradford.
Lncs.	1920.	Jolley, W., Breeze Hill, Urmston Lane, Stretford, Manchester.
—	1904.	Jones, Chas., Ninian Foundry, East Moors, Cardiff.
—	1916.	Jones, Chas. E., 12, Gordon Road, Cardiff.
Lncs.	1922.	Jones, G. A., 54, Fox Street, Edgeley, Stockport.
Lncs.	1922.	Jubbs, J. R., 71, Edward Street, Lower Broughton, Manchester.
S.	1921.	Kayser, J. F., 30, Oakhill Road, Nether Edge, Sheffield.
L.	1917.	Kelly, Jas., 74, Rotherfield Street, N.1.
Lncs.	1919.	Kenyon, H. W., Lime Mount, Whalley Road, Accrington.
Lncs.	1910.	Kenyon, M. S., Waterloo, Whalley Road, Accrington.
Lncs.	1904.	Kenyon, R. W., Entwistle & Kenyon, Limited, Accrington.
L.	1917.	Kesterton, Art., 151A, Englefield Road, Essex Road, N.1.
Lncs.	1907.	Key, A. L., 271, Reddish Road, S. Reddish, Stockport.
Sc.	1910.	Kidston, R., Callendar Ironworks, Falkirk, N.B.
Sc.	1914.	King, D., Keppock Ironworks, Possil Park, Glasgow.

B'nch.	Year of Election.	MEMBERS.
Sc.	1917.	King, D. M., Keppock Ironworks, Possil Park, Glasgow.
Sc.	1904.	King, J., 142, St. Vincent Street, Glasgow.
Sc.	1919.	Kinnaird, George, 12, Arundel Drive, Langside, Glasgow.
L.	1922.	Lake, W. B., Mount Place, Braintree, Essex.
L.	1921.	Lambert, Wesley, J. Stone & Co., Limited, Deptford, S.E.
Sc.	1907.	Landale, D. (Life), Gowrie House, Kirkcaldy, N.B.
C.	1919.	Lane, F.H.N., 46, Holyhead Road, Coventry.
—	1922.	Lane, H. M., 333, State Street, Detroit Michigan, U.S.A.
Lncs.	1917.	Langton, G. A., Mersey Brass Works, Heaton Lane, Stockport.
Lncs.	1917.	Langton, Saml., Mersey Brass Works, Heaton Lane, Stockport.
L.	1917.	Lawday, C. E., 3, Elmfield Road, Walthamstow, E.
L.	1921.	Lawrence, Geo. D., Donnington, Bushwood, Leytonstone, E.11.
Lncs.	1918.	Layfield, R. P., 472, Accrington Road, Burnley.
B.	1909.	Lee, Howl & Company, Engineers, Tipton.
S.	1920.	Leetch, S., 29, Deepdale Road, Rotherham.
C.	1922.	Lennox, D. Wm., The Orchard, Kenilworth.
—	1922.	Leonard, J. (Hon.), 51, Quai du Canal, Herstal, Belgium.
Lncs.	1922.	Lewis, A. H., 7, Westwood Road, Bolton.
Lncs.	1922.	Lewis, Thomas, Victoria Brass Works, Burnley.
W.R. of Y.	1922.	Liardet, A. A., 17, Apsley Crescent, Manningham, Bradford.
N.	1920.	Lillie, G., "Bloomfield," Strathmore Road, Rowlands Gill, Durham.
L.	1917.	Lindsay, E. E., Church Lane, Rampant Horse Street, Norwich.

B'nch.	Year of Election.	MEMBERS.
S.	1913.	Little, J., 20, St. Ann's Square, Manchester.
N.	1918.	Logan, A. (Hawthorn, Leslie & Company), St. Peter's Works, Newcastle.
S.	1904.	Longmuir, P., D.Met., Raven's Cragg, Wortley, Sheffield.
Lncs.	1913.	Longworth, T. P., Moorside, Horrocks Fold, Bolton.
W.R. of Y.	1910.	Love, A., 232, Gladstone Street, Bradford, Yorks.
W.R. of Y.	1913.	Loxton, H., Hill Bros., Nevin Foundry, Leeds.
E.M.	1913.	Lucas, J., "Sherwood," Forest Road, Loughborough.
L.	1922.	Luke, C. H., "Roslyn," Richmond Road, New Barnet, Herts.
L.	1921.	Lum, Harry, 54, Park Road, Dartford.
B.	1922.	Macaulay, J. M., B.Sc., A.M.I.M.E., 67, Clark Road, Wolverhampton.
L.	1916.	MacGuffie, D., 15, Osborne Road, Brimsdown, Middlesex.
Sc.	1914.	MacKenzie, Alex. D., 35, Braid Road, Edinburgh.
Sc.	1910.	Mackenzie, L. P., 5, Polwarth Terrace, Balcarres Street, Edinburgh.
N.	1923.	Mackley, J. R., "Meadowcroft," Stocksfield-on-Tyne.
Lncs.	1917.	Makemson, T., 21, Beresford Road, Stretford, Manchester.
S.	1921.	Mander, T. G., 17, Cliffe Field Road, Meersbrooke, Sheffield.
Lncs.	1922.	Markham, C., "Ringwood," near Chesterfield.
Lncs.	1919.	Markland, T. W., 327, Tonge Moor Road, Bolton.
Lncs.	1922.	Marsden & Son, J. (Subscribing Firm), 188, Regent Road, Liverpool.
S.	1922.	Marshall, J., "The Willows," Barrow Hill, Chesterfield.
L.	1923.	Martin, Chas. A. E., Madras & Southern Mahratta Rly., Perambur, Madras.
L.	1922.	Martin, M. J., 200, Park Road, Crouch End, N.

B'nch.	Year of Election.	MEMBERS.
S.	1915.	Mather, T., 149, Carholme Road, Lincoln.
N.	1912.	Mathews, W., 4, Burnside, Willington Quay-on-Tyne.
L.	1923.	Maybrey, H. J., B.A., D.I.C., 22a, Gloucester Road, South Kensington, S.W.7.
Sc.	1918.	Mayer, T., Morwell House, Dumbarton.
N.	1921.	Mayhew, C. M., 28, Grindon Terrace, Sunderland.
L.	1922.	McClelland, J. J., 1, Witham Road, Osterley, Middlesex.
L.	1922.	McConnell, S. J., 44, Blythe Vale, Catford, S.E.6.
N.	1922.	McCrory, C., 5, Station Road, Wallsend-on-Tyne.
Sc.	1919.	McFedries, T., 17, Kirktonholm Street, Kilmarnock, N.B.
S.	1916.	McGrah, F. E., "Rosegarth," Woodfield Avenue, Penn, Wolverhampton.
Sc.	1910.	McGregor, A., Thisbe, Newmains, Lanarkshire.
C.	1919.	McIntosh, A. E., 73, St. Michael's Road, Stoke, Coventry.
Sc.	1922.	McKinnon, Gavin, 1477, Dumbarton Road, Scotstoun, Glasgow.
Sc.	1923.	McKinty, J., 148, Great Western Road, Aberdeen.
Lncs.	1921.	McLachlan, Jas., 7, Rosedale Road, Higher Tranmere, Birkenhead.
—	1922.	McLain. D. (Hon.), 710, Goldsmith's Buildings, Milwaukee, Wis., U.S.A.
Lncs.	1923.	McLean, C. G., 14, Jemmett Street, Street, Preston.
Sc.	1920.	McLellan, Thos., Redding Road, Laurieston, By Falkirk, N.B.
N.	1918.	McPherson, T., M.B.E., 21, Percy Park Road, Tynemouth.
Sc.	1918.	McTurk, J. B., Dorrator Iron Company, Falkirk, N.B.
Lncs.	1917.	Meadowcroft, Wm. H., 72, Elliott Street, Tyldesley, nr. Manchester.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1919.	Medcalf, W., 265, Manchester Road, Burnley, Lancs.
L.	1922.	Melmoth F. A., Fairmont, Coggeshall Road, Braintree, Essex.
L.	1920.	Melville, A. C., F.I.C.
Lncs.	1912.	Milburn, J., Hawkshead Engineering Works, Workington.
C.	1919.	Miles, F. W.
S.	1921.	Miles (Major), R., Cowley Manor, Chapeltown, nr. Sheffield.
Lncs.	1916.	Miles, Rd. A., 46, Dean Lane, Newton Heath, Manchester.
Sc.	1921.	Millar, A. C., Parkview, Dalry, Ayrshire.
B.	1921.	Miller, Ernest, Ashley Villa, New Road, Bromsgrove, Birmingham.
S.	1913.	Mills, C. A. (Davy Bros.), Park Iron Works, Sheffield.
Lncs.	1918.	Mills, Hilton, 9, Stocks, Alkrington, Middleton, Lancs.
Sc.	1920.	Mitchell, W. W., Darroch, Falkirk, N.B.
Lncs.	1921.	Moffat, Wm., Linden House, Chapel-en-le-Frith.
—	1910.	Moldenke, Dr. R. (Hon. member).
E.M.	1914.	Moore, H. H., Holmwood, Leicester Road, Loughborough.
B.	1909.	Morcom, E. L. (M.A.) (Bellis & Morcom, Limited), Birmingham.
N.	1912.	Morris, A., Pallion Foundry, Sunderland.
S.	1917.	Morrison, C. O., Fullwood Hall, Fullwood, Sheffield.
Sc.	1920.	Motley, A. H. L., 8, Windsor Quadrant, Glasgow.
Sc.	1914.	Muirhead, Wm., Balcarres, North Mount Vernon, Glasgow.
L.	1914.	Naish, W. A., A.R.S.M., A.I.C., M.I.M.M., M.I.M., 24, University Mansions, Putney, S.W.
C.	1921.	Nevill, H. H., 16, Warwick Row, Coventry.
B.	1922.	Newby, Harry, senr., Phœnix Iron Foundry, West Bromwich.

B'nch.	Year of Election.	MEMBERS.
S.	1918.	Newell, Ernest, M.I.Mech.E., The Thorne, Misterton, *via* Doncaster.
N.	1912.	Newton, J. W., 19, Waverley Terrace, Darlington.
Lncs.	1920.	Newton, Sam, Linotype & Machinery, Ltd., Altrincham.
N.	1913.	Noble, H., "The Cedars," Low Fell, Co. Durham.
L.	1913.	Norman, A. J., 43, Dunvegan Road, Eltham, S.E.
S.	1921.	North, Cyril, 89, Banner Cross Road, Ecclesall, Sheffield.
N.	1921.	North-Eastern Marine Engineering Company (Subscribing Firm), Wallsend-on-Tyne.
W.R. of Y.	1922.	Nuttall, H., Spring Edge, Halifax.
Lncs.	1918.	Oakden, E., A.M.I.C.E., Glen Lea, Wellington Road, Fallowfield, Manchester.
B.	1917.	O'Keefe, Wm., 62, Stanhope Street, Birmingham.
N.	1920.	Oliver, R., 35, Edith Street, Jarrow-on-Tyne.
Lncs.	1915.	Onions, R., The Knoll, Torkington Road, Hazel Grove, Stockport.
Lncs.	1921.	Ormerod, J., 24, Barrett Street, Bury.
S.	1913.	Osborn, S., Clyde Steel Works, Sheffield.
L.	1906.	Oswald, J., "The Drive," Nightingale Lane, Wandsworth Common, S.W.
L.	1919.	Otto, C. A., 22, Owenite Street, Abbey Wood, S.E.
C.	1918.	Oubridge, W. A., A.M.I.M.E. (British Piston Ring Company, Limited), Holbrook Lane, Coventry.
S.	1921.	Oxley, G. H., Norton Grange, nr. Sheffield.
S.	1915.	Oxley, G. L., Vulcan Foundry, Attercliffe, Sheffield.
S.	1910.	Oxley, W., Vulcan Foundry, Attercliffe, Sheffield.

B'nch.	Year of Election.	MEMBERS.
N.	1921.	Palmer's Shipbuilding & Iron Company (Subscribing Firm), Hebburn-on-Tyne.
Lncs.	1920.	Park, S., "Cliffe," Gt. Harwood, Lancs.
W.R. of Y.	1922.	Parker, W., 22, Clay Pits Lane, Pellon, Halifax.
E.M.	1905.	Parker, W. B., 1, Murray Road, Rugby.
W.R. of Y.	1907.	Parkinson, J., Shipley, Yorks.
L.	1919.	Parr, J., 40, Hawthorn Road, Bexley Heath, Kent.
S.	1914.	Parramore, G. F., Housley, Chapeltown, Sheffield.
N.	1915.	Parsons, H. F., "Avondale," Heaton Park View, Heaton, Newcastle.
L.	1922.	Patchin, Geo., A.R.S.M., "Ashdene," Furzefield Road, Beaconsfield.
Sc.	1920.	Pate, G., Carron Grange, Carron, Falkirk, N.B.
N.	1920.	Paterson, J. S., D.Sc., F.I.C., Neville Chambers, Westgate Road, Newcastle-on-Tyne.
N.	1912.	Patterson, R. O., Thorneyholme, Wylam-on-Tyne.
L.	1919.	Patterson, V. A., "Termone," Shepherd's Lane, Dartford.
N.	1912.	Paulin, W. J., 1, Stannington Grove, Heaton, Newcastle.
L.	1917.	Pearce, F. T., 9, Paliwell Park, East Sheen, London.
E.M.	1913.	Pearson, N. G., Beeston Foundry Company, Limited, Beeston, Notts.
E.M.	1914.	Pegg, S. J., Alexander Street, Leicester.
Lncs.	1909.	Pell, J., 100 Rosegrove Lane, Rosegrove, Burnley, Lancs.
Lncs.	1922.	Pellatt, W. N., 43, Hawthorn Road, Deane, Bolton.
E.M.	1918.	Perkins, J. E. S., "Hillmorton," The Park, Peterborough.
C.	1920.	Perks, C., Phœnix, Castings, Ltd., Coventry.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1919.	Perryman, W., 17, Hurst Street, Bury.
N.	1922.	Phillips, E. S., 1, Beech Crest, Durham.
S.	1915.	Philp, H. R., 311, Abbey Road, Barrow-in-Furness.
L.	1922.	Pinder, J., "Jesmond Dene," 111, Violet Hill Road, Stowmarket, Suffolk.
L.	1922.	Pinder, R., Colenso Villas, 49, Ledington Road, Ipswich.
Lncs.	1922.	Place, J. H., "Girsie," 258, Manchester Road, Burnley.
Lncs.	1911.	Place, R. H. (Lupton & Place, Limited), Queen Street Ironworks, Burnley.
E.M.	1917.	Platts, W. H., Britannia Ironworks, Duke Street, Derby.
C.	1919.	Player, E., Cow Lees, Astley, nr. Nuneaton.
E.M.	1922.	Pochin, R. E., 246, Fosse Road, South Leicester.
Lncs.	1922.	Pollard, J. T., 7, Powell Street, Burnley.
W.R. of Y.	1912.	Pollitt, E. E. (Pollitt & Wigzell), Sowerby Bridge.
W.R. of Y.	1922.	Poole, W. H., Kings Grove, Villa Road, Bingley, Bradford.
B.	1919.	Pott, L. C., Ford Brook House, Pelsall, nr. Walsall.
S.	1920.	Potter, J. A., 636, Attercliffe Road, Sheffield.
Sc.	1913.	Potter, R., 50, Helen Street, Govan, N.B.
S.	1908.	Prestwich, W. C., Charnwood, Cecil Road, Dronfield.
Sc.	1920.	Price, F., 61, Dorrator Road, Camelon, N.B.
Sc.	1920.	Primrose, James, M., 47, Baird Street, Camelon, Falkirk, N.B.
S.	1920.	Proctor, B., 611, Ecclesall Road, Sheffield.
E.M.	1904.	Pulsford, F. C., "Kenmore," Sandown Road, Leicester.
N.	1917.	Punshon, J. J., 13, Longley Street, Newcastle-on-Tyne.

B'nch.	Year of Election.	MEMBERS.
—	1922.	Ramas, E. (Honorary), 2, Rue de Constantinople, Place de l'Europe, Paris.
N.	1912.	Rang, H. A. J., 2, St. Nicholas Buildings, Newcastle-on-Tyne.
Lncs.	1919.	Ranicar, W., 1, Parr Street, Tyldesley, Lancs.
S.	1921.	Rawlings, Geo., 23, Banner Cross Road, Sheffield.
L.	1911.	Read, R. H., Cadogan Ironworks, Chelsea.
B.	1909.	Reason, H. L., M.I.Mech.E., M.I.M., 29, Hallewell Road, Edgbaston, Birmingham.
Sc.	1920.	Reid, A. G., Budhill Foundry, Shettleston, N.B.
Sc.	1920.	Rennie, A., "Kilnside," Falkirk, N.B.
B.	1919.	Retallack, C., "Clifton," Anchorage Road, Sutton Coldfield.
Lncs.	1919.	Rhead, E. L., Prof. (Honorary Life), College of Technology, Manchester.
S.	1923.	Rhydderch, A., 165, Shirebrook Road, Sheffield.
Lncs.	1919.	Richardson, W. B., Hope Foundry, Farnworth, nr. Bolton.
Sc.	1911.	Riddell, M., Dungoyne, Aytoun Road, Pollokshields, N.B.
C.	1919.	Roberts, G. E., "Rosedale," Earlsdon Avenue, Coventry.
Lncs.	1921.	Roberts, G. P., 153, Brandlesholme Road, Bury, Lancs.
Sc.	1922.	Robertson, Donald M., 3, Rosehall Terrace, Falkirk, N.B.
Sc.	1911.	Robertson, R., Etna Ironworks, Falkirk, N.B.
W.R. of Y.	1908.	Robinson, J. G., 17, Gibraltar Road, Halifax.
Lncs.	1912.	Robinson, S., Leafield, Derby Road, Widnes.
S.	1910.	Robinson, W. H., 145, Burngreave Road, Pitsmoor, Sheffield.
N.	1921.	Robson, E. C.
Lncs.	1912.	Roe, S., 6, Grantham Street, Oldham.

B'nch.	Year of Election.	MEMBERS.
—	1909.	Ronceray, E. (Hon.), 3, Rue Paul Carle, Choisy-le-Roi, Seine, France.
B.	1922.	Ronceray, R. A. M., 195, Bristol Road, Birmingham.
C.	1921.	Rover Company, Limited (Subscribing Firm), Meteor Works, Coventry.
S.	1919.	Russell, D., 41. Endcliffe Rise Road, Sheffield.
S.	1918.	Russell, F., c/o General Refractories Company, Limited, Kelham Island, Sheffield.
E.M.	1915.	Russell, R. T. (R. Russell & Sons), Peel Foundry, Derby.
E.M.	1906.	Russell, S. H., Bath Lane, Leicester.
E.M.	1920.	Russell, W. S., 41, Westfield Road, Leicester.
N.	1915.	Sanderson, F. (Lawson, Walton & Company), 2, St. Nicholas Buildings, Newcastle-on-Tyne.
S.	1921.	Sandford, J., 46, Clifford Road, Sheffield.
N.	1915.	Saunders, J., Borough Road Foundry, Sunderland.
C.	1921.	Scampton, Chas., 8, St. Ann's Road, Stoke, Coventry.
N.	1917.	Scott, R., The Haydon Bridge Engineering Company Limited, Westgate Road, Newcastle-on-Tyne.
B.	1910.	Sexton, A. Humbolt (Hon. Life), 46, Kingsley Park Terrace, Northampton.
L.	1922.	Shannon, H., 112, Madrid Road, Barnes, S.W.
Sc.	1920.	Sharpe, Daniel, 28, Royal Exchange Square, Glasgow.
S.	1906.	Shaw, J., 39, Montgomery Road, Sheffield.
L.	1907.	Shaw, R. J., 41, Dorset Road, South Ealing, W.5.
N.	1922.	Shaw, W., & Company, Limited (Subscribing Firm), Wellington Cast Steel Foundry, Middlesbrough.

B'nch.	Year of Election.	MEMBERS.
S.	1908.	Sheepbridge C. & I. Company, Limited (Subscribing Firm), Sheepbridge Works, Chesterfield.
B.	1922.	Shenai, S. D., East Road, T.D. Temple, Cochin, E. India.
B.	1921.	Shepherd, H. H., 92, Queen's Head Road, Handsworth, Birmingham.
Lncs.	1907.	Sherburn, H. (Life), c/o Richmond Gas Stove and Meter Company, Limited, Grappenhall Works, Warrington.
Lncs.	1905.	Sherburn, W. H. (Life), Rotherwood, Stockton Heath, Warrington.
L.	1913.	Shillitoe, H., Mount Grace Road, Potter's Bar, N.
N.	1920.	Shipley, H. J., 49, Theresa Street, Blaydon-on-Tyne.
W.R. of Y.	1922.	Shoesmith, N., 8, Noster Hill, Beeston, Leeds.
Lncs.	1907.	Simkiss, J., Abington House, Hyde Road, Gorton, Manchester.
N.	1913.	Simm, J. N., 61, Marine Avenue, Monkseaton.
W.R. of Y.	1921.	Slingsby, W., Highfield Villa, Keighley.
N.	1921.	Smalley, O., 19, Marine Avenue, Monkseaton.
S.	1922.	Smith, A., "Oakroyd," Dodworth Road, Barnsley.
L.	1921.	Smith, A. E. McRae, 7, Hallford Village, Dartford, Kent.
S.	1922.	Smith, A. Qualter, 118, Dodworth Road, Barnsley.
B.	1919.	Smith, C. R., "Milverton House," Riches Street, Wolverhampton.
N.	1921.	Smith, Daniel, 7, Green Bank Villas, Ellison Street, Jarrow-on-Tyne.
N.	1908.	Smith, E., Belle Vue, Harton, South Shields.
S.	1921.	Smith, Fredk., Devonshire Villas, Barrow Hill, nr. Chesterfield.

B'nch.	Year of Election.	MEMBERS.
E.M.	1921.	Smith, George, 60, Denison Street, Beeston, Notts.
C.	1920.	Smith-Clarke, G. T., Glenroy, Kenilworth, nr. Coventry.
N.	1905.	Smith, J., "Harton Lea," Harton, South Shields.
N.	1922.	Smith, James, Holborn Foundry, Nile Street, South Shields.
Sc.	1920.	Smith, J. C. J., 25, Cluny Drive, Edinburgh.
N.	1917.	Smith, J. E., 7, Lily Avenue, Jesmond, Newcastle.
S.	1918.	Smith, J. Kent, 459, Queen's Road, Sheffield.
W.R. of Y.	1922.	Smith, J. W., 96, Beech Grove, Clayton Road, Bradford.
N.	1922.	Smith Patterson & Company, Limited (Subscribing Firm), Pioneer Works, Blaydon-on-Tyne.
N.	1913.	Smith, R. H., 16, Dulverton Avenue, South Shields.
N.	1919.	Smith, S. E., Woodside, Rowlands Gill, Newcastle-on-Tyne.
L.	1923.	Snook, S. W. G., 30, Lawrence Road, Tottenham, N.15.
L.	1914	Sommerfield, H. G., "Hanthorpe," Woodhouse Road, N. Finchley, London, N.12.
E.M.	1914.	Spiers, T. A., "Belah," Marston Road, Leicester.
Lncs.	1919.	Stamworth, J., M.B.E., "The Hollins," Rimington, Clitheroe, Lancs.
C.	1921.	Standard Motor Company, Limited (Subscribing Firm), Canley, Coventry.
Lncs.	1922.	Staveley Coal & Iron Company (Subscribing Firm), Staveley Works, nr. Chesterfield.
—	1910.	Stead, J. E. (Hon. member).
Sc.	1920.	Steven, A. W., Lauriston Ironworks, Falkirk, N.B.
E.M.	1914.	Stevenson, E., 112, Musters Road, West Bridgford, Nottingham.

B'nch.	Year of Election.	MEMBERS.
Sc.	1923.	Stewart, J. A., 21, Holmhead Road, Cathcart, Glasgow.
L.	1912.	Stone, J., 106, Harlaxton Road, Grantham.
—	1922.	Stones, J., 2, Marshall Road, Agarpara, Kamarhatti P.O., Calcutta, India.
N.	1921.	Stothard, A., 66, Highbury, Newcastle-on-Tyne.
E.M.	1916.	Street, W., 20, Burleigh Road, Loughborough.
Lncs.	1921.	Stubbs, Limited, Jos. (Subscribing Firm), Mill Street Works, Ancoats, Manchester.
Lncs.	1912.	Stubbs, O. (J. Stubbs, Limited), Openshaw, Manchester.
Lncs.	1919.	Stubbs, R. W., 209, Dickenson Road, Rusholme, Manchester.
C.	1921.	Sturch, H. A., A.M.I.Mech.E., A.M.I.M.E., Hazeldene, Kenilworth Road, Berkswell, nr. Coventry.
W.R. of Y.	1922.	Summerscales, W. H. G., 15, Castle Road, Keighley.
W.R. of Y.	1919.	Summersgill, H., Stanacre Foundry, Wapping Road, Bradford.
L.	1922.	Sutherland, H. W., 47, Amersham Vale, New Cross, S.E.14.
Lncs.	1918.	Swift, G. C., 31, Charlton Avenue, Trafford Road, Patricroft, Manchester.
S.	1918.	Swift, L. J., "The Farm," Hunter's Lane, Handsworth, Sheffield.
S.	1908.	Swinden, T., D.Met., 26, Oakhill Road, Nether Edge, Sheffield.
W.R. of Y.	1912.	Sykes, J. W., Birdacre House, Gomersall, Leeds.
N.	1919.	Taylor, C. R. R., Manor House, South Shields.
N.	1922.	Taylor & Son, Limited, C. W. (Subscribing Firm), North Eastern Foundries, South Shields.
Lncs.	1911.	Taylor, R. (Asa Lees & Company, Limited), Oldham.

B'nch.	Year of Election.	MEMBERS.
N.	1923.	Thomson, A., Percy House, Percy Park Road, Tynemouth.
Lncs.	1920.	Thompson, H., 6, Dobson Road, Bolton.
W.R. of Y.	1922.	Thornton, W. G., 1,081, Grangefield Avenue, Thornbury, Bradford.
W.R. of Y.	1906.	Thwaites Bros., Limited, Vulcan Iron Works, Bradford.
L.	1922.	Tortoiseshell, W. J.
—	1922.	Touceda, E. (Hon.), 943, Broadway, Albany, N.Y., U.S.A.
Lncs.	1921.	Town End Foundry Ltd. (Subscribing Firm), Chapel-en-le-Frith, Derbyshire.
L.	1922.	Tremayne, Chas., 26, Eversley Road, Charlton, S.E.7.
Sc.	1922.	Tullis, D. R., 10, Eglinton Drive, Kelvinside, Glasgow.
B.	1910.	Turner, Prof. T. (Hon. Member), The University, Birmingham.
Sc.	1923.	Tutchings, A., 152, Greenhead Drive, South Govan, Glasgow.
Lncs.	1909.	Tweedales & Smalley, Limited, Globe Works, Castleton, Lancs.
B.	1918.	Tyson, E. H., 406, Rotten Park Road, Birmingham.
S.	1916.	Underwood, G. H., Pye Bridge House, Pye Bridge, Alfreton.
Sc.	1919.	Ure, A. M., 355, Keppochhill Road, Glasgow.
Sc.	1913.	Ure, G. A., Bonnybridge, Scotland.
N.	1914.	Vardy, G., M.B.E., 46, Percy Park, Tynemouth.
—	1922.	Varlet, J. (Hon.), Esperance Longdoz Works, Liège, Belgium.
S.	1922.	Vickers, Limited (Subscribing Firm), River Don Works, Sheffield.
Lncs.	1922.	Vickers, Ltd. (Subscribing Firm), Barrow-in-Furness.
B.	1917.	Vickers, T., Central House, 75, New Street, Birmingham.
S.	1917.	Village, R., Jaggers Lane, Hathersage, nr. Sheffield.
S.	1907.	Walker, E., Effingham Mills, Rotherham.

B'nch.	Year of Election.	MEMBERS.
L.	1911.	Walker, E. J., 10, Bush Lane, Cannon Street, E.C.
—	1916.	Walker, J. E., 108, Park Street, St. Kilda, W., Melbourne, Victoria, Australia.
L.	1921.	Walker, Jos., 4, Francemary Street, Brockley, S.E.
S.	1918.	Walker, T. R., 7, Ranmore Hill, Hathersage, Derbyshire.
N.	1909.	Wallis, R., M.B.E., Wh.Sc., Point Pleasant Hall, Wallsend, Newcastle-on-Tyne.
N.	1921.	Wallsend Slipway & Engineering Co. (Subscribing Firm), Wallsend-on-Tyne.
—	1922.	Walters, A. F. (H. I. Dixon & Company, Limited), The Omiar Founding Eng. Company, Limited, Love Lane, Mazagon, Bombay, India.
S.	1908.	Ward, J. (T. W. Ward, Limited), Albion Works, Saville Street, Sheffield.
S.	1914.	Ward, J. C., Oak Park, Sheffield.
B.	1918.	Wardle, A., Beaconfield, Oxley Bank, Wolverhampton.
Lncs.	1920.	Wareing, W. B., 35, Accrington Road, Westgate, Burnley.
E.M.	1921.	Warren, H., 139, Fosse Road South, Leicester.
E.M.	1910.	Wassell, A., Ripley, Derby.
S.	1915.	Watson, J., 56, Crescent Road, Sharrow, Sheffield.
N.	1919.	Watson, J. H., 6, Sidney Grove, Newcastle-on-Tyne.
W.R. of Y.	1922.	Watson, Jos. J., 3, Springdale Avenue, Huddersfield.
Sc.	1911.	Watt, G., Overkirk, Oxhill, Dumbarton, N.B.
—	1919.	Weaver, W. G., Dept. of Mechanical Engineering, University of Cape Town, South Africa.
B.	1917.	Webb, B., 531, Stourbridge Road, Scott Green, Dudley.

B'nch	Year of Election.	MEMBERS.
L.	1920.	Webster, H. S., 20, Ossory Road, Old Kent Road, S.E.
Sc.	1920.	Weir, Rt. Hon. Lord, The, P.C., D.L., LL.D. (Life Member), G. and J. Weir, Limited, Cathcart, Glasgow.
N.	1912.	Weir, J. M., 7, Stanhope Road, South-Shields.
W.R. of Y.	1908.	Welford, R. D., Sociedad Española de Construcion Naval. el Arsenal, Apartudo, No. 1, Ferrol, Spain.
S.	1910.	Wells, G. E. (Edgar Allen & Co., Limited), Imperial Steel Works, Sheffield.
S.	1914.	Wells, J. A. E., Moorlands, Ringinglow Road, Sheffield.
S.	1921.	Wharton, E., Rosemont, Station Road, Brimington, Chesterfield.
N.	1913.	Wharton, J., Maryport, Cumberland.
S.	1920.	Wheddon, A. L., 33, Osborne Street, Winshill, Burton-on-Trent.
B.	1919.	Whitehouse, W., Wateroliet, Halesowen.
S.	1916.	Whiteley, A., 7, Glen Road, Nether Edge, Sheffield.
Lncs.	1910.	Whittaker, C. & Company, Limited, Dowry Street Ironworks, Accrington.
B.	1922.	Whyte, D., 8, Vale View, Porthill, Wolstanton, Stoke-on-Trent.
W.R. of Y.	1922.	Wigglesworth & Company, Limited, (Subscribing Firm), Engineers, Clutch Works, Shipley, Yorks.
N.	1920.	Wight, Chas. M., 184, Cleveland Road, Sunderland.
C.	1919.	Wild, M., 29, Beauchamp Avenue, Leamington.
B.	1921.	Wilkinson, D., 1,114, Bristol Road, South, Northfield, Birmingham.
W.R. of Y.	1919.	Wilkinson, G. (E. & W. Haley, Ltd.), Thornton Road, Bradford.
Lncs.	1917.	Wilkinson, R., 26, Broadbottom Road, Mottram, Cheshire.

B'nch.	Year of Election.	MEMBERS.
Sc.	1919.	Williams, H., c/o J. Cochrane, Ltd., Barrhead, N.B.
—	1916.	Williams, W., Alexandra Brass Foundry, East Dock, Cardiff.
N.	1913	Willott, F. J., 17, Park Road, Clydach-on-Tawe, Swansea Valley.
N.	1922.	Wilson, R. R., "Canonbury," Rowlands Gill, nr. Newcastle-on-Tyne.
Sc.	1906.	Winterton, H., 2, Lorne Terrace, Maryhill, Glasgow.
N.	1912.	Wise, S. W., Victoria House, Dunston-on-Tyne.
B.	1919.	Wood, D. Howard (Capt.), 7, Augusta Road, Moseley, Birmingham.
N.	1922.	Wood, E. (Capt.), B.Sc., "Overtoun," 18, Beverley Road, Monkseaton.
B.	1909.	Wood, E. J. (Patent Axlebox and Foundry Company, Limited), Wednesfield Foundry, Wolverhampton.
B.	1923.	Woodvine, G. R., "The Firs," Bowbridge, Shrewsbury.
L.	1911.	Worton, H. J., 97, Chesnut Road, Plumstead, S.E.
B.	1914.	Wright, E. N. (Life), Oxford Lodge, Penn Fields, Wolverhampton.
Sc.	1919.	Wyllie, W., 66, Titchfield Street, Kilmarnock, Ayr, N.B.
Lncs.	1911.	Yates & Thom, Limited, Canal Engineering Works, Blackburn.
S.	1915.	Yeardley, E., 124, Langsett Avenue, Wadsley, Sheffield.
N.	1914.	Young, H. J., F.I.C., North Eastern Marine Engineering Company, Limited, Wallsend-on-Tyne.

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
Sc.	1919.	Affleck, J., 21, Overdale Avenue, Langside, N.B.
E.M.	1921.	Airey, Albert V., 16, Longmore Lane, Sandiacre, Notts.
B.	1915.	Aldridge, S., 91, Dale Street, Walsall,

ASSOCIATE MEMBERS.

B'nch	Year of Election.	
Sc.	1918.	Alexander, D., 16, Kennedy Drive. Partick, N.B.
Sc.	1922.	Allan, Wm. Taylor, c/o Calder, "Kidderholme," Shotts, Lanarkshire.
Sc.	1921.	Anderson, J., 4, Church Street, Grahamston, Falkirk, N.B.
Sc.	1919.	Anderson, J. F., 4, Gladstone Terrace, Paisley, N.B.
Sc.	1920.	Anderson, W., 8, Moffat Place, Carron, Falkirk.
Lncs.	1907.	Andrew, F., 347, Blackburn Road, Darwen, Lancs.
N.	1913.	Archer, T. M., Fell Holme, Market Lane, Dunston-on-Tyne.
Lncs.	1917.	Armitage, R., 193, Lees Road, Oldham.
N.	1918.	Armstrong, G., 37, Sheriff's Highway, Gateshead-on-Tyne.
Sc.	1920.	Armstrong, John, 31, Union Road, Camelon, Falkirk, N.B.
Sc.	1920.	Arnott, J., A.I.C., 14, Percy Street, Ibrox, Glasgow.
Sc.	1920.	Arthur, Wm., 226, Main Street, Camelon, Falkirk, N.B.
C.	1919.	Ashmore, H., 26, Ellys Road, Coventry.
S.	1920.	Ashton, David, 45, Ellesmere Road, Sheffield.
Lncs.	1916.	Ashton, F., 24, Isherwood Street, Heywood, Lancs.
Lncs.	1918.	Ashton, L., 59, Seymour Street, Radcliffe, Lancs.
B.	1922.	Askew, Arthur, Dunkirk Bank, Amberley, nr. Stroud.
N.	1922.	Askew, Jacob, 26, General Graham Street, Sunderland.
L.	1905.	Aston, D. A., 36, Bastwick Street, St. Luke's, London, E.C.
Lncs.	1922.	Atkinson, Albert, 1, Guy Street, Padiham, Burnley.
S.	1920.	Atkinson, A. A., 24, Wath Road, Nether Edge, Sheffield.
S.	1916.	Atkinson, F. (Thos. Andrews & Company), Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1920.	Avill, Wm., 44, Albion Road, Rotherham.
S.	1912.	Ayres, J. A., "Aldbourne," Ecclesfield, Sheffield.
Sc.	1918.	Bacon, A. H., 228, Saracen Street, Glasgow.
Lncs.	1918.	Bagley, J., 97, Leopold Street, Loughboro'.
S.	1920.	Bailey, H. I., 42, Wellear Road, Woodseats, Sheffield.
S.	1909.	Bailey, P. T., 6, Hill Top, Dronfield, nr. Sheffield.
Sc.	1920.	Bain, Colin, 27, Napier Place, Bainford, Falkirk, N.B.
Sc.	1916.	Bain, W., Ardmore, Bonnybridge, Scotland.
Sc.	1917.	Baird, J., 32, Gibson Gray Street, Bainsford, Falkirk, N.B.
N.	1918.	Bairnsfather, Geo., 202, St. Vincent Street, South Shields.
E.M.	1918.	Baker, J., 31, Charles Street, Peterborough.
B.	1918.	Baker, W., "Ingleside," Wellington Road, Bilston, Staffs.
Lncs.	1921.	Ball, G., Cheetham Fold, Gee Cross, Hyde, Cheshire.
L.	1922.	Barker, A. G., 30, Aldworth Road, Stratford, E.15.
B.	1919.	Barker, S. B., 34, Darley Road, Coalbrookdale, Salop.
N.	1922.	Barkes, R. P., 23, Thomas Street, East Sunderland.
S.	1913.	Barnaby, N. F. (John Brown & Company, Limited), Scunthorpe, Sheffield.
Lncs.	1910.	Barnes, G., 16, Tremellan Street, Accrington.
Lncs.	1915.	Baron, E., 24, Grimshaw Lane, Newton Heath, Manchester.
S.	1912.	Barr, J. P., 94, Balfour Road, Darnall, Sheffield.
L.	1914.	Barrett, H. G.
E.M.	1916.	Barringer, E. A., 80, Lambert Road, Narborough Road, Leicester.

ASSOCIATE MEMBERS.

B'nch	Year of Election.	
N.	1921.	Barritt, Thos., 14, Barrasford Street East, Howden-on-Tyne.
N.	1914.	Bartlett, T., 41, Albert Street, Gateshead.
S.	1921.	Bashforth, E. J., 132, Osgathorpe Road, Sheffield.
L.	1911.	Batch, J., 60, Robertson Street, Queen Street, Battersea, S.W.
C.	1920.	Bates, J. E., 79, Ransome Road, Coventry.
E.M.	1921.	Bates, Thos. Wm., 25, Marcus Street, Derby.
B.	1904.	Bather, H. K. (Chamberlain & Hill), Chuckery Foundry, Walsall.
S.	1920.	Batty, F., 52, Hampton Road, Pitsmoor, Sheffield.
L.	1921.	Baxter, Percy L., 131, Ampthill Avenue, Benoni, Transvaal, S. Africa.
—	1911.	Bayles, R. (Douglas & Grant, Limited), Raith Engineering Works, Dunneedaw, Rangoon, Burmah.
B.	1907.	Bayliss, P. S., "Ashfield," Tettenhall, Wolverhampton.
W.R. of Y.	1923.	Beaumont, G., 109, Cross Green Lane, Leeds.
E.M.	1919.	Beck, H. J., 131, Upper Dale Road, Derby.
—	1921.	Beckett, J., "Wombourn," 47, Mill Street, Carlton, Sydney, N.S.W.
S.	1918.	Beech, H., 193, St. Lawrence Road, Tinsley, Sheffield.
Lncs.	1921.	Beecroft, J., 53, Culshaw Street, Fulledge, Burnley.
S.	1920.	Beeley, W. H., 216, Eccleshall Road, Sheffield.
E.M.	1917.	Beer, H., 40, Crosby Road, West Bridgford, Notts.
Sc.	1917.	Bell, J., 8, Gower Street, Ibrox, Glasgow.
N.	1918.	Bell, R., 12, Albert Place, Washington Station, Co. Durham.
Sc.	1910.	Bell, T., 2, Bellfield Street, Barrhead, Glasgow.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1918.	Bennett, A. M., 12, Brandon Grove, Newton Park, Leeds.
—	1912.	Bennett, J., Rosebank, Ebley, Stroud.
W.R. of Y.	1912.	Berry, F., 125, Watkinson Road, Illingworth, Halifax.
Lncs.	1920.	Berry, J. W., 180, Lodge Lane, Dukinfield, Manchester.
Lncs.	1917.	Berry, R. I., 4, Stratford Avenue, Rochdale.
C.	1920.	Betteridge, C. D., Fife Road, Hearsall Common, Coventry.
Lncs.	1921.	Bickerton, C. 153, Ashton New Road, Beswick, Manchester.
E.M.	1915.	Bigg, C. W., 17, Anondale Road, Derby.
Sc.	1920.	Binnie, Alex., 15, Cochrane Terrace, Pleasance Square, Falkirk, N.B.
N.	1919.	Binns, A. E., 534, Shields Road, Newcastle-on-Tyne.
B.	1916.	Birch, H., Inglewood, Chester Road, Streetley, Birmingham.
B.	1922.	Bird, J. B., Plas-Newydd, Streetley, nr. Birmingham.
Sc.	1919.	Black, A., 259, Calder Street, Govanhill, N.B.
Sc.	1920.	Black, J., 14, Leven Street, Bainsford, N.B.
Sc.	1920.	Blackburn, Wm., 59, Union Road, Camelon, Falkirk, N.B.
E.M.	1921.	Blackham, E. L., 44, May Street, Derby.
E.M.	1920.	Blackwell, Wm., 65, Sparrow Hill, Loughborough.
Sc.	1910.	Blackwood, R., "Kenilworth," Johnstone, Glasgow.
L.	1920.	Blackwood, R. W., "Rothesay," The Avenue, Erith.
E.M.	1919.	Blades, C., The Vines, Wanlip Road, Syston, nr. Leicester.
W.R. of Y.	1922.	Blakey, Wm., 15, Kirkburn Place, St. Margaret's Road, Bradford.
N.	1920.	Blenkinsop, S. D., 2, Richmond Terrace, Gateshead-on-Tyne.

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
N.	1919.	Blythe, J. D., 6, Churchill Road, Willington-on-Tyne.
S.	1915.	Booker, H. H., 153, Albert Road, Heeley, Sheffield.
W.R. of Y.	1922.	Booth, G. E., 80, Institute Road, Eccleshill, Bradford, Yorks.
N.	1915.	Borthwick, T., Crookhall House, Leadgate, Co. Durham.
W.R. of Y.	1923.	Bostock, S., 15, Holly Street, Hemsworth, Wakefield.
Sc.	1920.	Bound, W. H., Wh. Ex. A.M.I. Mech.E., 69, Minard Road, Shawlands, Glasgow.
Lncs.	1921.	Bowden, J., 72, Grange Road, Chorlton-cum-Hardy, Manchester.
L.	1906.	Bowman, A., 11, Southwell Road, Norwich.
Sc.	1919.	Boyd, W., 415, Eglinton Street, Glasgow.
S.	1916.	Bradley, H., 94, Abbey Lane, Woodseats, Sheffield.
N.	1918.	Bradley, J. H., 7, Crawley Road, Wallsend-on-Tyne.
S.	1920.	Bradley, J. T., 20, St. John's Road, Newbold Moor, nr. Chesterfield.
S.	1918.	Bragg, W. J., 139, Hadfield Street, Walkley, Sheffield.
Lncs.	1922.	Brandrett, T., 35, Ryall Street, Regent Road, Salford, Manchester.
N.	1921.	Brass, A., 44, Haydn Terrace, Gateshead-on-Tyne.
Lncs.	1921.	Brassington, H., 16, East Street, Hollingwood Park, Stockport.
B.	1908.	Bray, D., "Seacote," Carmen Sylvia Road, Llandudno.
S.	1915.	Brearley, A. W., Totley Brook Road, Sheffield.
Sc.	1923.	Brereton, C. F., c/o Mrs. Archibald, "Mossfield," Greenock Road, Paisley.
Lncs.	1917.	Brierley, A., 21, Milnrow Road, Rochdale.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1920.	Brindley, A. G. G., 14, Bexley Road, Belvedere, S.E.
Lncs.	1923.	Brockbank, A. H., 3, Hawkens Street, Old Trafford, Manchester.
E.M.	1918.	Brocklesby, C. E.
L.	1917.	Brookfield, D., 285, Camden Road, Holloway, N.7.
Sc.	1920.	Brown, D., Wellpark Terrace, Bonnybridge. N.B.
L.	1917.	Brown, E. H., 91, Devonshire Road, Forest Hill, S.E.23.
Lncs.	1917.	Brown, J., 298, Milnrow Road, Rochdale.
N.	1916.	Brown, J., 3, Hastings Street, Sunderland.
Sc.	1920.	Brown, J. M., 14, William Street, Kilmarnock, Ayrshire, N.B.
S.	1918.	Brown, T., 488, Chesterfield Road, Woodseats, Sheffield.
S.	1909.	Brown, T. W., 9, Coupe Road, Burngreave, Sheffield.
Sc.	1914.	Bruce, A., 52, Ashley Terrace, Edinburgh.
N.	1920.	Buckham, G. H., "Harewood," Grange Road, Newcastle-on-Tyne
Lncs.	1915.	Bulcock, A., c/o R. B. Robinson, 32, East Mount Terrace, Darlington.
W.R. of Y.	1922.	Bullock, Herbert, 19, Jesmond Avenue, Heaton, Bradford.
N.	1920.	Burcham, J., 35, Alverthorpe Street, South Shields
L.	1922.	Burningham, E.F., [illegible] Cambridge Road, Sidcup, Kent.
Sc.	1917.	Burns, J. K., 77, Sa[illegible]y Road, Renfrew, N.B.
Lncs.	1919,	Butterworth, J., 40, Clement's Royds Street, Rochdale.
W.R. of Y.	1921.	Butterworth, John, 19, Neville Street, Clare Mount, Halifax.
Lncs.	1920.	Buxten, J., 68, Nook Lane, Hurst, Ashton-u-Lyne.
S.	1920.	Cameron, N., 70, Glen Road, Nether Edge, Sheffield

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
Sc.	1912.	Campbell, D. McGregor, Torwood Foundry, Larbert, N.B.
L.	1914.	Campbell, J., 9, Western Gardens, Ealing, W.
N.	1919.	Campbell, J. A., 12, Denwick Terrace, Tynemouth.
Lncs.	1918.	Campbell, W., 12, Denbeigh Street, Stockport.
L.	1921.	Carrell. Hy. Alfred, 6J, Peabody Buildings, Farringdon Road, E.C.
W.R. of Y.	1908.	Carrick, R., 14, Avondale Mount, Shipley, Yorks.
Lncs.	1914.	Carter, E., 59, Chief Street, Oldham.
W.R. of Y.	1923.	Carver, W., 112, Valley Road, Pudsey, near Leeds.
Sc.	1917.	Cassels, T. M., 28. Bute Terrace, Strathbungo, N.B.
L.	1921.	Cast, F. H., 33, Radnor Street, Peckham, S.E.
Lncs.	1920.	Castle, S., 68, Uxbridge Street, Ashton-under-Lyne.
Lncs.	1921.	Castree, R. J., 4, Kirkgate, Burnley,
W.R. of Y.	1922.	Causer, L. W., 79, Fitzroy Road, Barkerend Road, Bradford.
L.	1921.	Chapman, Wm. J., 6, Rosedale Road, Forest Gate, E.7.
W.R. of Y.	1922.	Chappelow, Thos., 181, Taylor Street, Batley, Yorks.
Sc.	1921.	Charters, J., 12, Walworth Terrace, Glasgow.
E.M.	1918.	Cheetham, R. B., 43, Mansfield Road, Derby.
S.	1911.	Chope, H. F., 38, Church Street, Sheffield.
Lncs.	1921.	Christie, R. M., 21, Pendle Street, Padiham, Lancs.
C.	1919.	Clare, A. E., 29, Broadway, Earlsdon, Coventry.
E.M.	1919.	Clark, A. S., Leicester Road, Loughborough.
N.	1921.	Clark, Jas., 60, Bensham Road, Gateshead-on-Tyne.
N.	1920.	Clark, J. W., 133, Thomas Terrace, Blaydon-on-Tyne.

B'nch.	Year of Election.	
Sc.	1911.	Clark, R., 34, Mungalhead Road, Falkirk, N.B.
L.	1923.	Clark, W., 9, Jubilee Road, Basingstoke.
N.	1912.	Clarke, J., Battenburg Terrace, Newport Road, Tayport, N.B.
N.	1921.	Clarke, James, 20, Mortimer Road, South Shields.
Lncs.	1917.	Clayton, E. L., 75, Heywood Street. South West View, Bury.
N.	1920.	Clements, H. F., 14, Roseberry Crescent, Jesmond, Newcastle-on-Tyne.
Sc.	1922.	Cleverley, A.M., B.Sc., 18, Philip Street, Bainsford, Falkirk, N.B.
Lncs.	1922.	Cleworth, Alf., 25, Walnut Street, Bolton.
N.	1920.	Clowes, R., 30, Birchington Avenue, South Shields.
Lncs.	1921.	Coleman, J. I., West Dene, Brooklyn Road, Wilpshire, Blackburn.
L.	1923.	Coates, E. A., 48, Cheneys Road Leytonstone, E.11.
S.	1920.	Coles, W. H., 2, Gordon Avenue, Woodseats, Sheffield.
C.	1919.	Colgrave, W., 13, Windsor Street, Coventry.
E.M.	1918.	Colley, E., 510, Gladstone Street, Peterborough.
Sc.	1916.	Collins, B. L., Parkview Terrace, Bathgate, Glasgow.
S.	1920.	Collins, W. R., Sheffield Road, Sheepbridge, nr. Chesterfield.
Sc.	1920.	Colquhoun, John, 72, Balmoral Avenue, Cathcart, N.B.
S.	1907.	Cook, A. H., W. Cook & Sons, Washford Road, Sheffield.
E.M.	1916.	Cook, F., 168, Woods Lane, Derby.
S.	1914.	Cook, W. G., Washford Road, Sheffield.
Lncs.	1911.	Cooper, C. D., Dolphin Foundry, Chapel Street, Ancoats, Manchester.
S.	1914.	Cooper, J. F., 176, Atterclifte Road, Sheffield.

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
C.	1915.	Cooper, W., 123, Wyley Road, Coventry.
N.	1919.	Corbett, W. A., 22, Ash Grove, Wallsend-on-Tyne.
C.	1919.	Corden, S. H., Folly Lane Bungalow, Coventry.
Lncs.	1921.	Corsair, J., 1, Grimshaw Street, Stockport.
S.	1914.	Coupe, B., 317, Bellhouse Road, Shiregreen, Sheffield.
B.	1915.	Cowper, G. E., Conway Road, Bromsgrove, Worcs.
Sc.	1919.	Cree, A., 207, Caledonian Road, Polmadie, Glasgow.
L.	1910.	Cree, F. J., Fair View, Huntly Grove, Peterborough.
B.	1906.	Cresswell, D., 24, Herbert Road, Lightwoods, Smethwick.
Lncs.	1910.	Critchley, F., 631, St. Helens Road, Bolton.
S.	1912.	Critchley, T., 52, Limpsfield Road, Brightside, Sheffield.
S.	1916.	Crowther, A., 5, Sharrow Mount, Psalter Lane, Sheffield.
B.	1906.	Curnow, M. H., 415, Whitehall Road. Great Bridge, Tipton.
S.	1914.	Currie, J. A.
B.	1907.	Dalrymple, D., 20, Beeches Road, West Bromwich.
Sc.	1920.	Dalrymple, J., Bonhard Mill, Linlithgow, N.B.
S.	1920.	Darby, A., 5, Dobbin Hill, Greystones, Sheffield.
S.	1914.	Dargue, G., 20, Kimberley Street, Attercliffe Road, Sheffield.
S.	1909.	Darley, F., 187, Burngreave Road, Pitsmoor, Sheffield.
S.	1915.	Darley, G. F., Westgate Foundry, Rotherham.
E.M.	1923.	Darrington, L. G., 27, Kingston Avenue, Hallam Fields, Ilkeston
Sc.	1922.	Davidson, W. B., 18, Hayswell Road, Arbroath, N.B.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1915.	Davies, E., Atlas Foundry, Shrewsbury, Salop.
E.M.	1918.	Davis, C., 184, The Croft, Lincoln Road, Walton, Peterborough.
L.	1916.	Davis, E. J., 11, Beclair Street, Belfast.
Lncs.	1923.	Davis, J., 56, Old Road, Dukinfield, Cheshire.
L.	1914.	Davis, W. H., "Inglenook," Hambrook, nr. Emsworth, Hants.
N.	1915.	Davison, H., 3, Beaconsfield Square, Hartlepool.
N.	1921.	Davison, senr., J. G., Cottage People's Hall, Rye Hill, Newcastle.
N.	1921.	Davison, T. R., 72, Third Avenue, Heaton, Newcastle.
N.	1920.	Dawson, A. L. B., 5, Lesbury Road, Heaton, Newcastle-on-Tyne.
S.	1922.	Day, A. B., 19, Scarsdale Road, Dronfield, Near Sheffield.
Sc.	1911.	Deakin, J., Signal Works, 640, New City Road, Glasgow.
B.	1916.	Dean, S., 14, Dent Street, Tamworth.
Lncs.	1920.	Dearden, J., 18, Hulme Street, Elton, Bury.
Lncs.	1918.	Demaine, F. C., 279, Lees Road, Oldham.
Lncs.	1922.	Demaine (jun.), F. C., 279, Lees Road, Oldham.
Lncs.	1904.	Dempster, R., Vale Royal, Northwich, Cheshire.
E.M.	1918.	Dent, F. J., 78, Lincoln Road East, Peterborough.
Lncs.	1918.	Derbyshire, P., 23, Salisbury Road, Broadheath, Cheshire.
W.R. of Y.	1922.	Derrington, H., 6, Victoria Terrace, Hopwood Lane, Halifax.
E.M.	1909.	Derry, L. B., 108, Broadway, Peterborough.
S.	1915.	Dickinson, J., 43, Yarboro' Road, Lincoln.
N.	1916.	Dickinson, S., 103, Bede Street, Roker, Sunderland.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1920.	Dicks, G. E., 11, St. John's Road, Richmond Hill, Langley, near Birmingham.
S.	1914.	Dixon, A. F., 16, Botanical Road, Sheffield.
E.M.	1918.	Dobbs, W., Allen & Simmonds, Reading.
B.	1909.	Dobson, C., The Ivies, Barston, Hampton-in-Arden.
S.	1916.	Dobson, J., 24, Vickers Road, Firth Park, Sheffield.
B.	1909.	Dobson, J. G., 6, Daniels Road, Ideal Village, Bordesley Green, Birmingham.
Sc.	1920.	Dodo, H., Mitsubishi Dockyard and Engine Works, Kobe, Japan.
Lncs.	1921.	Dolphin, J. H., 201, Eskrick Street, Halliwell, Bolton.
Sc.	1919.	Donaldson, J. W., Scott's Shipbuilding and Engineering Company, Limited, Greenock, N.B.
Sc	1919.	Dorsie, J. C., Maplewood, Kirkintilloch.
Sc.	1911.	Downes, J., Cairn Dhu Cottage, Buchanan Street, Dumbarton.
N.	1921.	Downing, J. R., 137, Windsor Avenue, Gateshead-on-Tyne.
E.M.	1915.	Drakefield, G. E., The Quadrangle, King George's Crescent, Melbourne, Derbyshire.
B.	1920.	Dubberley, F., 44, Great Arthur Street, Smethwick, Staffs.
Sc.	1917.	Duncan, J., 78, Jellicoe Street, Dalmuir.
Lncs.	1921.	Dunkerley, James, 7, Pelham Street, Bardsley, Ashton-u.-Lyne.
N.	1920.	Dunn, J. W., 11, Seymour Road, Stoke, Ipswich.
Lncs.	1921.	Dyson, John, 143, Padiham Road, Burnley.
S.	1918.	Eastop, W. T., 868, Chesterfield Road, Sheffield.
Lncs.	1913.	Eastwood, J. H., 31, Samuel Street, Castleton, nr. Manchester.

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
L.	1912.	Eccott, A. E., The Elms, 68, Smithies Road, Plumstead, S.E.
Sc.	1911.	Edmiston, M., Rose Vale, Windsor Road, Renfrew, N.B.
W.R. of Y.	1922.	Edmondson, J., 107, Woodroyd Road, West Bowling, Bradford.
B.	1922.	Edwards, F. C., 32, Queen's Head Road, Handsworth, Birmingham.
N.	1920.	Elliott, J. V., 41, Eglesfield Road, South Shields.
E.M.	1909.	Ellson, J., Manor View, Ripley, Derby.
C.	1922.	Elston, Alfred, 62, Craven St., Coventry.
Sc.	1920.	Erskine, N. A. W., Morton Cottage, Camelon, N.B.
B.	1921.	Evans, Chas. Hy., 102, Llantarnam Road, Cwmbran, Mon.
C.	1920.	Everett, A., 28, Maycock Road, Coventry.
B.	1919.	Evitts, I., 77, Union Street, West Bromwich.
W.R. of Y.	1922.	Farrar, Levi, 22, Springswood Ave., Shipley, Yorks.
Lncs.	1919.	Farrow, C., 84, Louisa Street, Openshaw, Manchester.
Lncs.	1922.	Faulkner, Thos., 95, Bank Street, Clayton, Manchester.
Lncs.	1919.	Fawcett, W. R., 93, Rosegrove Lane, Burnley, Lancs.
S.	1919.	Fell, R. C. D., 167, Duncombe Street, Sheffield.
Lncs.	1923.	Fellows, F., 21, Bright Street, Gorton, Manchester.
Sc.	1912.	Ferlie, T., Steel and Iron Founder, Auchtermuchty, N.B.
Sc.	1919.	Finlayson, W., 18, Clifford Street, Ibrox, Glasgow.
W.R. of Y.	1922.	Firm, P., 39, Parsonage Road, Laisterdyke, Bradford.
Sc.	1910.	Fisher, A., 20, Drumcross Road, Bathgate, Glasgow.
Lncs.	1922.	Fist, Thos., 17, St. Ann Street, Bolton, Lancs.
Lncs.	1917.	Fitzpatrick, A., Ferngrove House, Ferngrove, Bury, Lancs.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
N.	1922.	Flack, E. W., 3, Falshaw Street, Washington Station, Co. Durham.
B.	1918.	Flavell, W. J., Carter's Green Passage, West Bromwich.
Lncs.	1923.	Flint, W. H., 225, Peel Green Road, Patricroft, Manchester.
Lncs.	1923.	Flower. E., 7, Marlborough Street, Higher Openshaw, Manchester.
—	1907.	Fontaine, C., Dock Foundry, Newport, Monmouth.
N.	1912.	Ford, H., 14, Oakwellgate Chare, Gateshead-on-Tyne.
B.	1919.	Ford, H. J., 22, Arundel Villas, Finchfield Hill, Compton, near Wolverhampton.
W.R. of Y.	1922.	Forrest, H., 43, Beaumont Road, Manningham, Bradford.
N.	1921.	Forster, G. N. O., 6, Hylton Street, North Shields.
L.	1912.	Fowler, T. E., 22, Station Road, New Southgate, N.11.
C.	1923.	Fox, F. S., 147, Foleshill Road, Coventry.
W.R. of Y.	1922.	Fox, Herbert, 36, Granville Road, Frizinghall, Bradford.
C.	1909.	Fraser, A., 193a, College Street, Chilvers Coton, Nuneaton.
S.	1912.	Freeman, W. H., 33, Greetwell Gate, Lincoln.
N.	1914.	Frier, J. W., 5, Northumberland Villas, Wallsend-on-Tyne.
N.	1920.	Futers, R., Wm., 107, Sandwich Road, South Shields.
B.	1910.	Gale, W., 36, Salisbury Road, West Bromwich.
N.	1921.	Gallon, Thos., 57, Joseph Street, Newcastle-on-Tyne.
Sc.	1904.	Galt, J., Henry & Galt, Sneddon Foundry, Paisley, N.B.
Lncs.	1922.	Garside, A., 8, Boydes' Buildings, Hazelhurst, Ashton-under-Lyne.
B.	1920.	Gaunt, J. W., 38, Emily Street, West Bromwich.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1921.	Gay, C. J. E., Ryeford, near Stonehouse, Glos.
B.	1920.	Gell, J. V. P., 56, Blythswood Road, Acocks Green, Birmingham.
N.	1916.	Gibbon, O. R., Thornley Terrace, Tow Law, S.O., Co. Durham.
Sc.	1919.	Gibson, J., 452, Paisley Road West, Glasgow
N.	1917.	Gibson, J. A., 17, Lynn Street, Blyth, Northumberland.
Sc.	1922.	Gibson, J. E., "Armont," Falkirk, N.B.
Lncs.	1923.	Gilpin, W., "Sunnyside," Birch Grove, Rusholme, Manchester.
B.	1921.	Gledhill, A., Apple Tree Cottages, Rednal.
Lncs.	1922.	Gledhill, F., 205, East View, Bradford Road, Brighouse, Yorks.
S.	1918.	Glentworth, J., 29, Harrowden Road, Tinsley, Sheffield.
B.	1917.	Glynn, T. A., 67, Green Lane, Handsworth, Birmingham.
W.R. of Y.	1922.	Goff, R. M., 78, Lower Rushton Road, Thornbury, Bradford.
C.	1923.	Goss, W., 57, Beaconsfield Road, Coventry.
E.M.	1919.	Goodwin, T., 210, Parliament Street, Derby.
B.	1920.	Gotham, R. E., 75, Kenilworth Road, Handsworth, Birmingham.
C.	1919.	Gourd, C. D., 25, Shaftesbury Road, Earsldon, Coventry.
Sc.	1919.	Graham, R., 116, Stratford Street, Maryhill, N.B.
Sc.	1920.	Grant, Wm., 27, Silver Row, Falkirk, N.B.
Sc.	1912.	Gray, J., 2, Station Road, Dumbarton.
S.	1919.	Greaves, J. B., 121, Upperthorpe, Sheffield.
E.M.	1914.	Green, C. H., 33. St. Stephen Road, Leicester.
S.	1917.	Green, F. N., Brook House, Ecclesfield, Sheffield.

B'nch	Year of Election.	ASSOCIATE MEMBERS.
S.	1914.	Green, P., 43, Jessamine Road, Shiregreen, Sheffield.
Lncs.	1920.	Greenhalgh, W., 76, Lonsdale Road, Bolton.
L.	1918.	Gregory, E., 16, Mansfield Road, Beech Hill, Luton.
N.	1917.	Gresty, C., North-Eastern Marine Engineering Company, Limited, Wallsend-on-Tyne.
Lncs.	1919.	Grimwood, E. E. G., 6, Balmoral Terrace, Glebelands Road, Ashton-on-Mersey.
Lncs.	1912.	Grundy, H. V., 47, Moreton Avenue, Stretford, Manchester.
Lncs.	1917.	Grundy, J. H., 14, King Street, Earlstown, Lancs.
E.M.	1921.	Guest, Chas., 67, Mansfield Road, Derby.
L.	1920.	Gurney, S. J., 24, Burns Road, Battersea, S.W.
N.	1922.	Haddon, C. L., M.Sc., A.I.C., Silverhill, Denton Burn, Newcastle.
S.	1921.	Hagon, Wm., 35, Southgrove Road, Ecclesall, Sheffield.
Sc.	1920.	Haig, J., Taylor's Building, North Main Street, Stenhousemuir, N.B.
Sc.	1920.	Haig, T., 23, Livingston Terrace, Larbert, N.B.
B.	1922.	Haines, Alfred, 17, Aston Street, Toll End, Tipton, Staffs.
S.	1909.	Hall, E. D., 327, Penistone Road, Sheffield.
B.	1916.	Hall, Frank, 230, Carter Knowle Road, Sheffield.
L.	1921.	Hall, Geo., 1, Sylverdale Road, West Croydon.
N.	1914.	Hall, J. J., Clyde Vale, Rowlands Gill, Co. Durham.
L.	1920.	Halsey, L., 63, Killyon Road, Clapham, S.W.
C.	1920.	Hamblin, H., 55, King Edward Road, Rugby.
Sc.	1919.	Hamilton, W., 53a, King Street, Coatbridge, N.B.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1921.	Hamilton, W. B., 16, Brighton Place, Ibrox, Glasgow.
L.	1921.	Hammond, L., 27, North Way, North Heath, Erith.
L.	1918.	Hand, H. E., 189, Manwood Road, Crofton Park, S.E.4.
C.	1911.	Handy, C. F.
E.M.	1918.	Hanson, S. W., 350, Gladstone Street, Peterborough.
N.	1921.	Hardy, J., 35, Albert Terrace, Wallsend-on-Tyne.
Lncs.	1919.	Hargraves, R. R., (Grandridge and Mansergh, Ltd.), Wheathill Street, Salford, Manchester.
Lncs.	1921.	Hargreaves, G. E., 18, Creswick Ave., Rose Hill, Burnley.
Lncs.	1911.	Harper, H., 28, Alexandra Street, Castleton, nr. Manchester.
B.	1919.	Harper, J. H., 206, Bushbury Road, Fallings Park, Wolverhampton.
Lncs.	1922.	Harris, F., 18, Holland Street, Padiham, Lancs.
E.M.	1923.	Harris, F. C., 10, Great Central Road, Loughborough.
N.	1921.	Harris, Geo., Cleveland Avenue, North Shields.
S.	1909.	Harrison, J., Woodlea, Richmond Road, Handsworth, Sheffield.
C.	1919.	Harrison, J. A., 7, Edmund Road, Coventry.
C.	1915.	Harrow, H., 81, Richmond Street, Coventry.
Sc.	1916.	Harrower, J. (Bo'ness Iron Company), Bo'ness, N.B.
Sc.	1914.	Hartley, R. F., London Road Foundry, Edinburgh.
L.	1922.	Harwood, John P., 112, Nithdale Road, Plumstead, S.E.
Lncs.	1922.	Hasan, M. A., 459, Chesters Road, Old Trafford, Manchester.
Lncs.	1917.	Haughie, C. M., 12, Grosvenor Street, Stretford, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
E.M.	1920.	Hawley, T. H., Eton House, 82, Sydney Street, Horninglow, Burton-on-Trent.
Sc.	1910.	Hay, J., 12, Albany Drive, Burnside, Rutherglen, Glasgow.
L.	1912.	Hayes, A., 116, Rusthall Avenue, Bedford Park, W.
B.	1910.	Hayward, G. T., 8, The Laurels, Marroway Street, Birmingham.
Lncs.	1923.	Hayward, R., 219, Tottington Road, Bury.
L.	1922.	Hayward, Wm., 33, King's Avenue, Ipswich.
N.	1921.	Heddon, R. C., 13, Gladstone Street, Lemington-on-Tyne.
N.	1922.	Heap, G. H., 269, Bensham Road, Gateshead-on-Tyne.
B.	1917.	Hefford, S., 377, Pershore Road, Selly Park, Birmingham.
E.M.	1915.	Hegg, J.,115, Taylor Street,Osmaston, Derby.
Lncs.	1922.	Henderson, G., 1120, Eleventh Street, Trafford Park, Manchester.
L.	1910.	Henderson, G. B., 23, College Road, Woolstan, Southampton.
N.	1923.	Henderson, J. W., c/o Singapore Harbour Board, Singapore, Straits Settlements.
Sc.	1911.	Henderson, R., 67, Love Street, Paisley.
N.	1921.	Henderson, R., 173, Derwentwater Road, Gateshead-on-Tyne.
Sc.	1921.	Henry, John, 75, Alma Street, Grahamston, Falkirk, N.B.
Lncs.	1922.	Henshaw, J. E., 427, Stockport Road, Lower Bredbury, Stockport.
S.	1921.	Hepworth, G. W., 21, Gainsford Road, Darnall, Sheffield.
E.M.	1920.	Hey, James Wm., 43, Howe Street, Derby.
L.	1922.	Hibbert, J., 138, Burlington Road, Thornton Heath, Croydon.
Lncs.	1920.	Higginbottom, J., 6, John Street, Heyrod, Stalybridge, Lancs.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1915.	Hill, A., 114, Middleton Road, Heywood, Lancs.
C.	1919.	Hill, F., 86, Broomfield Road, Coventry.
Lncs.	1921.	Hilton, F., 39, Mather Street, Radcliffe, Manchester.
E.M.	1917.	Hilton, H. J. S., 29, West Avenue, Derby.
Lncs.	1909.	Hilton, T. G., Block 4, Rose Hill Road, Burnley.
B.	1921.	Hinley, Geo. H., 53, Park Lane End, Tipton, Staffs.
E.M.	1914.	Hipkins, B., 35, Boyer Street, Loughborough.
B.	1912.	Hird, B., Foundry Dept., Guest, Keen and Nettlefolds, Ltd., Cwmbran Works, nr. Newport, Mon.
W.R. of Y.	1922.	Hird, W., Smokers' Corner, Harden, Bingley, Yorks.
Lncs.	1914.	Hirst, S., 1, Saint Andrew's Street, Radcliffe, Lancs.
B.	1913.	Holberry, F., Hedley Terrace, Llanelly, S. Wales.
C.	1918.	Holder, F. W., 131, Eagle Street, Coventry.
S.	1920.	Holland, G. A., 57, Baltic Road, Attercliffe, Sheffield.
Lncs.	1922.	Holland, W., 71, Coniston Road, Stretford, Manchester.
B.	1917.	Hollinshead, A. E., 68, King's Road, Sedgley, Dudley.
B.	1917.	Homer, W. C., 51, Lodge Road, West Bromwich.
N.	1921.	Hopper, Geo. A., 141, Westminster Street, Gateshead-on-Tyne.
Lncs.	1921.	Hopwood, Wm., 4, off Redhouse Lane, Bredbury, near Stockport.
Lncs.	1919.	Horrocks, H., 16, Kimberley Avenue, Romiley, nr. Stockport.
L.	1921.	Hotchkis, J. D., 29, Romberg Road, London, S.W.17.
S.	1906.	Houghton, E., Dunston Villa, Sheepbridge, Chesterfield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
C.	1922.	Houghton, J., 15, Mayfield Road, Coventry.
Lncs.	1921.	Howcroft, J., 5, St. James' Street, New Bury, Farnworth, nr. Bolton.
—	1922.	Howe, C. A., 14, Brougham Hayes, Bath, Somerset.
Sc.	1920.	Howie, J., Burnside Cottages, Denny, N.B.
W.R. of Y.	1917.	Hoy, R. E., 5, Barker Street, North Holmfield, nr. Halifax.
N.	1923.	Hudson, F., 28, Curtis Road, Fenham, Newcastle-on-Tyne.
L.	1914.	Hurst, J. E., 3, Sandilands, Troon, Ayr.
L.	1922.	Husselbury E., 147, Marlborough Road, Bedford.
N.	1918.	Hutchinson, S., 4, Gladstone Terrace, Birtley, Co. Durham.
Lncs.	1917.	Inskip, A., 4, Welbeck Street, Gorton, Manchester.
Sc.	1920.	Irvine, A., The Point, North Main Street, Stenhousemuir, N.B.
Lncs.	1917.	Jackson, H. G., 1, Brierley Street, Stalybridge, Lancs.
Lncs.	1921.	Jackson, J., 25, Clarance Street, Burnley.
C.	1919.	Jackson, T. G., 63, Whitmore Road, Kenilworth.
L.	1906.	Jackson, W. J., 23, Willeys Avenue, Exeter.
Lncs.	1920.	Jacques, J. W., 9, Stanton Street, Clayton, Manchester.
Lncs.	1923.	Jacques, T., The Cottage, Hill Top, Romiley, near Stockport.
C.	1909.	Jacques, W., 131, Wyley Road, Coventry.
B.	1914.	James, W., 96, Grove Lane, Handsworth, Birmingham.
N.	1919.	Jay, H. C., 97, Cardigan Terrace, Heaton, Newcastle-on-Tyne.
N.	1921.	Jobes, G. B., 18, South Street, Gateshead-on-Tyne.
S.	1914.	Johnson, D. R., 11, Somerset Road, Pitsmoor, Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1919.	Johnson, J. B., 27, Ball Fields, Tipton.
Lncs.	1916.	Jones, J. H., "Elleray," Temple Drive, Swinton, Manchester.
Lncs.	1919.	Jowett, H., 53, Turf Hill Road, Rochdale.
C.	1919.	Judd, G. H., 8, Ludlow Road, Coventry.
Lncs.	1922.	Kay, Wm., 9, Eastbank Street, Bolton, Lancs.
W.R. of Y.	1922.	Kaye, H., 6, Fryergate Terrace, New Scarboro', Wakefield.
Lncs.	1907.	Kemlo, R. W., 104, Barton Road, Stretford, Manchester.
C.	1921.	Kemp, J. A., 1, Fairfax Street, Coventry.
Sc.	1912.	Kennedy, J., "Dunard," Howieshill, Cambuslang, N.B.
Sc.	1921.	Kennedy, Luke, 927, Gt. Eastern Road, Glasgow.
Lncs.	1922.	Kent, C. W., 16, Beech Grove, Withington, Manchester.
N.	1921.	Kent, Geo. A., 5, High West Street, Gateshead-on-Tyne.
E.M.	1918.	Kerfoot, J., 23, Cumberland Road, Loughborough.
E.M.	1920.	Kerfoot, Jos., 119, Leopold Street, Loughborough.
Sc.	1914.	Kerr, W., 101, Ardgowan Street, Glasgow.
N.	1922.	Kirby, J. E., 31, Laburnum Gardens, Monkton, Jarrow-on-Tyne.
W.R. of Y.	1922.	Kirkbride, A. D., 4, Cecil Grove, Armley, Leeds.
Sc.	1920.	Kirkwood, J., 102, Balgrayhill Road, Springburn, Glasgow.
B.	1922.	Kitchen, B., 1, Hughes Avenue, Birches Barn Road, Wolverhampton.
L.	1922.	Klouman, F. A., "Bengarth," Hare Lane, Claygate, Surrey.
C.	1919.	Klyver, F. D., 45, Farman Road, Coventry.
S.	1908.	Knowles, J. (c/o. Walkers), Manchester Road, Stocksbridge, Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1922.	Laidlow, Wm., 9, Griffin Road, Plumstead, S.E.
Lncs.	1923.	Laing, J., Green Dragon Hotel, Workington.
S.	1920.	Laing, Wm., 4, Main Road, Handsworth, Sheffield.
Sc.	1920.	Lang, J. N., Thornwood, Bridge of Weir, N.B.
Sc.	1922.	Lang, Wm., 5, Third Terrace, Radnor Park, Clydebank, N.B.
Sc.	1907.	Lawrie, Alex., 40, Glebe Road, Kilmarnock.
Sc.	1919.	Lawrie, R. D., 21, Clarendon Street, Glasgow.
S.	1920.	Laycock, E.
Lncs.	1917.	Leach, R., 53, Tower View, Lord Street, Stalybridge.
Lncs.	1914.	Leaf, J. W., 20, Clovelly Street, Newtown, Rochdale.
N.	1913.	Lee, J., 38, Point Pleasant Terrace, Wallsend-on-Tyne.
—	1921.	Leech, Wm. Creighton (N.S.W. Gov. Railways), Wentworth and Rutledge Street, Eastwood, Sydney, N.S.W.
Lncs.	1907.	Leigh, A. P., Vulcan Works, Blackfriars Road, Manchester.
E.M.	1919.	Lemmy, T. C., 16, St. Paul's Road, Peterborough.
C.	1920.	Lengden, W. A., 34, Churchill Avenue, Coventry.
S.	1920.	Lewin, H., Gov. Inspector of Castings, Kulti, E.I. Rly., India.
B.	1919.	Lewis, D. (John Harper & Company, Limited), Albion Works, Willenhall, Staffs.
B.	1910.	Lewis, G., Strathmore, Paget Road, Wolverhampton.
N.	1921.	Lewis, Martin, 6, Grosvenor Road, Jesmond, Newcastle-on-Tyne.
Sc.	1919.	Lindsay, J., 95, Drygate Street, Glasgow.
C.	1919.	Linnett, A. T., 4, Earlsdon Avenue, Coventry.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1919.	Lisby, T., 7, Meanley Road, Manor Park, E.
N.	1919.	Little, J. E. O., 83, Rothwell Road, Gosforth, Newcastle-on-Tyne.
Sc.	1910.	Littlejohn, A., 11, Esmond Street, Yorkhill, Glasgow.
L.	1922.	Littleton, W. H., 29a, Wabeck Road, Anerley, S.E.20.
Lncs.	1921.	Livesey, T., 80, Church Street, Little Lever, nr. Bolton.
N.	1916.	Loader, W. S., 282, Stanhope Road, South Shields.
Sc.	1910.	Logan, J., 14, Chapelwell Street, Saltcoats, N.B.
Lncs.	1920.	Lomax, J., 89, Moorfield Grove, Bolton.
S.	1917.	Long, J., 62, Sheldon Road, Nether Edge, Sheffield.
B.	1921.	Longden, Ed., 80, Regent Road, Handsworth, Birmingham.
Sc.	1922.	Longden, J., 11, Drumny Road, Clydebank.
W.R. of Y.	1922.	Lowe, E., 40, Woodhouse Grove, Keighley, Yorks.
Lncs.	1919.	Luby, W., 10, East Avenue, Burnage, Manchester.
Sc.	1923.	Lumley R., Garden Row, Bonnybridge, N.B.
Lncs.	1910.	Lupton & Sons, H. E., Scaithcliffe Works, Accrington.
S.	1913.	Macdonald, W. A., 62, Bannerdale Road, Sheffield.
Sc.	1917.	MacDougall, Miss E., 22, Clarendon Street, St. George's Cross, Glasgow.
B.	1908.	Mace, C., 64, Port Street, Manchester.
Sc.	1910.	Macfarlane, J., 31, Kings Park Avenue, Cathcart, Glasgow.
Sc.	1910.	Mackay, G., 103, Glasgow Road, Paisley, N.B.
S.	1916.	Mackley, A., 151, Malton Street, Sheffield.
Lncs.	1922.	Maclachlan, J. R., 52, Jackson Street, Stretford, Manchester.
Lncs.	1921.	Mallett, E., 1152, Chorley Old Road, Bolton.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1909.	Marks, J., 73, Crosswells Road, Langley, Birmingham.
Lncs.	1923.	Marlow, E., 53, Flixton Road, Urmston, Manchester.
W.R. of Y.	1922.	Marsden, J. W., 20, Steadman Terrace, Bradford, Yorks.
Sc.	1921.	Marshall, A., 7A, Hendry Street, Bainsford, Falkirk, N.B.
Sc.	1910.	Marshall, G., "Fereneze," Russell Street, Burnbank, Lanark, N.B.
L.	1922.	Marshall, H. C., 29, Westward Road, S. Chingford, E.4.
Sc.	1910.	Marshall, J., Kelspoke, Potter Hill, Paisley, N.B.
Sc.	1920.	Marshall, R., 159, Mungalhead Road, Falkirk, N.B.
Sc.	1913.	Marshall, W., Woodlands Cottage, Armadale, N.B.
Sc.	1912.	Marshall, W. G., "Kyleakin," Larkhall, N.B.
Lncs.	1913.	Marsland, T., 401, Manchester Road, Droylesden, Manchester.
W.R. of Y.	1922.	Martin, F., 67, Nowell Terrace, Harehills Lane, Leeds.
E.M.	1907.	Mason, H. P., 46, Hawcoat Lane, Barrow-in-Furness.
B.	1919.	Mason, T., 29, Old Park Road, King's Hill, Wednesbury.
Lncs.	1917.	Masters, J., 2nd 17, Cheetham Hill Road, Stalybridge.
B.	1922.	Masters, T. J., 12, Glover Street, West Bromwich.
B.	1913.	Mather, H., "Doris," Deykin Avenue, Witton, Birmingham.
B.	1909.	Mathews, J., 20, Earl Street, Walsall.
B.	1921.	Mauby, R. A., Gorsty Hayes, Tettenhall, Staffs.
Lncs.	1920.	Mayoh, W., 90, Maslin Street, Newton, Hyde, Cheshire.
N.	1919.	McBride, T. B., 3, Kingsley Avenue, Whitley Bay.
Sc.	1910.	McCall, J. J., 348, New City Road, Maryhill, Glasgow.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1922.	McCleallan, C. J., 110, Carver Street, Sheffield.
Sc.	1919.	McConnell, W., 136, Carsaig Drive, Craigton. Glasgow.
Sc.	1913.	McDonald, W. F., 5, Hutchinson Place, Cambuslang, N.B.
Sc.	1911.	McEachen, J., Regent Street, Kirkintilloch, N.B.
Sc.	1917.	McFadzean, J., 29, Fullarton Street, Kilmarnock, N.B.
B.	1904.	McFarlane, T., Farm Road, Horsehay, Salop.
Sc.	1914.	McGavin, R., 26, Kilbowie Road, Clydebank, N.B.
Sc.	1919.	McGillivray, D., 986, Maryhill Road, Glasgow.
Sc.	1920.	McGovan, A., 69, Battlefield Avenue, Langside, Glasgow.
Sc.	1910.	McGowan, R. R., 14, Wilton Drive, Glasgow.
Sc.	1919.	McGregor, G., Ardchoille, Stevenston, N.B.
Sc.	1910.	McGrouther, T., Ingleside, Bonnybridge, N.B.
N.	1916.	McIntosh, S., 50, Hollywell Avenue, Monkseaton.
Sc.	1919.	McKay, J. M., 26, Cambus Cottages, Westwood Road, Newmains, N.B.
Lncs.	1923.	McKenzie, Wm., Ford Lane Works, Pendleton, Manchester.
Sc.	1922.	McKinnon, J. C., Leaside Cottage, Barrhead, N.B.
Sc.	1910.	McLachlan, W., 5, Dawson Terrace, Carron, Falkirk, N.B.
N.	1921.	McLaren, A. J., 45, Panmure Street, Scotswood Road, Newcastle-on-Tyne.
Lncs.	1919.	McLaren, R., 19, Milton Street, Padiham, Lancs.
N.	1922.	McLaughlin, P., Patterson Street, Blaydon-on-Tyne.
Sc.	1919.	McLay, A. W., 22, Elizabeth Street, Ibrox, N.B.

B'nch	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1915.	McNab, J., Bumfort House, Falkirk, N.B.
Sc.	1910.	McPhie, H., 40, Philip Street, Falkirk, N.B.
Sc.	1910.	McQueen, D., Eastfield, Lauriston, Falkirk, N.B.
Sc.	1914.	Mearns, A., 54, Nairn Street, Glasgow.
C.	1919.	Meech, G. R., 23, Oliver Street, Coventry.
N.	1921.	Melville, J. T. E., 1, Elizabethville, Birtley, Durham.
S.	1918.	Meredith, W. C., 14, Raby Street, Tinsley, Sheffield.
C.	1921.	Meston, J. M., 37, Melville Road, Coventry.
S.	1913.	Millar, A., 90, Bawtry Road, Tinsley, Sheffield.
C.	1921.	Miller, G. A., 68, St. Margaret's Road, Coventry.
Sc.	1912.	Milligan, A., 39, Bank Street, Greenock.
N.	1921.	Mills, Wm. J., 66, Bournmouth Terrace, Elswick, Newcastle-on-Tyne.
S.	1918.	Milner, H., 163, Cross Hill, Ecclesfield, nr. Sheffield.
W.R. of Y.	1923.	Milner, J. W., 29, Welbeck Street, Sandal, Wakefield.
W.R. of Y.	1923.	Mitchell, G. W., Stafford Cottage, 5, S. Westhorpe Road, Wakefield.
Sc.	1919.	Mitchell, J., 6, Broomfield Terrace, Springburn, Glasgow.
Sc.	1920.	Mitchell, J., 12, George Street, Barrhead, Glasgow.
W.R. of Y.	1923.	Mitchell, J., 16, Pincheon Street, Wakefield.
Sc.	1922.	Mitra, S. B., c/o Bengal Iron Co., Ltd., Kulti, E. I. R., India.
Lncs.	1918.	Moffat, J., 12, Dryden Street, Padiham, Lancs.
B.	1919.	Moffat, J., 212, West North Road, Northfield, Birmingham.
Sc.	1916.	Moir, J. D., Bo'ness Iron Company, Bo'ness, N.B.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1916.	Moles, T., 7, Delville Street, Churchill, Wednesbury.
B.	1919.	Molineux, W. J., 212, Oxford Gardens, Stafford.
Sc.	1919.	Montgomery, A. W., Annfield, St. Catherine's Road, Giffnock, N.B.
E.M.	1921.	Moodie, Colin, 169, Station Road, Beeston, Notts.
B.	1916.	Moore, W. H., 39, Cresswells Road, Langley Green, Birmingham.
N.	1920.	Moorhead, H. A., 22, Moorland Crescent, Walker Estate, Newcastle.
L.	1904.	Morehead, C., Hill View, Pollards Hill West, Norbury, S.W.16.
Sc.	1909.	Morehead, J. S., c/o Saunders, 33, Ingleby Drive, Dennistoun, Glasgow.
B.	1919.	Morewood, J. L., 37, Paignton Road, Rotton Park, Birmingham.
C.	1920.	Morgan, B. S., B.Sc., A.I.C., 42, Park Road, Rugby.
—	1922.	Morgan, W., 34, Coronation Terrace, Porth, Glam., So. Wales.
C.	1922.	Morris, H. J., New Shop, Heath Road, Swan Lane, Coventry.
L.	1920.	Morris, J. S., 11a, Kingdon Road, West Hampstead, N.W.6.
Sc.	1920.	Morrison, G. B., 671, Hawthorn Street, Springburn, Glasgow.
Lncs.	1920.	Morrison, H., 88, Crete Street, Oldham.
N.	1913.	Murray, J., 5, Elmwood Avenue, Willington, Quay-on-Tyne.
S.	1914.	Naylor, A., 69, Scott Road, Pitsmoor, Sheffield.
Lncs.	1915.	Naylor, F., 26, Nowell Crescent, Harehills Lane, Leeds.
N.	1914.	Nekervis, J., 14, Broughton Road, South Shields.
Lncs.	1920.	Newport, F., 1428, Ashton Old Road, Higher Openshaw, Manchester.
Lncs.	1912.	Nicholls, J., 146, Hulton Street, Trafford Road, Salford.
N.	1921.	Nicholson, J. D., 13, Taylor Street, South Shields.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1918.	Nisbet, H. L., 11, Braeside Street, Glasgow.
Lncs.	1920.	Noble, A., 42, Central Road, Gorton, Manchester.
L.	1921.	Norman A. H., 43, Dunvegan Road, Eltham, S.E.
C.	1919.	North, L. P., 5-8, Men's Hostel, Holbrook Lane, Coventry.
E.M.	1918.	Northcliffe, S., 66, Harris Street, Peterborough.
—	1921.	Nowland, J. E., 37, Provost Street, Holbeck, Leeds.
N.	1918.	Oakford, E. F., "Uplands," Birtley, Co. Durham.
S.	1921.	Offiler, G., 9, Ward Place, Highfields, Sheffield.
Lncs.	1921.	Oldham, F., 42, Lodge Lane, Flowery Fields, Hyde, Cheshire.
Lncs.	1921.	Oldham, Harry, 11, St. Thomas Street, South Oldham, Lancs.
Lncs.	1920.	Oldham, R., 191, Dill Hall Lane, Church, Lancs.
Sc.	1920.	Oliver, J., 34, Rae Street, Stenhousemuir, Larbert, N.B.
N.	1910.	Olsen, W., Cogan Street, Hull.
Sc.	1920.	Orman, Wm., 27, Hamilton Street, Camelon, N.B.
Lncs.	1921.	Orme, R., 31, Stockport Road, Hyde, Cheshire.
Lncs.	1921.	Osborne, W. H., 51, Hufling Lane, Burnley.
E.M.	1922.	Ottewell. H., The Meads, Swanwick, Alfreton, Derby.
B.	1922.	Owen, A. C., 33, Park Street, Madeley, Salop.
S.	1914.	Oxley, C., c/o Oxley Bros., Mowbray Street, Sheffield.
S.	1920.	Page, S., 7, Scott Road, Pitsmoor, Sheffield.
Lncs.	1923.	Palmer, T., 5, Marmaduke Street, Oldham.
N.	1921.	Parkinson, A., 25, Prudhoe Street, Backworth, nr. Newcastle-on-Tyne.

B'nch.	Year of Election	ASSOCIATE MEMBERS.
L.	1920.	Parnell, H., "Freda Villa," Queen's Road, Burnham-on-Crouch.
B.	1918.	Parsons, A., 32, Cordley Street, West Bromwich.
Sc.	1914.	Patrick, A., 65, Mungalhead Road, Falkirk, N.B.
N.	1921.	Patterson, F. E., 17, Mariners' Homes, Tynemouth.
Sc.	1916.	Paul, R., 1, Bellfield Street, Barrhead, N.B.
B.	1907.	Peers, J., 13, Idwal Street, Neath, S. Wales.
E.M.	1906.	Pemberton, H., 15, Wolfa Street, Derby.
Sc.	1920.	Penman, Wm., 68, Mungalhead Road, Bainsford, Falkirk, N.B.
B.	1918.	Percival, A. E., "Claverdon," Colwyn Crescent, Rhos-on-Sea, Colwyn Bay
Lncs.	1919.	Perkins, F. S., 55, Slaney Street, Newcastle-under-Lyme, Staffs.
Lncs.	1914.	Pevitt, Hy., 75, Orford Street (Central), Warrington.
Sc.	1920	Philip, G., 44, Dalderse Avenue, Grahamston, Falkirk, N.B.
Lncs.	1922.	Phillips, A., 48, Harley Road, Sale, near Manchester.
Sc.	1921.	Phillips, Wm., Mary Street, Falkirk, N.B.
C.	1919.	Phipps, H., 93, Raglan Street, Coventry.
B.	1918.	Picken, J., Lilac Cottage, Doseley, Dawley, Salop.
L.	1920.	Pierce, G. C., 11, Athelney Street, Bellingham, S.E.
Sc.	1919.	Pinkerton, J., 57, King Street, Blairhill, Coatbridge, N.B.
B.	1911.	Plant, W. H., Beacon House, Tipton.
E.M.	1918.	Poole, A., 626, Oakhill, Stoke-on-Trent.
Lncs.	1918.	Potts, W., 1, Far Lane, Hyde Road, Gorton, Manchester.
W.R. of Y.	1922.	Poulter,H., 4, Beech Grove, Undercliffe, Bradford, Yorks.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1918.	Powell, H. J., 132, Tividale Road, Tipton.
Lncs.	1922.	Prescott, J., 3, Louisa Street, Bolton, Lancs.
C.	1919.	Prickett, R., 26, Ludlow Road, Coventry.
Lncs.	1922.	Priestley, Jos., 258, Waterloo Street, Bolton, Lancs.
Lncs.	1922.	Priestley, Thos., 185, Kay Street, Bolton, Lancs.
L.	1912.	Primrose, H. S., 12A, Rectory Lane, Chelmsford.
Lncs.	1912.	Primrose, J. S. G., 17, Salisbury Road, Chorlton-cum-Hardy, Manchester.
E.M.	1921.	Prince, Thos., 176, Mansfield Road, Derby.
B.	1909.	Pugh, C. B., 1 Bescot Road, Walsall.
S.	1917.	Pugsley, T. M., Noah's Ark Hotel, Intake, Sheffield.
E.M.	1916.	Radford, H. P., 151, Barclay Street, Fosse Road South, Leicester.
Lncs.	1920.	Ramsey, W., 9, Creswick Avenue, Rose Hill, Burnley.
Sc.	1904.	Rankin, R. L. (Sharp & Company), Lennox Foundry, Alexandria, N.B.
L.	1920.	Rasbridge, W. J., 160, Evelyn Street, Deptford, S.E.
Lncs.	1910.	Rawlinson, W., "Woodston," Little Hulton, Bolton.
C.	1921.	Reading, G. F., 46, Waterloo Street, Leamington Spa.
L.	1917.	Reaman, H., 13, Adelaide Road, Brockley, S.E.4.
S.	1907.	Redmayne, L., Little London Road, Sheffield.
N.	1921.	Reece, D., 24, Forster Street, Gateshead-on-Tyne.
E.M.	1916.	Reffin, J. J., 79, Barclay Street, Fosse Road, South Leicester.
Lncs.	1907.	Reynolds, W., 13, Park View Terrace, Oldham.
W.R. of Y.	1922.	Rhodes, W., 1, Vernon Place, Undercliffe, Bradford, Yorks.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1922.	Rhodes, Wm., Hartley Brook Lane, Ecclesfield, nr. Sheffield.
N.	1912.	Richardson, W., 204, South Frederick Street, South Shields.
Lncs.	1911.	Riley, J., 3, Glen Road, Oldham.
S.	1912.	Roberts, G. E., 149, Sharrow Vale Road, Sheffield.
N.	1921.	Robertson, H., 13, Leamington Street, Sunderland.
Sc.	1920.	Robinson, C. H., 42, Smith Street, Hillhead, Glasgow.
Lncs.	1920.	Robinson, F., 369, Wigan Road, Deane, Bolton.
N.	1917.	Robinson, J. H., 22, Park Parade, Whitley Bay.
Lncs.	1920.	Robinson, J. R., 12, Cobden Street, Padiham, Lancs.
W.R. of Y.	1922.	Robinson, W. G., 15, Keswick Street, Laisterdyke, Bradford, Yorks.
N.	1919.	Robson, F., 44, Stannington Place, Heaton, Newcastle-on-Tyne.
N.	1919.	Robson, G. E., The School House, Birtley, Co. Durham.
N.	1916.	Robson, J., 21, Glebe Crescent, Washington, Co., Durham.
S.	1913.	Rodgers, E. A., 11, Bowood Road, Sharrow, Sheffield.
S.	1913.	Rodgers, F., Marquis of Granby Hotel, Bamford, nr. Sheffield.
C.	1919.	Rodgers, H. W., 76, Railway Terrace, Rugby.
S.	1913.	Rodgers, J. R. R., 362, Firth Park Road, Sheffield.
B.	1917.	Roe, H. J., 33, Herbert Road, Bearwood, Birmingham.
E.M.	1913.	Roe, J., Globe Foundry, Stores Road, Derby.
C.	1920.	Rogers, C. F., 28, Maycock Road, Coventry.
N.	1919.	Ronchetti, W., 72, Biddlestone Road, Heaton, Newcastle.
Sc.	1919.	Ross, A., 257, Crown Street, Glasgow.
Sc.	1922.	Ross, E. J., 12, Afton Street, Langside, Glasgow.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1922.	Rowe, F. W., 2, Langdale Road, Stretford, Manchester.
W.R. of Y.	1922.	Rowntree, F., 28, Campbell Street, Bowling Back Lane, Bradford, Yorks.
E.M.	1915.	Russell, H. (R. Russell & Sons), Peel Foundry, Derby.
N.	1913.	Samson, A., 14, Sea Terrace, Middleton, Hartlepool.
S.	1913.	Samworth, E. A., 14, Hamilton Road, Firth Park, Sheffield.
L.	1923.	Sanders, H. H., 21, Etherley Road, Harringay, N.15.
E.M.	1921.	Sanders, Horace L., 24, St. Paul's Road, Derby.
B.	1905.	Sands, J., 27, Victoria Street, West Bromwich.
W.R. of Y.	1922.	Sayers, H., 239, Goodman Terrace, Hunslet, Leeds.
N.	1916.	Scott, G. W., 1, Northumberland Villas, Wallsend-on-Tyne.
N.	1921.	Scott, Henry, B., 33^{F}, Albert Road, Birtley, Co. Durham.
N.	1918.	Scott, W., 7, Lynwood Avenue, Blaydon-on-Tyne.
S.	1921.	Senior, George, 84, Latimer Street, Sheffield.
W.R. of Y.	1913.	Shackleton, H. R., Upper Pear Tree Farm, Hainsworth Shay, Keighley.
W.R. of Y.	1922.	Shackleton, S., 22, Tivoli Place, Bradford, Yorks.
W.R. of Y.	1922.	Shaw, A., 28, Marlboro' Road, Shipley, Bradford.
C.	1920.	Shaw, A., 89, Manor Road, Rugby.
B.	1921.	Shaw, Geo., New End, Callowbrook Lane, Rubery, Birmingham.
Lncs.	1922.	Shaw, S., 35, Frog Lane, Wigan, Lancs.
Lncs.	1911.	Shawcross, G.N., M.B.E., M.I.Mech.E., Lakelands, Horwich, Lancs.
C.	1920.	Shepherd, H., 6, Lydgate Road, Coventry.

B'nch.	Year of Election.	ASSOCIATE MEMBERS
E.M.	1915.	Shield, F. M., 3, Atherton Crescent, Hungerford, Berks.
B.	1920.	Shorthouse, W. H., 60, Edward Street, West Bromwich.
Lncs.	1922.	Simkiss, H., 28, Energy Street, Bradford Road, Manchester.
S.	1914.	Simmons, C., The Brightside Foundry and Engineering Co., Wicker Works, Sheffield.
S.	1917.	Simpson, C. D., 17, Willis Road, Hillsbro', Sheffield.
B.	1914.	Simpson, H., Greenhurst, Doseley, Dawley, Salop.
N.	1916.	Sinclair, J., 25, Granville Street, Millfield, Sunderland.
Lncs.	1905.	Skelton, H. S., "Lindsey." Old Lane, Eccleston Park, Prescot, Lancs.
L.	1911.	Slater, H. O., "Sunny Hill," Lessners Park, Belvedere, Kent.
Lncs.	1906.	Smethurst, J. H., Briery Croft, Lodge Lane, Warrington.
E.M.	1918.	Smith, A. J., 45, Lincoln Road, Peterborough.
C.	1919.	Smith, F. G., 15, Cherry Street, Coventry.
E.M.	1920.	Smith, F. J., 98, Derby Road, Loughborough.
S.	1913.	Smith, J., Abney House, Gleadless Road, Sheffield.
Sc.	1921.	Smith, J., Woodburn House, Kerse Road, Falkirk, N.B.
Sc.	1911.	Smith, Jos., 235, Hospital Street, Glasgow.
Sc.	1914.	Smith, J. M., 64, Lennox Avenue, Scotstoun, Glasgow.
B.	1917.	Smith, S., 240, Bromford Lane, West Bromwich.
Lncs.	1909.	Smith, S. G., 86, Barton Road, Stretford, Manchester.
E.M.	1917.	Smithard, S., 19-21, Thames Street, Leicester.
Lncs.	1921.	Spencer, F. W., 159, Briercliffe Road, Burnley.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1904.	Sperring, B. F., 244, Lake Road, Portsmouth.
Sc.	1920.	Spittal, J. 80, Noreham Street, Shawlands, Glasgow.
E.M.	1918.	Stacey, C. W., (pro tem.) c/o H. Bunting, 17, Marcus Street, Derby.
B.	1908.	Stacey-Jones, J. E., Beaconsfield Street, Leamington Spa.
Sc.	1918.	Stark, W. C., 37, Summertown Road, Govan, N.B.
B.	1917.	Starr, F. G. S., 128, Selwyn Road, Rotton Park, Birmingham.
Lncs.	1917.	Stead, H., 1st 36, Cheetham Hill Road, Stalybridge.
S.	1914.	Steggles, A. L., 178, Brackin Road, Shiregreen, Sheffield.
B.	1914.	Stephen, S. W. B., The Woodlands, Beech Lanes, Birmingham.
B.	1916.	Sterland, J., 4, Barnby Crossing, Newark.
L.	1921.	Stevens, Wm., Hawarden Villa, Rodbourne, Cheney, Swindon.
Lncs.	1921.	Stevenson, M., 9, Fountains Avenue, Firwood, Bolton.
Sc.	1919.	Stewart, A., 38, Ferguslie, Paisley, N.B.
N.	1914.	Stobbs, R., 32, Armstrong Terrace, South Shields.
N.	1912.	Stobie, V. (Stobie Steel Co.), Dunstan-on-Tyne.
S.	1919.	Stocker, W. E., 109, Ellesmere Road, Pitsmoor, Sheffield.
L.	1915.	Stone, E. G., 137, Broomwood Road, Clapham Common, S.W.
Lncs.	1920.	Storer, W. H., 175, Settle Street, Great Lever, Bolton.
E.M.	1918.	Stott, C., 26, De Montford Street, Reading.
C.	1919.	Stynes, A. H., "Field View," Lythalls Lane, Coventry.
L.	1922.	Summers, H. G., 35, Perry Hill, Catford, S.E.6.
Lncs.	1910.	Sutcliffe, A., 1, Firwood Grove, Tonge Moor, Bolton.

B'nch.	Year of Election.	
W.R. of Y.	1922.	Sutcliffe, A., 44, Ferney Lee Road, Todmorden, Yorks.
Lncs.	1919.	Sutcliffe, W., 32, Stinps Lane, Rochdale.
C.	1919.	Sutton, E. W., Selwood, Lythalls, Lane, Foleshill, Coventry.
S.	1920.	Swain, J. R., 209, Grimesthorpe Road, Sheffield.
Lncs.	1923.	Swann, H., 31, Alexandra Road, Patricroft, Manchester.
W.R. of Y.	1922.	Swann, H., 5, Heywood Street, Great Horton, Bradford.
C.	1919.	Swindells, A., 30, Hillside, Stoke Heath, Coventry.
S.	1921.	Sykes, H., 32, Dixon Road, Hillsborough, Sheffield.
S.	1907.	Sykes, W., 53, Harcourt Road, Sheffield.
N.	1922.	Tait, A. H., Armagh House, Wallsend-on-Tyne.
S.	1913.	Tait, E., Brightside Foundry & Engineering Company, Limited, Sheffield.
Sc.	1921.	Tannahill, H., 6, Mayfield Place, Morningside, Newmains, N.B.
Lncs.	1922.	Tate, C. M., Brook Royd, Todmorden Road, Burnley.
—	1906.	Taylor, A. (Fielding & Platt, Limited), Atlas Ironworks, Gloucester.
C.	1920.	Taylor, E., 19, Station Street, West Coventry.
—	1905.	Taylor, F. (Taylor & Sons, Limited), Britonferry, South Wales.
Lncs.	1921.	Taylor, H., 16, West Street, Dukinfield, Manchester.
Lncs.	1921.	Taylor, James, 3, Tremellen Street, Accrington.
N.	1921.	Temple, G. T., 35, Grosvenor Drive, Whitley Bay.
Lncs.	1922.	Thatcher, E. H., "Trostrey," Wraxall, Somerset.
Lncs.	1917.	Thewlis, S. J., Holly View, Dobcross, near Oldham.
L.	1909.	Thomas, E., 41, Kingshill Road, Swindon.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W.R. of Y.	1922.	Thompson, E., La S. E. de C. N. Apartudo No. 1, Ferrol, Spain.
S.	1921.	Thomson, Thos. R., Priest Furnaces, Limited, Orchard Chambers, Church Street, Sheffield.
W.R. of Y.	1907.	Thonger, W. F. (Denison & Son, Limited), Hunslet Foundry, Leeds.
S.	1923.	Thornton, A. E., 34, Hampton Road, Pitsmoor, Sheffield.
Lncs.	1911.	Timmins, A. E., 133, Roose Road, Barrow-in-Furness.
N.	1921.	Tinning, W. H., 69, Dilston Road, Newcastle-on-Tyne.
E.M.	1919.	Tokins, E., 114, Belsize Avenue, Woodston, Peterborough.
Lncs.	1919.	Toplis, H., Hans Renold, Limited, Burnage Works, Didsbury, Manchester.
Lncs.	1914.	Topping, G., 17, Bebbington Street, Clayton, Manchester.
B.	1909.	Toy, J. H., 374, Bearwood Road, Smethwick, Staffs.
Sc.	1920.	Trapp, P., Kilns Cottage, Falkirk, N.B.
N.	1921.	Tremayne, J., 82, Third Street, Gateshead-on-Tyne.
Sc.	1923.	Turnbull, Alex W., Primrose Cottage, Bonnybridge, N.B.
C.	1919.	Turner, F. J., 24, Marlborough Road, Coventry.
S.	1918.	Turner, W., 90, Edgedale Road, Sheffield.
C.	1923.	Twigger, T. R., Post Office, Bubbenhall, nr. Kenilworth.
Sc.	1920.	Ure, R., Stenhouse House, Carron, Falkirk, N.B.
Sc.	1919.	Ure, W. G., 355, Keppochhill Road, Glasgow.
E.M.	1921.	Vaughan, Benj. H., 25, Holmes Street, Derby.
B.	1917.	Vaughan, G. A., 15, Green Street, West Bromwich.
Lncs.	1921.	Vernon, G. W., 11, Ashfield Road, Burnley.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1911.	Waddell, R. C., 2, Percy Street, Ibrox, Glasgow.
N.	1914.	Wainford, E. H., 38, Langholme Crescent, Darlington.
Sc.	1911.	Walker, A., Gowanbank, Montrose Gardens, Milngavie, N.B.
L.	1921.	Walker, Alex. W., "Brailli," 41, Pomeroy Street, Clarence Road, Cardiff.
L.	1911.	Walker, C. F., 42, Windsor Street, Wolverton, Bucks.
Sc.	1920.	Walker, D., 5, New Houses, Anderson Street, Bonnybridge, N.B.
L.	1922.	Walker, F. D., 153, Greenvale Road, Eltham, S.E.
Sc.	1920.	Walker, G., 21, Napier Place, Bainsford, Falkirk.
E.M.	1920.	Walker, Geo. H., 2, Camp Street, Derby.
Sc.	1920.	Walker, John, 130, Wallace Street, Falkirk, N.B.
Sc.	1920.	Walker, Wm., Gowanlea Cottages, Anderson Street, Bonnybridge, Falkirk, N.B.
B.	1916.	Wall, J., 18, Flavell Street, Woodsetton, Dudley, Staffs.
Lncs.	1915.	Wallwork, R. M., 9, Birch Vale Drive, Romiley, Stockport.
N.	1919.	Walsh, T., 7, The Crescent, Dunston-on-Tyne.
E.M.	1919.	Ward, J. F., 64, Clarence Road, New England, Peterborough.
C.	1919.	Wareham, H., 37, Broadway, Coventry.
L.	1919.	Wares, F. J., 216, Cromwell Road, Peterborough.
S.	1911.	Wasteney, J., Vulcan Foundry, Eckington, Sheffield.
C.	1914.	Watson, R., 49, York Street, Rugby.
Sc.	1912.	Watt, J. M., 8, Westerlea Terrace, Dumbarton, N.B.
Sc.	1919.	Watt, R., Etna Ironworks, Falkirk, N.B.
Sc.	1920.	Waugh, Wm., 683, Dumbarton Road, Glasgow.
N.	1921.	Weathers, J. H., 76, Stanton Street, Newcastle-on-Tyne.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1923.	Webb, A. W. J., 1, Sidney Street, Gloucester.
E.M.	1921.	Webb, Ernest Alfred, 109, Warwick Street, Leicester.
S.	1909.	Webster, C., 34, Milton Road, Rotherham.
B.	1922.	Webster, H. E., 46, Dovey Road, Moseley, Birmingham.
W.R. of Y.	1922.	West, W., 32, Oakfield Road, Manningham, Bradford.
Lncs.	1921.	Weston, H. L., 26, Railway Street, South Wigston, nr. Leicester.
B.	1911.	Westwood, J. H., 163, St. Paul's Road , Smethwick, Staffs.
WR. of Y.	1913.	Whitaker, E., Cotwell Iron Foundry, Victoria Road, Holbeck, Leeds.
Lncs.	1919.	Whiteley, B., The Moorlands, Tintwistle, Hadfield, nr. Manchester.
B.	1904.	Whitfield, C. O., King's Road, Tyseley, Birmingham.
L.	1911.	Whiting, A., Brynbella, Pembroke Road, Erith, Kent.
Lncs.	1922.	Whittle, Harry, 69, Westbourne Avenue, Great Lever, Bolton.
Lncs.	1919.	Whittle, P., 50, Victory Road, Little Lever, Bolton.
C.	1919.	Whitworth, E., 274, Munition Cottages, Holbrook's Lane, Coventry.
S.	1907.	Wild, A., Midland Brass Foundry, Sheffield.
B.	1920.	Wilkins, A. J. R., 149, Toll End Road, Ocker Hill, Tipton.
N.	1910.	Wilkinson, T., Stockton Street, Middlesbrough.
N.	1920.	Wilkinson, T.
S.	1919.	Williams, A., 31, Burngreave Bank, Sheffield.
C.	1919.	Williams, A. Morgan-, 43, Queen's Road, Coventry.
C.	1923.	Williams, R., 166, Cross Road, Foleshill, Coventry.
Sc.	1911.	Williamson, H., 3, Main Street, Dalmuir, N.B.

B'nch.	Year of Election.	
Sc.	1920.	Williamson, J., 111, Stirling Street, Denny, Stirlingshire.
L.	1911.	Willis, A., "Bermuda," Riverside Avenue, Broxbourne, Herts.
L.	1920.	Willsher, W. H., "Breydon," Oakhill Gardens, Woodford Green, London, E.18.
Sc.	1911.	Wilson, A., 29, Laird Street, Coatbridge, N.B.
Lncs.	1919.	Wilson, A. E., 84, Dewhurst Road, Syke, Rochdale.
Sc.	1919.	Wilson, E., 17, Westonlea Terrace, Dumbarton, N.B.
N.	1912.	Wilson, F. P., Parkhurst, Middlesbrough.
Sc.	1920.	Wilson, H., 46, Mungalhead Road, Bainsford, N.B.
W.R. of Y.	1923.	Wilson, H. T., 34a, Commercial Street, Thornes Lane, Wakefield.
Lncs.	1904.	Wilson, W. R., 15, Sackville Street, Liverpool.
E.M.	1921.	Winfield, F., 30, Holcombe Street, Derby.
C.	1919.	Winter, W. E., 66, Yardley Street, Coventry.
Lncs.	1912.	Wolstenholme, J., 111, Carlton Terrace, Bury, and Bolton Road, Radcliffe, Manchester.
B.	1922.	Wood, A., 5, Wesley Place, Toll End, Tipton, Staffs.
E.M.	1922.	Wood, F., 6, Victoria Road East, Leicester.
E.M.	1921.	Wood, James H., 18, Alcester Road, Sheffield.
W.R. of Y.	1922.	Wood, John, 6, Hudswell Street, Sandal, Wakefield.
S.	1916.	Woodcock, J. G., 21, Croydon Street, Sharrow, Sheffield.
E.M.	1914.	Worcester, A. S., 27, Keythorpe Street, Leicester.
Lncs.	1917.	Worrall, J. N., 77, Ansdell Road, Turf Hill, Rochdale.
N.	1922.	Worth, J. W., 18, Tynemouth Road, Heaton, Newcastle-on-Tyne.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W.R. of Y.	1923.	Wright, L., 168, Oxford Road, Gomersall, near Leeds.
Sc.	1913.	Wright, W., Burnbank Foundry, Falkirk, N.B.
N.	1917.	Wright, W. H., 12, Mill Lane, Loughborough.
Sc.	1919.	Young, J., 45, Cochrane Street, Paisley, N.B.
N.	1921.	Young, James, 72, Carlisle Street, Felling-on-Tyne.
N.	1915.	Young, T., 12, Bensham Crescent, Gateshead-on-Tyne.

ASSOCIATES.

B'nch.	Year of Election.	
N.	1923.	Allcock, H., 164, H. S. Edwards Street, South Shields.
B.	1912.	Attwood, E., 42, Priory Villas, Hazlebeach Road, Saltley, Birmingham.
S.	1920.	Ayres, Sidney, Hampton House, Barnardiston Road, Darnall, Sheffield.
N.	1916.	Baker, T., 51, St. Mary's Terrace, Tyne Dock, South Shields.
N.	1920.	Banks, V. L., St. Cuthbert's Vicarage, Newcastle-on-Tyne.
N.	1919.	Batey, J., 77, Warwick Street, Heaton, Newcastle-on-Tyne.
N.	1921.	Bentham, J. W., 9, Cumberland Street, Gateshead-on-Tyne.
B.	1922.	Bettley, H., 3, Regent Street, Willenhall, Staffs.
N.	1913.	Bewley, J. E. T., 13, Woodlands Terrace, Leadgate, Co. Durham.
N	1922.	Boudry, C., 23, Esplanade Place, Whitley Bay.
B.	1914.	Boyne, W., 157, Wood End Road, Erdington, Birmingham.
N.	1917.	Brown, C. H., 72, Wardsworth Street, Gateshead-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
N.	1920.	Brunton, S. J., 191, Dunsmuir Grove, Gateshead-on-Tyne.
N.	1923.	Careless, T., 84, McIntyre Street, Jarrow-on-Tyne.
N.	1917.	Carr, S., 44, Stanley Street, Rosehill, Wallsend-on-Tyne.
N.	1923.	Chapman, L.B., Daisy Cottage, Dene Villas, Chester-le-Street, Co. Durham.
N.	1923.	Charlton, F. J., 23, Cedar Grove, Cleadon, South Shields.
E.M.	1919.	Charlton, R. H., Wentworth House, Wentworth Street, Peterborough.
S.	1920.	Coates, L., 30, Oakwood Road, Rotherham.
S.	1921.	Cooling, Geo. W., 10, Osberton Place, Endcliffe, Sheffield.
C.	1918.	Currie, E. M., 3, Stockton Road, Coventry.
N.	1923.	Davison, R., 79, Second Avenue, Heaton, Newcastle-on-Tyne.
N.	1917.	Dunn, G. N., 96, Brinkburn Street, Newcastle-on-Tyne.
N.	1918.	Eglen, T., 22, Morley Street, Heaton, Newcastle-on-Tyne.
L.	1922.	Elder, Alex., 54, Ford End Road, Bedford.
L.	1922.	Ellis, J. P., 6, Eckstein Road, Clapham Junction, S.W.11.
S.	1913.	Else, L. H. (Wm. Cooke & Co., Ltd.), 26, Victoria Street, London, S.W.1.
C.	1922.	Elston, A. G. W., 62, Craven Street, Coventry.
E.M.	1915.	Farmer, W., 112, City Road, Derby.
N.	1923.	Farrell, T. P., 6, St. Mary's Terrace, Willington Quay.
N.	1917.	Ferguson, J., 62, South Palmerston Street, South Shields.
N.	1923.	Ferrier, J. E., 29, Maple Grove, Cleadon Park, South Shields.
S.	1922.	Firth, Tom L., 157, Fox Street, Sheffield.
Lncs.	1915.	Fisher, J. L., 124, Folly Lane, Swinton, Manchester.

B'nch.	Year of Election.	ASSOCIATES.
N.	1922.	Flinn, A., 16, Guildford Place, Heaton, Newcastle.
N.	1913.	Ford, A., 43, Moore Street, Gateshead.
N.	1917.	Francis, J., Straughan House, Felling-on-Tyne.
N.	1923.	Galbraith, R., 18, Byethorne Street, South Shields.
L.	1919.	Gaskin, J. A., 196, Merton Road, Wandsworth, S.W.18.
N.	1923.	Gibson, W., 66, King George Road. Cleadon, South Shields.
B.	1917.	Gilbert, F., 17, Maria Street, West Bromwich.
S.	1920.	Gleadhall, C., 332, Edmons Road, Heeley, Sheffield.
N.	1921.	Gobey, Wm., 3, Burnley Street, Blaydon-on-Tyne.
N.	1923.	Golder, T., 7, Orange Street, South Shields.
B.	1919.	Gordon, W. A., 176, Sams Lane, West Bromwich.
N.	1922.	Gospel, W., 65, Seventh Avenue, Heaton, Newcastle-on-Tyne.
N.	1923.	Gould, M., 42, Elswick East Terrace, Newcastle-on-Tyne.
E.M.	1917.	Grant, G., Kirbell Cottages, 7, Barrow Road, Quorn, Loughborough.
Sc.	1914.	Gray, R., 19, McKerrel Street, Paisley.
C.	1923.	Griffiths, T. J., 35, Sir Thomas White's Road, Coventry.
B.	1909.	Grindlay, C., 10, Massom Road, Erdington, Birmingham.
S.	1920.	Hague, S. E., 39, Wostenholm Road, Sharrow, Sheffield.
B.	1909.	Hamilton, G., 18, Anderson Road, Tipton.
N.	1923.	Harle, J. E., 162, South Palmerston Street, South Shields.
S.	1921.	Heeley, John Jas., 644, Penistone Road, Owlerton, Sheffield.
N.	1923.	Henderson, T. E., 2, Percy Street, Wallsend-on-Tyne.
B.	1914.	Hewitt, J., 63, Heeley Road, Bournbrook, Birmingham.

B'nch.	Year of Election.	ASSOCIATES.
Sc.	1920.	Hill, T., 9G, Mitchell Street, Airdrie, N.B.
B.	1920.	Holberry, F. B., 22, Hedley Terrace, Llanelly, S. Wales.
E.M.	1922.	Holland, G., Costock, near Loughborough.
E.M.	1917.	Holmes, A., 78, Albert Promenade, Loughborough.
N.	1923.	Holmes, A., 20, Earl Street, Jarrow-on-Tyne.
E.M.	1916.	Hughes, J. O., 27, Evington Road, Leicester.
Sc.	1919.	Hunter, J., 11, Whitehead Street, Paisley, N.B.
Sc.	1916.	Irvine, J., 14, Clarence Street, Paisley, N.B.
N.	1923.	Jennings, P., 23, Cullercoats Street, WelbeckRoad, Newcastle-on-Tyne.
B.	1919.	Johnson, J. B., junr., Slater Street, Great Bridge, Tipton.
E.M.	1919.	Jones, A. C., 13, South View Road, Walton, near Peterborough.
Sc.	1922.	Jones, W. C., Blair Terrace, Hurlford, Ayreshire.
N.	1922.	Kelly, F. J., 1554, Walker Road, Walker, Newcastle-on-Tyne.
N.	1914.	Lawson, J. W., 16, Hartington Street, Gateshead-on-Tyne.
N.	1923.	Lewins, W., 90, H. S. Edwards Street, South Shields.
N.	1922.	Liddell, L., 7, Tyne View, Lemington-on-Tyne.
E.M.	1922.	Limbert, H., 15b, Factory Street, Loughborough.
N.	1920.	Lindsay, A. W., 16, Phillipson Street, Willington Quay.
Sc.	1920.	Livingston, J., 36, Haggs Road, Pollokshaws, Glasgow.
Lncs.	1913.	Longson, Jas., 37, Rupert Street, Reddish, nr. Stockport.
L.	1914.	Lowe, J., 98, Marlborough Road, Bowes Park, N.22.
Lncs.	1914.	Lucas, G. E., 36, Langford Street, Leek, Staffs.

B'nch.	Year of Election.	
S.	1920.	Mantle, G. F., 835, Abbeydale Road, Sheffield.
Lncs.	1923.	Masters, N., 2nd 17, Cheetham Hill Road, Stalybridge.
N.	1911.	Mather, D. G., 8, Church Road, Ashford, Kent.
B.	1913.	Mather, F., Doris, Deykin Avenue, Witton, Birmingham.
Sc.	1910.	Mathieson, J. B., 3, Cowan Street, Hillhead, Glasgow.
N.	1923.	Matthews, G. W., 4, Burnside, Rosehill, Willington Quay-on-Tyne.
N.	1919.	McDonald, H., 57, Hedley Place, Newcastle-on-Tyne.
Sc.	1913.	McLeish, J., 7, Buchanan Terrace, Paisley, N.B.
Sc.	1913.	McLeish, R., 7, Buchanan Terrace, Paisley, N.B.
Sc.	1912.	McLintock, G., Woodhead Avenue, Townhead, Kirkintilloch, N.B.
Lncs.	1923.	Meadowcroft, H., 72, Elliott Street, Tyldesley, Manchester.
S.	1913.	Middleton, Wm., 455, Jenkins Road, High Wincobank, Sheffield.
N.	1922.	Miller, J. G., 79, Clarence Street, Newcastle-on-Tyne.
L.	1919.	Murdoch, H., "Cardale," 24, Woolwich Road, Belvedere, Kent.
N.	1914.	Murray, J., 13, Dean Road, South Shields.
N.	1917.	Oliver, J., 74, King Edward Street, Gateshead-on-Tyne.
N.	1922.	Paterson, J. W., 108, Corbridge Street, Byker, Newcastle-on-Tyne.
N.	1923.	Peacock, J. E., 42, Bolam Street, Newcastle-on-Tyne.
N.	1923.	Peacock, S., 12, John Street, South Shields.
N.	1922.	Picken, A. D., 2, Tweed Street, Hebburn-on-Tyne.
N.	1922.	Pittuck, M. D. (Miss), 4, Catherine Terrace, Whitley Bay.
N.	1913.	Quick, W. H., 54, Avenue Road, Gateshead-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
Sc.	1921.	Rae, Alex., Kilns Place, Falkirk, N.B.
N.	1917.	Rang, E. J., Edwalton House, Cleveland Road, North Shields.
N.	1922.	Redpath, J., 25, Burnley Street, Blaydon-on-Tyne.
L.	1922.	Rendell, R. J., 23, Royston Avenue, South Chingford, E.4.
N.	1922.	Robson, A. E., 26, West View, Lemington-on-Tyne.
N.	1920.	Robson, E. V., 86, Addycombe Terrace, Heaton, Newcastle-on-Tyne.
Sc.	1919.	Rodger, J. W., 18, Kennedy Drive, Partick, Glasgow.
N.	1920.	Slater, B., 7, Fowler Gardens, Dunston-on-Tyne.
Sc.	1920.	Smith, J., 46, Glasgow Road, Barrhead, N.B.
Sc.	1920.	Smith, J., 23, Carlibar Road, Barrhead.
Sc.	1911.	Smith, W. H., 19, Victoria Place, Airdrie.
N.	1912.	Spence, W. D., 3, Gladstone Terrace, Newcastle.
N.	1922.	Spencer, F. C., 17, Belgrave Terrace, Newcastle-on-Tyne.
B.	1910.	Spiers, F., 116, Wilton Road, Sparkhill, Birmingham.
Sc.	1920.	Stark, A., Bellmont Cottage, Kirkintilloch.
N.	1923.	Stobbs, T., 32, Armstrong Terrace, South Shields.
E.M.	1915.	Styles, W. T., 52, Roe Street, Derby,
B.	1910.	Sutton, W. H., 147, Antony Road. Saltley, Birmingham.
Sc.	1913.	Sword, J., 13, Paisley Road, Barrhead, N.B.
B.	1917.	Thomas, J. E. L., 210, Oldbury Road, Greets Green, West Bromwich.
N.	1923.	Towns, E., 50, Whitehead Street, South Shields.
N.	1921.	Tunnah, R. C., 22, Ripon Gardens, Jesmond, Newcastle-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
N.	1921.	Turnbull, R. G., "Norwood," Westwood Avenue, Heaton, Newcastle-on-Tyne.
S.	1922.	Tyler, G. H., 86, Pickmere Road, Crookes, Sheffield.
N.	1914.	Usher, J. W., 10, The Avenue, Leadgate, Co. Durham.
N.	1922.	Van-der-Ben, C. R., 169, Dunsmuir Grove, Gateshead-on-Tyne.
N.	1923.	Watson, J., 3,Percy Court, Northumberland Street, North Shields.
L.	1911.	Wells, G. E., 89, Larcom Street, Walworth, S.E.
N.	1914.	Wilkinson, J.. Westoe Vicarage, South Shields.
Lncs.	1917.	Wilson, A., 51, Woodfield Road, Altrincham.
Sc.	1911.	Wilson, J., Alpha Cottage, Kirkintilloch, N.B.
L.	1922.	Wooding, J. F., 30, Marlborough Road, Queen's Road, Bedford.
S.	1920.	Wordsworth, W. A., 11, Coverdale Road, Millhouses, Sheffield.
Sc.	1919.	Young, C., 74, Cramond Street, Glasgow.

Members changing their address are requested to notify the same immediately to the General or Branch Secretary of the District.