Mr. V. C. Faulkner (President 1926-27).

Mr. Faulkner was trained in the metallurgical department of Sheffield University under Dr. Arnold. After spending a few years in the laboratories of Messrs. Hobson, Houghton & Company, and Vickers, Limited, he became interested in the manufacture of electric steel, being associated successively with the Stobie Steel Company; National Steam Car Company, Limited; Electro Metals, Limited, and Watson's (Metallurgists) Limited. Work in this connection involved long periods on the Continent supervising the starting up of the furnaces. Mr. Faulkner was appointed Editor of The Foundry Trade Journal on its change to a weekly publication in January, 1921. He is President of the Foundry Trades Supply and Equipment Association. He is also a member of the Iron and Steel Institute, the Institute of Metals, and the French and American Foundrymen's Associations.

PROCEEDINGS OF THE INSTITUTE OF BRITISH FOUNDRYMEN.

1925-1926.

Containing the Report of the Twenty-third Annual Conference, held in London, June 15th, 16th, 17th, 18th and 19th, 1926; and also Papers and Discussions presented at Branch Meetings held during the Session 1925-1926.

Institute of British Foundrymen.

Head Office:
Saint John Street Chambers, Deansgate, Manchester.
(Registered Office: 49, Wellington Street, Strand, London, W.C.2.)

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49, Wellington Street, Strand, London, W.C.2.

THE INSTITUTE OF BRITISH FOUNDRYMEN.

OFFICERS 1926—1927.

President :

V. C. Faulkner, 49, Wellington Street, Strand, London, W.C.2.

Vice-Presidents :

J. T. Goodwin, Sheepbridge Coal and Iron Company, near Chesterfield.
S. H. Russell, Bath Lane, Leicester.

Past-Presidents :

R. Buchanan. (Deceased 1924.) 1904-1905.
H. Pilkington. (Deceased.) 1906-1907.
F. J. Cook, 31, Poplar Avenue, Edgbaston, Birmingham 1908-1909.
P. Longmuir, D.Met., 2, Queen's Road, Sheffield. 1910-1911.
C. Jones. (Deceased 1923.) 1912.
S. A. Gimson, 20, Glebe Street, Leicester. 1913-1914.
W. Mayer. (Deceased 1923.) 1915.
J. Ellis, 20, Lambourn Road, Clapham Junction, London, S.W.4. 1916-1917.
T. H. Firth. (Deceased 1925.) 1918.
John Little, M.I.Mech.E., 20, St. Ann's Square, Manchester. 1919.
Matt. Riddell, 35, Aytoun Road, Pollokshields, Glasgow. 1920.
Oliver Stubbs, M.I.Mech.E., Openshaw, Manchester. 1921.
H. L. Reason, M.I.Mech.E., M.I.M., White House, Birches Barn Road, Wolverhampton. 1922.
Oliver Stubbs, M.I.Mech.E., Openshaw, Manchester. 1923.
R. O. Patterson, Pioneer Works, Blaydon-on-Tyne. 1924.
J. Cameron, Cameron & Roberton, Limited, Kirkintilloch, Scotland. 1925.

Hon. Treasurer:

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

General Council:

†F. Allan, 7, Dene Street, Sunderland.
*A. R. Bartlett, 1, Lower Park Road, Belvedere, Kent.
†A. Campion, 3, Strathview Gardens, Bearsden, by Glasgow.
†F. C. Edwards, 32, Queen's Head Road, Handsworth, Birmingham.
*W. T. Evans, Mount Pleasant, Sunny Hill, Normanton, Derby.

*A. Firth, 50, Clarendon Road, Sheffield.
†J. W. Frier, 5, Northumberland Villas, Wallsend-on-Tyne.
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*J. Haigh, Stoneclough, Carr Lane, Sandal, Wakefield.
†H. E. Hand, 189, Manwood Road, Crofton Park, S.E.4.
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†W. Jolley, Breeze Hill, Urmston Lane, Stretford, Manchester.
†J. F. Kayser, 30, Oakhill Road, Nether Edge, Sheffield.
†A. L. Key, 271, Reddish Road, S. Reddish, Stockport.
*Wesley Lambert, J. Stone & Company, Limited, Deptford, S.E.14.
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†Geo. L. Oxley, Vulcan Foundry, Attercliffe, Sheffield.
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H. Pemberton, 15, Wolfa Street, Derby.
†G. C. Pierce, 11, Athelney Street, Bellingham, Kent.
†J. M. Primrose, Mansion House Road, Camelon, Falkirk.
†J. S. Glen Primrose, 17, Salisbury Road, Chorlton-cum-Hardy, Manchester.
G. E. Roberts, "Rosedale," Earlsdon Avenue, Coventry.
*J. Shaw, Mount Vernon, 15, Western Parade, Southsea.
†H. Sherburn, Ellesmere, Padgate, Warrington.
†J. N. Simm, 61, Marine Drive, Monkseaton.
†H. O. Slater, Sunny Hill, Lessners Park, Belvedere, London, S.E.
†T. A. Spiers, "Delamere," Uppingham Road, Leicester.
†F. G. Starr, 128, Selwyn Road, Rotten Park, Birmingham.
†W. T. Thornton, 1,081, Grangefield Avenue, Thornbury, Bradford, Yorks.
†S. B. Toy, The Ridge, Saltburn-by-the-Sea.
†B. H. Vaughan, 25, Holmes Street, Derby.
*H. Winterton, "Moorlands," Milngavie, Dumbartonshire.

* Elected at Annual Conference. † Branch Delegates.

BRANCH PRESIDENTS AND SECRETARIES.

(Ex-officio on General Council.)

BIRMINGHAM.

D. H. Wood, "Kingswood," Park Road, Mosley, Birmingham.
F. K. Neath, B.Sc., 16, Sarehole Road, Hall Green, Birmingham.

EAST MIDLANDS.

E. Stevenson, "Charnwood," Sunnydale Road, Carlton, Notts.
H. Bunting, 17, Marcus Street, Derby.

LANCASHIRE.

S. G. Smith, 86, Barton Road, Stretford, Manchester.
H. Stead, 1st 36, Cheetham Hill Road, Stalybridge, Manchester.

BURNLEY SECTION OF LANCASHIRE.

T. G. Hilton, 171, Rose Hill Road, Burnley.
J. Pell, 17, Mersey Street, Rose Grove, Burnley.

LONDON.

R. J. Shaw, 41, Dorset Road, South Ealing, W.5.
H. G. Sommerfield, Charterhouse Chambers, Charterhouse Square, E.C.1.

NEWCASTLE-ON-TYNE.

E. Wood, B.Sc., "Overtoun," 20, Beverley Road, Monkseaton.
C. Gresty, 101, Queen's Road, Monkseaton, Northumberland.

SCOTTISH.

A. F. Mearns, 54, Nairne Street, Yorkhill, Glasgow.
J. Bell, 60, St. Enoch Square, Glasgow.

SCOTTISH—FALKIRK SECTION.

J. M. Primrose, Mansion House Road, Falkirk.
A. M. Cleverley, 45, Kennard Street, Falkirk.

SCOTTISH—PAISLEY SECTION.

Jas. Galt, Sneddon Foundry, Paisley.
Jas. Y. Anderson, Messrs. Fullerton, Hodgart & Barclay, Limited, Vulcan Works, Paisley.

SHEFFIELD.

George Edginton, "Silverdale," St. Margaret's Drive, Chesterfield.
R. Viltage, Bircholme, Dronfield, near Sheffield.

WALES AND MONMOUTH.

J. P. Galletly, "Ben Cleuch," Pencisely Road, Cardiff.
J. J. McClelland, M.I.Mech.E., "Druslyn," 81, Bishop's Road, Whitchurch, Glam.

WEST RIDING OF YORKS.

W. Parker, 11, Mayfield Mount, Halifax.
S. W. Wise, 110, Pullan Avenue, Eccleshill, Bradford.

MIDDLESBROUGH.

F. P. Wilson, Parkhurst, Middlesbrough.
N. D. Ridsdale, 3, Wilson Street, Middlesbrough.

General Secretary:

T. Makemson, St. John Street Chambers, Deansgate, Manchester.

AWARDS 1925—1926.

THE "OLIVER STUBBS" GOLD MEDAL

1926 Award to Mr. A. R. BARTLETT,

"for meritorious services rendered to the Institute over a period of many years."

DIPLOMAS OF THE INSTITUTE

were awarded as follows:—

J. LONGDEN, for his Paper on "Liquid Shrinkage in Grey Iron," given before the Lancashire Branch and the Paisley Section of the Scottish Branch.

Major K. C. APPLEYARD, for his Paper on "The Training and General Position of the Craftsman," given before the Newcastle Branch.

J. R. HYDE, for his Paper on "Improving Cast Iron," given before the Sheffield Branch.

W. WEST, for his Paper on "Oil Sand and Production," given before the Burnley Section of the Lancashire Branch.

A. J. RICHMAN, for his Paper on "The Production of Diesel Engine Castings in Pearlitic Cast Iron," given before the Lancashire Branch.

M. J. COOPER, for his Paper on "The Necessity of Standardisation in Modern Foundry Practice," given before the London Branch.

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The Institute of British Foundrymen

ANNUAL CONFERENCE HELD IN LONDON.

June 15, 16, 17, 18 and 19, 1926.

The twenty-third annual convention of the Institute of British Foundrymen, under the presidency of Mr. V. C. Faulkner, was held in London from June 15 to 19, 1926, coincidently with the International Foundry Trades Exhibition, which latter was held at the Royal Agricultural Hall from June 10 to 19. Conferences were held on June 16 and 17 at the Royal Agricultural Hall, and during the week those attending the Convention were afforded opportunities for inspecting a large number of works around London. The Convention opened with a reception at the Spring Gardens Gallery, Spring Gardens, Trafalgar Square, on Tuesday, June 15.

A feature of the Convention was the large number of foreign delegates who attended.

WEDNESDAY, JUNE 16

The business of the Convention opened on Wednesday, June 16, when the members and delegates were welcomed by the Rt. Hon. Arthur Henderson, P.C., M.P.

Mr. J. Cameron, J.P. (the retiring President of the Institute), who presided at the opening of the proceedings, introduced Mr. Henderson, whom, he said, was a real foundryman, having been a moulder for a number of years.

Mr. Arthur Henderson said it afforded him unqualified pleasure to welcome sincerely the members of the Institute and the delegates to the Convention. After some amusing speculations as to the reason why he had been asked to extend a welcome to them, he said he had come to the conclusion that the reason why the Convention Committee had conferred that honour upon him was that he himself was a product of the iron foundry—(applause)—and that, before he had devoted so much of a very long public life to the moulding of public opinion, it had been his business to mould castings. In fact, in foundry parlance, he was a "sand rat," or, in the more polite language of the present day, an "artist in sand." He had been interested to learn that morning that the chain of office worn by the President had been presented to the Institute by one who had been his foreman in the foundry, namely, Mr. W. Mayer (a past-President), probably one of the most capable men in the iron-founding industry that he had ever met. All these facts had added to the pleasure which his presence at the Convention had afforded him. Dealing with the aims and achievements of the Institute of British Foundrymen, he said that in his judgment its greatest importance lay in the fact that it was concerned with the welfare of an important industry, and aimed at the academic, technical and practical improvement of its members. In these days rule-of-thumb, haphazard, hand-to-mouth methods of conducting business or trade could not possibly lead to success. One of the drawbacks for which the large-scale use of machinery in industry was responsible was that it tended to restrain the free play of individuality, and sometimes failed to provide the men engaged in industry with the opportunities for becoming real artists. All good workmanship was art; in all occupations there should be room for good workmanship, and the fullest inducements should be offered for its encouragement. How profoundly true it remained that many workmen connected with modern industry were no longer permitted to express those instincts and impulses which gave the craftsmen of earlier years so much pride and satisfaction in their work, that feeling of profound satisfaction which a workman derived from the consciousness that he had produced an intrinsically beautiful thing by his own hands. The only satisfaction which many workmen enjoyed in these days was that of knowing that they had performed a mechanical or routine task as well as it could be performed Surely it must be admitted that this process had had to some extent a demoralising effect. It checked the development of personality, it discouraged the study of technical subjects, and it prevented the growth of a legitimate ambition to foster and maintain the status of craftsmanship. It was the work of the Institute of British Foundrymen to prevent, by proper education, the deterioration to which he had referred. Moreover, the increasing difficulties and complications of industrial and commercial life demanded from all classes of officials and workmen the highest standard of education, and unless care was exercised the amazing development of mechanical inventions, standardisation and mass production might lead to a more complete servitude and subordination of the man to the machine. To the American visitors he would say —without wishing to be in the slightest degree critical—that the one thing which had impressed him more than any other during a visit to the United States at the end of last year was this danger. He had seen the system of repetition and mass production made so perfect that he could not but exclaim that in that system the man was supplementary to the machine and the automatic process instead of the machine and the automatic process being supplementary to the man. In modern history we should aim not only at raising the standard of intelligence but of developing the latent forces of character and of personality. In saying this he did not for a moment deny the utilitarian significance of education, but wished to emphasise that in many respects we were still technically an ill-educated people, and the stage had probably been reached in our economic development when failure to achieve more efficient education on the lines he had suggested might lead, not to progress, but to retrogression. Moreover, it could not be denied, having regard to the keenness of the competition of the age, that a higher standard of education was absolutely essential in any producing country if that country were to keep abreast of its competitors. He offered his sincere congratulations to the Institute because of its educational efforts, so vital to the economic and even to the spiritual development of its members.

Referring to the system of presenting exchange papers on technical foundry problems written by the representatives of different countries, and the fact that there were present a large number of representatives from various countries, he said that papers were to be read at the Convention by authors in America, France and Belgium, and that since the idea of exchanging papers between the different countries had been inaugurated more than fifty papers had passed. This was all to the good. No longer could trade and commerce be regarded as a local or even a national concern, and for that reason he extended, on behalf of the members of the Institute, a hearty welcome to the foreign delegates present. Trade, he said, was world-wide. Our raw materials flowed into this country from the remotest parts of the earth; our food was grown under foreign skies; and the products of our mills, factories and workshops were used by the peoples of every land. The earth was a store-house, and all the nations of the earth were our customers. Recent years had witnessed a serious and unprecedented disturbance of the economic balance between nations. Every country was now striving, and rightly so, to concentrate its productive energies upon the recovery of lost ground, seeking, by increased production, to become again prosperous, stable and secure. Having regard to these things, surely he was right in saying that any Institution that brought men together for the pooling of their ideas, the interchange of their views, the removal and avoidance of misunderstandings, and the strengthening of ties of friendship, deserved every encouragement. Therefore, he had the greatest possible pleasure in extending, not only to the members of the Institute, but to visitors from overseas, a most sincere welcome, and expressed the hope that their deliberations would be highly successful.

Presentation of the "Oliver Stubbs" Gold Medal.

The Oliver Stubbs Gold Medal, awarded for outstanding work on behalf of the foundry industry, was presented to Mr. A. R. Bartlett (Past-President of the London Branch).

Mr. Cameron paid a tribute to the distinguished work which Mr. Bartlett had done in connection with the industry, and said that he was indeed a worthy recipient.

Mr. Henderson presented the medal, and said he had no doubt in his own mind that it was the reward of real merit.

Mr. Bartlett, returning thanks for the honour conferred upon him, said that in connection with the work he had tried to do for the benefit of the Institute and the industry he had not been influenced by self-interest. That work had been done, for the most part, before the Oliver Stubbs Medal was instituted, and he assured his hearers that in the future, as in the past, he would endeavour to impart his knowledge and experience to his fellow-members in the Institute and the trade.

Vote of Thanks to Mr. Henderson.

Mr. Oliver Stubbs (Past-President of the Institute) proposed a vote of thanks to Mr. Henderson for having extended a welcome to the members and delegates, and for having delivered such an excellent address. Mr. Henderson's career, he said, was an example of what one could do if one tried, and he hoped that other members of his Trade Union Executive would emulate his example and accept invitations to attend the conferences of the Institute. The members of the Institute were anxious to develop and maintain good-fellowship, and so clear away some of the troubles that existed at present.

Mr. V. C. Faulkner (President Designate), seconding, said that the Institute was deeply indebted to Mr. Henderson because he felt sure that when his message reached the foundrymen of Great Britain they would take a great deal of notice of it, and would be able to enter the ranks of the Institute with the knowledge that their great leader had said they should do so.

Mr. Cameron, supporting the vote of thanks, also expressed indebtedness to Mr. Henderson for his thoughtful address and for the welcome he had extended to the members. He thanked him for having appreciated so exactly what the Institute really stood for, *i.e.*, to make the craftsman proud of his craft and of his work, and to encourage those social meetings and interchanges of experience which were so valuable.

Mr. Henderson Elected an Honorary Life Member.

Mr. Cameron then proposed that the Institute should honour itself by electing Mr. Henderson an honorary life member.

The proposal was greeted with enthusiasm, and Mr. Henderson was unanimously elected.

Mr. Henderson, expressing his appreciation, said that no greater reward could come to a public representative than the spontaneous expression of thanks to which the members of the Institute had given utterance. He had been honoured in being permitted to be present; he had renewed old associations, and had felt that he could not resist the invitation extended to him. Speaking of the sixteen years which he had devoted to foundry work, he said that during the whole of his career he had never regretted it. It had certainly given him a knowledge of a very important trade, and had brought him into close contact with the working classes, whom he tried so hard to benefit during the later years of his life. He would be glad to exercise any influence he might have upon his fellows in the iron-founding industry and the members of the organisaton whose official he had been for 42 years out of 43 years of membership. For 23 years he had represented the moulders in the House of Commons, and that was one of the achievements that he valued highly. It was out of the moulders' union that his opportunities had come, the members of that union having invited him to become a Parliamentary candidate in 1902. In 1903 he was sent to the House of Commons as their representative.

The Annual General Meeting.

The business of the annual general meeting was then proceeded with.

The minutes of the last annual general meeting, held in Glasgow on June 10, 1925, were read, confirmed and signed.

The annual report of the General Council for the session 1925-26, and the accounts for the year ended December 31, 1925, were adopted by the meeting without discussion.

ANNUAL REPORT OF THE GENERAL COUNCIL.

The General Council have pleasure in presenting to the members their Report of the progress and work of the Institute during the past Session, 1925-26.

Three General Council meetings have been held during the session at York, London and Birmingham respectively. Representatives of the Branches from all parts of the country have attended the meetings, and there has been an average attendance of twenty-six.

The respective Branches have the following members attached:—

	Members.	Associate Members.	Associates.	Total.
Birmingham, Coventry, and W. Midlands	72 (48)	122 (81)	22 (14)	216 (143)
East Midlands	31 (32)	52 (54)	5 (8)	88 (94)
Lancashire	103 (105)	187 (197)	8 (9)	298 (311)
London	92 (75)	77 (68)	10 (12)	179 (155)
Newcastle	76 (80)	72 (86)	88 (76)	236 (242)
Scottish	50 (54)	112 (114)	30 (26)	192 (194)
Sheffield	83 (85)	89 (88)	11 (12)	183 (185)
West Riding of Yorks.	28 (34)	45 (50)	2 (—)	75 (84)
Wales and Mon.	18 (19)	12 (12)	3 (—)	33 (31)
Middlesbrough	19	19	7	45
General	26 (47)	3 (44)	— (4)	29 (95)
	598 (579)	790 (794)	186 (161)	1574 (1534)

The figures in brackets are for the Session 1924–1925.

The total number of members on the roll of the Institute on April 30, 1926, was 1,574. The members will be pleased to learn that a new Branch has been opened at Middlesbrough, which promises to be very successful, and the Birmingham and Coventry Branches have now joined forces under the title of the Birmingham, Coventry and West Midland Branch. The Council regret to have to report that six deaths have taken place during the year.

The members would learn with regret of the death in July last of Mr. T. H. Firth, who was President of this Institute in 1918. Mr. Firth was also a trustee and took a very keen interest in everything appertaining to the welfare of the Institute.

Annual Conference, 1926.

This will be held on June 16, 17, 18 and 19 at the Royal Agricultural Hall, Islington, London, N.1, by the kind permission of Messrs. F. W. Bridges and Sons (organisers of the Foundry and Allied Trades Exhibition).

"Oliver Stubbs" Gold Medal.

The fourth medal was awarded to Mr. A. Campion, of the Scottish Branch, for meritorious services rendered to the Institute over a period of many years.

Diplomas.

These have been awarded to the following for Papers read at meetings:—D. Wilkinson, Birmingham; J. W. Frier, Newcastle-on-Tyne; H. Jowett, Burnley; F. C. Edwards, Birmingham, for Paper read before the East Midlands Branch.

General Council.

The members who retire in accordance with the rules are: Messrs. A. R. Bartlett, Wesley Lambert, H. Pemberton and J. Shaw. Messrs. A. R. Bartlett, Wesley Lambert, H. Pemberton and J. Shaw offer themselves for re-election. Four members will require to be elected at the London Conference to complete the ten members as provided for in the bye-laws.

Standardisation of Test Bars.

Your committee have not met during the year on account of the B.E.S.A. not having concluded its sittings. It may now be taken for granted that most of the clauses set forth in the I.B.F. tentative specification will be adopted. The chief outstanding point is the proposal that the bars be geometrically proportional. This, while scientifically correct for a homogeneous material, does not hold good for a metal like cast iron. It is quite probable that before the Conference is held that difference of opinion will be over. Once the B.E.S.A. agrees to accept a specification the way will be open for your committee to meet and submit proposals for the International Convention to be held at Detroit in September next.

British Cast Iron Research Association.

The past year has been a very momentous one in the history of the Association. It was reported in the last conference programme that a laboratory had been acquired in which certain investigations and tests could be conducted. During the past year an amalgamation has been effected between the Association and the Foundry Technical Institute, Falkirk, which provides the Association with laboratories in Scotland, and with a group of new members in the important light castings section of the industry. The Association has made considerable progress with its research programme and the number of members during the year has also increased considerably, some of the new members being of an extremely influential character.

The five-year period during which the Association was guaranteed support by H.M. Government expires in June next, and pursuing its usual plan in such cases the Government set up a small expert and impartial committee to make a thorough examination of the work of the Association at all places where work was being carried out, both at the headquarters offices, the laboratories at Birmingham and Falkirk, and at the universities and national institutions where research work is done. The report prepared by the inspectors has been transmitted by the Department of Scientific and Industrial Research to the Association, and this is a confidential document not for publication. It has been circulated to the members, and any founder seriously contemplating membership will be forwarded a copy on application.

It can, however, be said that the report is of such a highly favourable character· that the department has had no hesitation in asking the Government to continue its support for a further period of five years on exceptionally favourable terms, and have been so arranged to make it advantageous for the Association to get the maximum possible support from the industry. Every development which has taken place since the Association was organised on a stable basis has received the cordial approval of the inspectors and the department, and the council now feels that the Association is on a permanent and stable basis and can look forward to a highly promising future. The council, therefore, confidently hopes that with the improvement of trading conditions membership will be extended among all producers of grey and malleable iron, whether engineering works or jobbing foundries, and also on the part of the blast furnace plants producing foundry pig-iron.

The annual subscription for the services rendered is extremely small, and is the sole charge made by the Association. It can be treated by member firms as a business expense not subject to income tax. The Association expends solely for the benefit of members some £8,000 per annum.

American Foundrymen's Association.

It is anticipated that a large delegation will attend the second International Foundrymen's Congress at Detroit, U.S.A., next autumn. About twelve European countries will be represented. Exchange Papers will be presented by the Foundry Associations of Great Britain, France, Belgium, Germany, and Czecho-Slovakia. Nearly sixty American foundries have offered to open their works for inspection by the foreign delegates.

John Cameron, *President*.
W. G. Hollinworth, *General Secretary*.

The accounts and balance sheet are presented herewith:—

Balance Sheet.

INCOME & EXPENDITURE ACCOUNT.

Expenditure.				£	s.	d.
Postages				87	2	0
Printing and Stationery, including Printing of Proceedings				513	0	7
Council, Finance and Annual Meeting Expenses				48	17	7
Illuminated Address				10	10	0
Branch Expenses—						
Lancashire	£112	2	9			
Birmingham	102	18	6			
Scottish	88	4	11			
Sheffield	91	11	1			
London	47	5	7			
East Midlands	24	5	10			
Newcastle	78	14	1			
West Riding of Yorkshire	15	3	1			
Wales and Monmouth ..	26	16	2			
				587	2	0
Audit Fee				6	6	0
Incidental Expenses				17	7	0
Salaries—Secretary and Clerk				400	0	0
Rent of Office				65	0	0
Depreciation of Furniture				8	10	9
				£1,743	15	11

Income.	£	s.	d.
Subscriptions Received	1,677	2	6
Sale of Proceedings, etc.	6	11	6
Interest on War Loan and Cash on Deposit	32	15	10
Surplus Surtees Memorial Fund	10	1	4
Surplus from Coventry Branch	3	15	9
	£1,730	6	11
Excess of Expenditure over Income ..	13	9	0
	£1,743	15	11

Liabilities.	£	s.	d.	£	s.	d.
Subscriptions paid in advance				120	14	6
Sundry Creditors				315	18	7
The Oliver Stubbs Medal Fund—						
Balance from last Account	206	18	8			
Interest to Date ..	8	13	4			
	215	12	0			
Less : Cost of Medal ..	9	10	0			
				206	2	0
Surplus at December 31st, 1924	999	14	6			
Less : Excess of Expenditure over Income for the year ended December 31st, 1925	13	9	0			
				986	5	6
				£1,629	0	7

Assets.	£	s.	d.	£	s.	d.
Cash in Hands of Secretaries—						
Lancashire	5	8	4			
Birmingham	7	5	10			
Scottish	0	12	7			
Sheffield	72	18	9			
London	53	1	6			
East Midlands	32	14	7			
West Riding of Yorkshire	28	17	6			
Newcastle	5	2	10			
Wales and Monmouth ..	5	3	10			
				211	5	9
Lloyds Bank, Limited—						
General Account	302	6	3			
Deposit Account ..	400	0	0			
				702	6	3
Oliver Stubbs Medal Fund—						
£342 5s. 7d. Local Loans £3 per cent. Stock at cost ..	200	0	0			
Balance in hands of Lloyds Bank, Ltd.	6	2	0			
				206	2	0

Assets.—*Continued.*

	£ s. d.	£ s. d.
Investment Account—		
£100 5% National War Bonds, £350 5% War Loan at Cost		432 10 1
Furniture, Fittings and Fixtures		
Per last Account ..	85 7 3	
Less : Depreciation 10%	8 10 9	
		76 16 6
		£1,629 0 7

We have prepared and audited the above Balance sheet with the Books and Vouchers of the Institute and certify same to be in accordance therewith.

(*Signed*)
J. & A. W. Sully & Co.,
Chartered Accountants,
Auditors.

Induction of the New President.

Mr. Cameron, in handing over the office of President to Mr. V. C. Faulkner, said how much he had enjoyed the trust which the members of the Institute had imposed upon him during the past year. He had tried to do his best to maintain the traditions of that office. During the year he had visited nearly all the Branches of the Institute, and had been fortunate, as few Presidents had been fortunate, in having a most harmonious and splendid Council to work with. In handing over the office to his successor, he said that Mr. Faulkner came eminently qualified to hold such a position; he was a trained metallurgist, an expert journalist, and had made his mark in the foundry industry. As Editor of The Foundry Trade Journal he had made that paper a success; indeed, he had made such a success of it that it was absolutely indispensable to every up-to-date foundryman to-day. That was due to Mr. Faulkner's ability and his enthusiasm for the foundry business.

Mr. Faulkner then assumed the chain of office and formally occupied the chair, amid prolonged applause. He expressed his deep consciousness of the honour conferred upon him, and of the work the office involved, but expressed the hope that when industrial conditions settled down the Institute could look forward to a prosperous year. He knew he would have the full support of the Past-Presidents and Vice-Presidents.

The New Vice-Presidents.

Mr. J. T. Goodwin and Mr. S. H. Russell were unanimously elected Senior and Junior Vice-President respectively. The election of Mr. Goodwin was proposed by the President and seconded by Mr. R. O. Patterson (Past-President); that of Mr. Russell was proposed by Mr. Goodwin and seconded by Mr. F. J. Cook (Past-President).

Members of Council.

The result of the ballot for four members to serve on the general Council, to fill vacancies caused by retirement, was the re-election of the following:—Mr. A. R. Bartlett (London), Mr. Wesley Lambert (London), Mr. H. Pemberton (East Midlands), and Mr. J. Shaw (Sheffield).

Trustees.

On the proposition of Mr. G. E. Roberts, seconded by Mr. W. Jolly, the trustees were re-elected. They are Mr. Oliver Stubbs (Past-President), Mr. F. J. Cook (Past-President), and Mr. R. O. Patterson (Past-President).

Diplomas.

The recommendations of the Awards Committee that Major Appleyard (Newcastle), Mr. M. J. Cooper (London), Mr. J. R. Hyde (Sheffield), Mr. J. Longden (Paisley), Mr. W. West (Burnley), and Mr. A. J. Richman (Lancs) should receive the Diploma of the Institute was agreed to.

Vote of Thanks to the Retiring President.

The PRESIDENT proposed a vote of thanks to Mr. Cameron for his services as President of the Institute during the past year. The office of President, he said, entailed a good deal of travelling; inasmuch as Mr. Cameron lived in Glasgow, it would be impossible to choose a President who would have more travelling to do, but, at the same time, the Institute could not have chosen a President who would have done it more willingly. He must have travelled many thousands of miles on the Institute's business, and during the year had visited every Branch of the Institute, with the exception of the East Midlands Branch; also, he had conducted the affairs of the Institute expeditiously, and under the happiest conditions.

The vote of thanks was accorded with acclamation.

New Medal for Past-Presidents.

The President then announced that it had been decided to present to Presidents of the Institute, on the completion of their year of office, a souvenir in the shape of a gold medal, instead of an illuminated address, as had been the practice in the past. It was felt that Past-Presidents would prefer to have a medal. He presented both to Mr. Cameron and to Mr. R. O. Patterson (Mr. Cameron's immediate predecessor) a medal as a memento of their year of office.

Mr. Cameron, responding to the vote of thanks, admitted that whilst it was a relief to hand over the responsibility of office, he did so with a tinge of regret, because he had so much enjoyed the confidence and trust which the members had imposed in him. He had also enjoyed working on behalf of the Institute, and as the result of being privileged to hold the position of President, he felt himself bound more closely than ever to its members and its aims He returned thanks for the medal which had been presented to him.

Mr. Patterson, who also returned thanks, said that the medal would remain with him through all his life as a very happy memento of his year of office.

PRESIDENTIAL ADDRESS.

The President then delivered his address as follows:—

Gentlemen,—I thank you most sincerely for the honour which you have just conferred upon me by electing me your president, but with this sense of appreciation there is mingled a feeling of doubt as to my ability to carry on the work of the Institute in so efficient a manner as my immediate predecessors. In recent years they have been large employers of labour and possessed proved business ability. I regard my election not as a personal one, but perhaps a too-generous recognition of the work of the London Branch during the last few years, and I should have hesitated to assume this office, which becomes more onerous each year, had I not the knowledge of the enthusiastic support of both this Branch and the General Council.

Membership Distribution.

In recent years the Institute has taken its place as one of the leading technical organisations ot the country; its work is studied and quoted by the world's leading technicians. Its membership not only includes British living in all parts of the world, but Americans, French, Spaniards, Italians, Czecks, Belgians, and the time has arrived seriously to consider whether Germans should not also be admitted, as Science knows no boundaries.

Widening the Scope of the Institute.

A study of the topographical distribution of the membership reveals that the excellent system of organising branches in the various districts containing a fair number of foundries has resulted in a curious situation. Conditions are now such that the Institute is expected to provide a branch wherever two or three foundries exist in one community. The propaganda of the Institute must be so directed and the conduct of its affairs is so arranged that it is definitely advantageous for a foundryman—no matter where he is residing—to associate himself with the Institute. An obvious suggestion is that there should be two meetings annually, one to be in London and to be devoted purely to the reading of technical papers, and the second to be in the provinces or abroad and to take the form now so well established.

Meeting Modern Necessities.

The isolated foundryman, whether at home or abroad, will demand two types of papers—the metallurgical and the practical. About the latter a certain amount of confusion is apparent, traceable to the platitude which enunciates that "what is one man's meat is another man's poison." It is suggested that in the preparation of such papers authors should endeavour (1) to eliminate as many indeterminate expressions, such as "on the hot, soft or dry, side, and the like." The work done in the foundries of the world is of such a diverse character that such expressions do not admit of universal translation and application; (2) to deal with underlying basic principles and to record the successful or unsuccessful making of any particular type of casting as an example of those principles; and (3) to retain as many of his samples as possible, so that if an aspect requires either added metallurgical or engineering work for confirmation, they are available. At the moment, there exists a vast amount of excellent practical theses on foundry topics which demand co-ordination with special reference to underlying principles. At the moment they represent the greatest unedited collection of contradictions the world has ever seen.

Metallurgical and Physical Research.

Foundry industry is urgently requiring a number of constants from which reliable calculations can be made, and there exist two schools of thought as to whose business it is to occupy themselves with this work of a fundamental character. One section insists that this work should be carried out by the British Cast Iron Research Association and another the National Physical Laboratory. Logically, we believe it is more the work of the latter until such time as the former has enrolled 100 per cent. of iron foundries of Great Britain. Again, if an apparatus has been established for determining the specific heat of cast iron at 1,200 deg. C., it is also probably suitable for similar determinations on non-ferrous metals and would thus be outside the scope of the British Cast Iron Research Association. Thus on the grounds of economy work of this type should be delegated to the National Physical Laboratory, which co-operates with most other research organisations. It should be remembered that being a key industry any progress made by the foundry industry does in varying degrees affect every other industry.

A Key Industry.

During the war Great Britain discovered that its textile industry was basically jeopardised because it was to a large extent dependent on Germany for its dyes. It will be remembered that the Government were considerably perturbed over the situation, and invested the taxpayers' money in a concern formed to create what was designated a key industry. Supposing for a moment that the engineering—civil, mechanical, electrical, agricultural, textile, mining, railway, marine, automobile, constructional, printers, chemical, sanitary and domestic—industries had been dependent on Germany for their castings, then our value as an ally of France would have been about as useful as that of an obscure South American Republic.

Yet to-day, we doubt if the Government or any other representative body recognises the industries the Institute represents as being of " key " character. As a separate entity it does not exist.

Lack of Basic Statistics.

The amount of " raw " materials it uses or imports are unknown, whilst the product of our work is lost in a maze of statistics, only bits appearing as " cast-iron pipes, tubes, etc.," " electrical fittings," " machinery," " agricultural implements," and " other items not specified." Thus is Britain's key of key industries neutral. It is almost entirely unaware of the foreign competition it is expected to meet.

Lack of Buyers' Co-operation.

Furthermore, the industry which should be its best friend—that of general engineering—is often its worst enemy, as it cares but little beyond the unfailing production of a cheap article. There is often less sympathy exhibited between the engineer's buyer and the foundry than between a crooked bookmaker and an impecunious backer.

The correct way for the engineer to assure a constant supply of sound castings is to accord the foundries the fullest co-operation and confidence. The foundries on their part must be in a position to know that the prices they submit are based on reliable costing data, open, if necessary, to inspection and to the techncal excellence of product. Of the former the Institute can do nothing beyond the enunciation of underlying principles, but for the latter consideration they willingly admit engineers as members with the object of the mutual consideration of the joint problems.

I consider it essential that those leaders of the engineering industry who possess their own foundries must be taught to realise that they are foundrymen. They exercise some control both as to the wages paid to the industry and the prices received for its product, but judged by their contributions to technical discussions on foundry topics they would benefit considerably by associating themselves much more closely with our industry.

By continued progress the Institute will attract to itself this very important type of hybrid foundryman, who can do so much to promote the industry as a whole. A few of the more enlightened have joined us, and their membership is extremely valuable.

The Modern Foundry.

There is at the moment a distinct field for men who can manage efficiently any type of foundry, whether it makes Diesel engines or rainwater goods. These two extremes have been given because the first requirement for the former is a serious metallurgical knowledge and for the latter a real appreciation of monetary value of the automatic handling of materials. The two are found side by side in a large automobile foundry, which I believe constitutes the best training ground for the potential manager, even though it does lack work of a heavy character. Most foundrymen consider the jobbing shop the ideal school. If a man's object in life is to be an expert moulder there is little room for doubt that it could hardly be improved upon. A knowledge of moulding, however, should not occupy more than 3 per cent. of the thought output of a modern foundry manager. His energy has to be devoted to work of an experimental character and to controlling the efficiency of his staff, the metal, the sands, the facing, the machinery, the handling of materials, and the costing system. These, combined with efficient co-operation with the drawing office and pattern shop will diminish to the lowest possible order the control of the moulding, except perhaps in the purely jobbing shop.

Co-ordination by Retrospect.

A well-known pathologist recently stated to me that medical science would benefit if research was prohibited for a few years and an inventory was taken of existing knowledge. I am not at all sure whether this is not equally applicable in the field of metallurgy, excepting, of course, the provision of fundamental data.

The Exhibition.

Though the Institute is precluded from industrial enterprises, its London Branch Council has co-operated with the organisers of the Exhibition in the closest possible way on the technical side. This co-operation has been of the most cordial character, and I believe it has resulted in getting together the finest technical Exhibition of a non-commercial character ever presented to the British Foundry public. Its conception was due to the first president of the Institute, and the strenuous work of its organisation to a very distinguished committee presided over by Mr. Wesley Lambert, who has devoted a great amount of time and energy to its collection and display. I specially ask you all to spend as much time as possible in examining these exhibits.

Finally, gentlemen, I thank you most sincerely for electing me as your president, and I trust that the experiment of having a professional man instead of a business man to preside over your meetings will not prove unsatisfactory.

Vote of Thanks to the President.

Mr. J. E. Fletcher proposed a vote of thanks to the President for his very able address. The members, he said, were delighted to see Mr. Faulkner in the Presidential chair, and they all looked forward to a year of very great usefulness. The Presidential address had raised many interesting points, which would provide much food for thought.

The vote of thanks was carried with acclamation, and the President briefly responded.

Telegram from Czecho-Slovakia.

The President announced the receipt of telegrams from the American Foundrymen's Association, the French Foundrymen's Association, and

Professor Pisek (President of the Czecho-Slovak Foundrymen's Association), congratulating him upon his election to the Presidential chair, and expressing the hope that the Institute would have a very prosperous year. The members of the Institute, he said, would be very deeply indebted to these Associations, and he suggested that suitable replies be sent.

This course was agreed to.

The following Papers were read and discussed:—

"Quality in Quantities" (American Exchange Paper), by Mr. Arnold Lenz.

"The Practical Utilisation of Apparatus for Measuring the Permeability and Cohesion of Moulding Sands" (French Exchange Paper), by Monsieur Lemoine.

"A Comparison of the Results Obtained When Improving the Tensile Qualities of Cast Iron" (Belgian Exchange Paper), by Monsieur L. Piedboeuf.

At the conclusion of the first session of the Convention, and on the motion of the President, a very hearty vote of thanks was accorded the authors of the three Papers discussed.

LUNCHEON.

The officers of the Institute and the Reception Committee were entertained to luncheon on Wednesday at the Royal Agricultural Hall by Messrs. F. W. Bridges & Sons (Organisers of the Exhibition). Mr. V. C. Faulkner (Chairman of the Foundry Trades' Equipment and Supplies Association) was in the chair.

The Loyal Toast having been duly honoured,

Captain R. B. Crewdson (Deputy Chairman and Joint Managing Director, Industrial Newspapers, Limited) proposed "The Institute of British Foundrymen." Speaking as one who had recently become connected with the Institute for the first time, he said it seemed to him that there were three things which indicated that it was playing its part in the industrial and scientific progress of this country, and playing it really well. In the first place, the country was faced with a grave industrial dispute, and it seemed to him that, instead of bemoaning their fate and looking at things in a dejected frame of mind, the foundrymen were doing their very best to use the time by improving their great industry, by studying its technicalities and thereby advancing it. The fact that at such a time the Exhibition could have been organised, and that everyone had been ready to seek out everything that might help to improve the industry, was a sure sign of how deeply and truly the Institute entered into the well-being of the industry, and of how truly everybody was working to keep the British foundry trade foremost in the world. In the second place, he had been very greatly impressed with the international aspect of the Institute. It was a very great thing that the Institute did not remain insular in outlook. Although the practice of exchanging Papers with the foundry industries of this and other countries had been established only five years ago, he understood that already sixty Papers had been exchanged, and that those Papers, written by experts in France, Belgium, America and this country, had been very much valued and appreciated. Thirdly, the fact that the objects of the Institute were technical and social, and not political nor commercial, was a very important thing; it was a great achievement that, after an existence of 23 years, its aims should still be technical and social. He was very greatly impressed, in a humble way, as a student of industry, with the ideals of the Institute, to pool the knowledge of all engaged in the trade—which, after all, was one of the greatest corner stones of British industry—for the benefit of British industry. Dealing with the establishment of the Institute, he said that it resulted from some anonymous correspondence published in THE FOUNDRY TRADE JOURNAL 23 years ago, and that the man who had written the first letter was a Past-President, Mr. "Jimmie" Ellis. (Mr. Ellis, who was present at luncheon, was greeted with loud applause.) In that period of 23 years the Institute had accomplished something which many industries were still striving to accomplish, but could not; it had accomplished a feeling of goodwill throughout the industry, not only in this country, but abroad, a feeling which made for peace in the industry and, therefore, for its betterment. It was, therefore, with humility—because this was the first time he had been able to meet its members—with admiration for what it had done in the past, and with best wishes for its future success, that he proposed the toast of "The Institution of British Foundrymen."

Mr. John Cameron (Past-President), responding, commented that for the first time in his experience the members had been addressed by two gentlemen (Mr. Arthur Henderson and Capt. Crewdson), in the course of one day, who had really appreciated what the Institute stood for. Dealing with international relationships, he said that the Institute had just received an invitation to attend the international gathering to be held at Barcelona in 1928. Mr. Cameron emphasised the value of these international meetings, and expressed regret that so few from this country would be able to attend the International Congress at Detroit this year. In urging the members to take advantage as much as possible of opportunities to visit other countries, he assured them that those visits were not only enjoyable, but also most instructive. Discussing further the aims of the Institute, he said how very much he had been impressed by the breaking down of the old jealousies which had existed between one firm and another in the trade before the Institute was established; the activities of the Institute had been responsible for that, and founders were now able to meet together, compare notes and talk over their difficulties, to the benefit of all. They also encouraged their staffs and workmen to do so, and it was a pleasure to him to be associated with a body so democratic in its basis as the Institute of British Foundrymen. Finally, he said he came before the members that day with a clear conscience, and believed that he had handed over the Institute to Mr. Faulkner in a very healthy condition. He did not think that at any time had there been so much good fellowship, so much serious work and so much real endeavour to get to the bottom of things as at present. There was a feeling in the country that it was now becoming almost a necessity for a firm to be connected with the Institute. As the result of a little missionary expedition to Middlesbrough last year a branch had been formed there; it was in a very healthy condition numerically and in enthusiasm, and he felt sure that before long Middlesbrough would provide the Institute with a worthy President.

Commander L. Jackson (Past-President, Sheffield Branch) proposed "The Chairman." Mr. Faulkner, he said, was President of the Foundry Trades' Equipment and Supplies Association as well as President of the Institute, and all the members looked upon him with a great deal of feeling and affection. He assured Mr. Faulkner that he could depend in the future upon the loyalty which the members of the Institute had always extended to their Presidents in the past.

The toast was received with musical honours.

The Chairman, in a brief response, said he was not present in his capacity as President of the Institute, but was acting on behalf of Messrs. F. W. Bridges & Sons, who were the hosts. Therefore he proposed a toast to the success of the Exhibition, coupling with it the name of Messrs. Bridges.

Mr. K. W. Bridges briefly responded.

Official Visit to the Exhibition.

In the afternoon the members and delegates visited officially the Exhibition, and were entertained to tea by Messrs. Bridges.

INSTITUTE BANQUET.

The Institute banquet was held in the Grand Hall at the Hotel Cecil on Wednesday evening, The President (Mr. V. C. Faulkner) was in the chair, and there were present some 200 members and visitors, many of the latter from overseas. The company included the Rt. Hon. Sir Alfred Mond, Bart., P.C., M.P.; Sir William Larke, K.B.E. (Director, National Federation of Iron and Steel Manufacturers); Mr. F. W. and Mr. K. W. Bridges (Messrs. F. W. Bridges & Sons, organisers of the International Foundry Trades' Exhibition), Mr. John Cameron, J.P. (Past-President), and Mrs. Cameron; Mr. F. J. Cook (Past-President); Mrs. V. C. Faulkner, Mr. J. T. Goodwin (Vice-President) and Mrs. Goodwin; Mr. Barrington Hooper, C.B.E., Mr. Wesley Lambert and Mrs. Lambert; Monsieur G. Masson (President, Belgian Foundrymen's Association); Brig.-Gen. F. E. Metcalfe, C.B., C.M.G., D.S.O.;

Mr. R. O. Patterson (Past-President); Mr. J. G. Pearce (Director, British Cast Iron Research Association); Mr. Geo. C. Pierce (President, London Branch); Sir John Prestige; Sir Berkeley Sheffield, Bart., M.P.; Monsieur E. Ronceray (Vice-President, French Foundrymen's Association); Mr. S. H. Russell (Vice-President); Mr. J. Ellis (Past-President); Mr. Oliver Stubbs (Past-President); Capt. R. B. Crewdson; and Mr. H. G. Sommerfield (Hon. Convention Secretary).

The Loyal Toast having been duly honoured.

The Rt. Hon. Sir Alfred Mond, Bart. P.C., M.P., proposed "The Institute of British Foundrymen." The Institute, he said, had been in existence for some years; in fact, it had come of age. It had reached the age of 22 years, an age at which we all believed that youth was the only thing that mattered, and when the things we could not tolerate were old age and experience. As one who thoroughly believed in the great advantage of being young, he considered that a young Institute was likely to be vigorous and progressive. Its objects were excellent, its membership was magnificent, and he was perfectly certain that the work which it would do, both nationally and internationally, would be of the greatest importance. After all, founding was a very respected and aged science; it took us back to the days when the casting of church bells was one of the principal occupations of the founder. Some of those bells still emitted tones of such beauty that he doubted whether, with all the modern science we had created, we could equal the mixtures which the old-time founders so empirically created. To-day the foundry industry had become more varied and more important to the progress of the world than at any other period. After all, if anything was distinguishing us from our forefathers, it was the fact that we were living in an age of mechanical progress, above all, mechanical progress so rapid that greater and greater demands were being made daily upon all forms of technical execution. The engineer to-day called for consistency of performance, and demanded the fulfilment of conditions which were almost incredible many years ago. It was very interesting to look back over industry, especially chemical industry, and to reflect upon the evolution of processes which to-day were becoming commonplace—the processes of synthesis under high pressure and high temperature, which called for castings of steel, as he himself had said recently at his Billingham works, giving most remarkable performances, and which were a triumph of British workmanship. It was interesting to think how many of those things were possible now but were never attempted in former times because the technical means were not available; the machinery for their production was non-existent. He had looked back at the history of Messrs. Brunner, Mond & Company's chemical works, and had recently looked at an old engine which had been working for forty years, and was still working—a tribute to those who built it. He remembered, as a child, the difficulties his father had in getting compressing machinery of a type which would cause one to smile if it were suggested to-day.

Demand for Special Alloys.

Again, in the aeroplane industry to-day there were demands for metals which were light and strong, for all ranges of products, for nickel-chrome steel, new aluminium alloys, etc.; new forms of alloys were springing up like mushrooms, many of which, of course, were essential factors in future progress. Foundrymen must play a very important *rôle* there, for, after all, the aero engine required very delicate and special castings, and the study and utilisation of these new materials in the foundry would undoubtedly cause new problems to be put up and solved. The little experience he had had of foundry work and its results had left on his mind the impression that it was extremely anxious work. After the most infinite care and trouble, something went wrong; an expensive casting had a crack, the contract which looked so profitable began to appear otherwise, the works manager began to look anxious, and the sales manager began to tear his hair. It was difficult work, and to some extent metals were rebellious creatures which, in spite of the care and trouble devoted to them, did not always obey those scientific laws laid down for them. Of course, greater control of temperature and improvements on modern methods would eliminate more and more those difficulties. At the same time, it was his opinion that a good foundry foreman was sometimes worth a large number of text books. (Hear, hear.) By some uncanny method, some peculiar instinct known only to himself, he produced results upon which he could not give a scientific lecture, but which were very satisfactory.

International Ramifications.

Reverting to the Institute itself, Sir Alfred said he was very glad that it appreciated the importance of the maintenance of close contact internationally. To-day there was no monopoly in any country in the world in scientific thought or industrial progress. In fact, science had invaded the whole world, and no one could tell in what corner of the globe some new idea might emerge; no one could tell what new process might be discovered or what problems might be solved one day in Japan, another day in France, another day in Germany, another day in America, or elsewhere. It was of the greatest importance to the progress of the world that these new ideas should not remain hidden in one corner of it, and should not be monopolised, but should become the property of the world. Therefore, it was wise for us to disregard and to discourage the old-fashioned ideas and formulæ, according to which everybody had a secret carefully guarded from everybody else, just as, in the old days, somebody had a ledger which he did not understand, but which nobody else was allowed to see. After all, we gained more by an interchange of ideas with other human beings than we were likely to gain by thinking that we were the only clever people who would ever discover anything. It was international amity and progress which undoubtedly made for the development of the world. That was how those in industry to-day really conceived it. Incidentally, they liked to see, if possible, some return for their labour and their capital. There were such people as shareholders, who, having put their money into industry, most unreasonably expected some remuneration. (Laughter.) They were not often gratified; they did not seem to understand that the service they were rendering ought to satisfy them beyond all means, particularly in the engineering industries, the most difficult of all he had ever been connected with, which did not show any profits at all except upon paper before the contracts were completed. (Laughter.) For all that, however, the British engineering and foundry industries were by no means played out. He had an infinite belief in the capacities of the people, even in the middle of the most stupid coal strike from which we had ever suffered, and which was paralysing industry.

Essentials for Progress.

In spite of these occasional aberrations of otherwise reasonable people, we managed to pull through, and even if sometimes he felt we were really slow, we had a curious habit of moving rather quickly when we made up our minds to move. So long as we did not wait too long it was all right. He was certain that in modern industry, progress, concentration and co-operation were the three things required to put us where we ought to be, in the front rank. Old traditions had disadvantages, but they also had values. It was quite true that we did not hustle around and tell people we were hustling quite so much as our American cousins did; they were so busy telling us how they were hustling that we wondered when they did any work—(laughter)—but somehow we did get results slowly, and sometimes pretty surely, and he could say, speaking as one with an experience extending over many years in industry, that British engineering, inventive capacity, and the capacity to solve problems was as good as that of any other country in the world; if we obtained the right people with the right training, gave them the necessary means and opportunities, and backed them with courage and determination, we could obtain the results. We suffered more from cold feet on the part of the people at the top to-day than we suffered from the incapacity of the people who were doing the work; we wanted a little more of the old pioneer spirit exhibited by the men who created British industry.

Oil from Coal.

It was important that those directing industries should have some knowledge of the industries they were directing, and should not look upon their industries merely as money-making machines. Only a few days ago he had read of the great progress which some of our friends in Germany were making in connection with various new synthetic processes. He had no doubt that similar progress would be made in this country, and when the demand was made for new forms of apparatus, involving, as he hoped it would, orders to many foundries and engineering works in this country in vast proportions, we should not be wanting. It was interesting to reflect, for instance, upon what would be the effect upon the engineering industry of the world when we really started to make oil from coal on a large scale, when we began to convert, not a few thousand tons of coal a day, but hundreds of thousands of tons a day, by some of these new processes. Interested as he was in an engineering works, he looked forward to a better time than had been experienced in the last few years; the iron and steel industry would once more come into its own, and that would stimulate matters all round. He was afraid he was an incurable optimist; he had no patience with those who sat down with folded arms and awaited our extinction; there was no logical reason for such expectations. Just as he believed that humanity, far from having achieved its destinies, was only now on the threshold of achievement; that locomotion would advance so that distances would disappear and countries would be practically as contiguous as suburban villas; that the resources of the world would not become exhausted; that the world would not become overcrowded—for it was obvious that the progress and development of all kinds of modern ideas with regard to fertilisers and food production would enable us to support a population so vast as to be inconceivable now; equally he was convinced that this country had before it a glorious destiny, and that those who were young to-day would see the development on a large scale of many great and new ideas, and when they grew old would be able to tell their children of the astonishing kind of cave existence which we led in 1926. The Institute of British Foundrymen would watch all these interesting developments; it would find new and fascinating subjects for its members to study and to utilise; it would find also, he hoped, new resources to turn to profitable undertakings. This picture was not the product of a visionary, but of one who had spent over a quarter of a century in the direction of some of the largest industrial concerns in this or any other country. He had seen markets lost and new ones opened up; he had seen people despondent at the thought that consumption had come to a standstill, and had seen that consumption rise year by year; he had seen people imagining that in their own processes perfection had been reached, but we were still revolutionising what we considered to be obsolete plants, and new works were as different from the old as any works could be. When one had lived through that, one was able to speak with conviction. It was in this spirit, not merely of hope, but of certainty, that he proposed the toast of "The Institute of British Foundrymen," and coupled with it the name of a young and energetic pioneer, its President.

Powdered Fuel in Foundries.

The PRESIDENT, responding, expressed his thanks for the cordial manner in which the toast had been proposed and received. In a tribute to Sir Alfred Mond, he said that at the present time there were in the Cabinet at least two students of Professor T. Turner, an esteemed Hon. Member of the Institute, and expressed the hope that in the near future it would include a third metallurgist, namely, Sir Alfred Mond. There was at present a special Bill in Parliament, and he hoped that that Bill would soon pass into law, so that Sir Alfred could fill a position which he had filled before with such great distinction. Addressing Sir William Larke, who, as the Director of the National Federation of Iron and Steel Manufacturers, is closely concerned with statistics, the President pointed to the difficulties which faced the foundry industry as the result of the absence of statistics. The industry, he said, was the key of key industries; Sir Alfred Mond could not turn out alkalies or any other products without some cast iron somewhere. Surely then, the great key of key industries should have some statistics for itself. It did not know at the moment the competition it was supposed to meet, and it did not know what it exported. The statistics relating to cast iron exports included cast-iron pipes, tubes, electrical fittings, and all sorts of things, which in truth were castings, but such statistics did not offer the industry any guidance. Unfortunately, the industry was diverse in character; the men who made gutters for the roofs of houses, or pipes used under the streets, or the engines at the generating stations, had but little in common; all they had in common at the moment was the Institute. He asked Sir William, therefore, for his help in the production of the statistics which the industry needed. Speaking of the Institute, he said that it prided itself not only upon its national but also upon its international relations. He had received that day telegrams expressing good wishes from the foundrymen's associations in America, France, Czecho-Slovakia and Spain. These associations were working for the same common object as that for which the British Institute was working, and he announced that the Institute had been invited by the Spanish Association to attend a conference in Barcelona. Finally, commenting upon Sir Alfred Mond's remarks, he said he was glad to hear him hold out the hope of obtaining oil from coal on a large scale. He himself had heard a good deal about it, but it was a little in the air at the moment. An allied problem, however, to which foundrymen would do well to devote close study, was that of the use of powdered fuel. He was pleased to hear only that morning that the largest malleable iron foundry in Great Britain had decided to use powdered fuel, and he believed that the second largest would be chasing it in an effort to be first. That, he said, was good news.

Scientific and Practical Collaboration.

Mr. Oliver Stubbs (Past-President) proposed "Scientific Institutions and Allied Industries," which, he said, included the National Physical Laboratory, the Iron and Steel Institute, the Institute of Metals, the Research Department at Woolwich, and last, but not least, the British Cast Iron Research Association. The Institute of British Foundrymen, he said, was delighted to welcome representatives of those bodies, and wished to thank them for their support in the past. At the same time, he assured them that the Institute was anxious to do all it could to help them, for the benefit of all. In a reference to the benefits which accrued from an interchange of ideas between all these bodies, he pleaded for an even greater co-ordination between the scientific and the practical aspects of the industry than perhaps had been manifest in the past. In acknowledging the valuable work carried out by the British Cast Iron Research Association and the necessity for its continuance, he said that, as the result of the splendid record of that body in the last five difficult years they had been able to put such a strong case before the Department of Scientific and Industrial Research that the latter, he believed, had practically decided to grant to the Association the terms they had asked for for another five years. (Applause.) He took pride in the fact that the Institute of British Foundrymen was the father of the Research Association. As to the Institute itself, he said it was one of the few bodies which included within its membership the men in the shops, the foremen, the managers and the employers, and emphasised that if there were more bodies through the medium of which the workpeople and those who were responsible for the control of industry could be brought so closely into contact one with the other, there would be far less trouble in the industrial world. He had every sympathy with the British worker. It was quite true, as Sir Alfred Mond had said, that we were only at the beginning of progress, and for that reason he appealed for support of the work of the Institute and other such bodies, which, it must be remembered, was carried out by men who were keen enough to devote their leisure to it.

Captain R. B. Crewdson (Joint Managing Director, Industrial Newspapers, Limited), who responded, in the absence of Sir Joseph Petavel, F.R.S. (Director, National Physical Laboratory), said that just as the research work carried out by the various bodies mentioned was playing a more and more vital part in keeping British industry where we wished to see it, so the members of those bodies felt that they depended for their success upon the support and encouragement which they might receive from the industries they sought to serve. The eloquence with which Mr. Oliver Stubbs had proposed the toast, and the hearty manner in which it had been received, would be an encouragement to the members of those bodies and an inspiration to them in their work throughout the coming session.

Mr. F. J. Cook (Past-President) proposed the toast of "The Guests," and thanked them for having honoured the Institute by their presence. The Institute, he said, was proud to welcome such men as Sir Alfred Mond, Sir William Larke, and other giants of industry who were present. It was also proud of the fact that there were also present representatives from America, France, Belgium, Sweden, Denmark, Czecho-Slovakia and Germany, and he commented with pleasure on the fact that one table was occupied entirely by representatives from Sweden, including a Past-President of the Swedish Foundrymen's Association. He extended to all the guests a very hearty welcome.

Lessons from the Coal Crisis.

Sir William Larke, K.B.E., responded, and thanked the Institute, on behalf of the guests, for the hospitality extended to them. He dwelt upon how much functions of this character contributed towards the welfare of the industries with which they were connected, and emphasised the value of the free exchange of information, discovery and experience between the representatives of all industries in all countries. Nothing could be gained, he said, by attempting to retain a technical monopoly, because such a monopoly could not be retained, and, if it were retainable, it was not worth retaining, because collective knowledge and experience was of far greater benefit to the individual who contributed to it than any individual contribution he himself could make. He himself had been brought up as an engineer and had been associated with industry all his life, and knew full well that the technical difficulties we all met with in our daily life, and which needed so much solving, were frequently solved by someone else, working in another direction altogether, whose knowledge would not be conveyed to us except by the establishment of the closest possible contact and the free interchange of ideas. One of Sir William's epigrams was that the problems of 1926 cannot be solved with a 1914 mind. Like Sir Alfred Mond, he was an optimist; he was one of those who believed that a pessimist was a man who saw a difficulty in every opportunity, and that an optimist was a man who saw an opportunity in every difficulty. If that were true, what opportunities did he see in the recent emergency through which the country had passed, and the crisis with which the country was still faced? He saw the opportunity of laying the foundation of that mutual confidence between all people in this country, which would enable us to rise to that unity of thought and singleness of purpose which had characterised our efforts during the war, and that unity and confidence, when secured—as he believed it would be secured as the result of the solution of the present difficulties—would enable us to use the finest industrial capacity in the world. Those who had been privileged to see the war effort from a position which enabled them to survey the effort of the whole country, particularly those who had been trained as industrialists, knew full well—and he said it without fear of contradiction—that the industrial effort of this country during the war period was unprecedented in the world in this or any other time. Such effort would bring us prosperity in the future, and all that was needed to secure it was mutual confidence on the part of all engaged in industry, so that they worked to a common end. Dealing with the suggestion that the foundry industry had not sufficient statistics on which to base commercial policy, he said it was less than a week ago when he had first heard that there was any such need. He was delighted, however, to hear the remarks which had been made, and his efforts at least to meet that need could be relied upon. It did not rest entirely with him or his colleagues, however; there were others involved, such, for instance, as Customs officials, but so far as it was possible, the statistics which the foundry industry required would be prepared and incorporated in the national statistics, for which he was responsible, to the iron and steel industry.

Mr. John Cameron, J.P. (Past-President), proposed the final toast, that of "The Convention Committee and the London Branch." An enormous amount of work was involved, he said, in recent years to make the annual gatherings of the Institute the success they had been, but on this occasion those responsible for the arrangements had come through some special difficulties with very great credit. For the first time in the history of the Institute it had been doubtful, until a comparatively short time before the Convention was to be held, whether or not it would have to be postponed. There had been difficulties arising out of reduced railway services and many other factors, but the Convention Committee and the London Branch were maintaining the high standard attained in connection with the Institute's Conventions in the last three or four years. On this occasion the Convention was more attractive than ever, because it had been arranged to have a wonderfully good exhibition running concurrently with it. As one who had been to every Exhibition since 1913, he could say that it was the finest foundry Exhibition ever seen in this country, and he congratulated the organisers, Messrs. F. W. Bridges & Sons, as well as the Convention Committee and the London Branch, upon their enterprise. No one recognised more than he the educational value of such Exhibitions; it was always his practice to send his managers and foremen to visit them, and they came back to their work encouraged and enthused with new ideas. They met old friends and made new ones, and they returned with new interest and new enthusiasm for their work, which would be impossible but for the efforts of the Institute. The members of the Convention Committee were Col. W. F. Cheesewright, D.S.O., Mr. Faulkner (the President), Mr. Wesley Lambert, Mr. H. Shillitoe, Mr. G. C. Pierce (President of the London Branch), and last, but not least, Mr. H. G. Sommerfield (Hon. Secretary of the London Branch, and Hon. Convention Secretary and Treasurer). He paid a tribute particularly to Mr. Sommerfield for the enormous amount of work he had done, and said it was a great pleasure to ask for recognition of that work. The Branch had given a good lead to the Institute in having taken a broad-minded view in such matters, and it was the desire of the Institute to recognise it. He coupled the toast with the name of Mr. G. C. Pierce (London Branch President).

Mr. G. C. Pierce, in a brief speech, expressed thanks on behalf of both the Committee and the Branch, and said they were amply repaid by the assurance that those attending the Convention had found it to be enjoyable and instructive. He also acknowledged in glowing terms the services which Mr. Sommerfield had rendered.

Mr. H. G. Sommerfield also responded in a speech characteristically brief. It was a pleasure to him, he said, to find so many in sympathy with the work done in connection with the Convention. That in itself had been ample recompense.

During the dinner musical selections were rendered by the Corelli Windeatt Sextette, and later a concert, under the direction of Mr. Arthur Hayes, contributed to the success of the evening.

THURSDAY, JUNE 17.

The proceedings were resumed on Thursday morning in the lecture room at the Royal Agricultural Hall.

British Cast Iron Research Association.
New Grade of Membership.

Mr. J. G. Pearce (Director, British Cast Iron Research Association), at the invitation of the General Council of the Institute, outlined a new scheme regarding membership of the Research Association. Quite recently the Council of the Association had adopted a new arrangement, which had been accepted by the General Council of the I.B.F., whereby members and associate members of the I.B.F. could take advantage of associate membership of the Research Association at a subscription of 20s. per annum.

Mr. Pearce also took the opportunity of correcting an impression which had got abroad some years ago, that an associate member was entitled to receive the whole of the Research Reports and other confidential reports circulated by the Association. It would be obvious, he said, that it would be impossible to provide, for a small and limited subscription, information for the receipt of which the full members paid many times that amount each year. He felt sure, however, that the service which could be given for the small sum of 20s. per annum would be more than sufficient recompense to those who subscribed. In addition to circulating to such associate members the Quarterly Bulletin—which watched the world's literature on founding, on behalf of the foundrymen of this country—and placing at their disposal the Library and Information Bureau, the Association was prepared to deal with any inquiry on behalf of an associate member for information relating to any aspect of founding practice; it would supply that information from books, trade literature and periodicals, provide translations from foreign literature, and books, pamphlets and periodicals could also be borrowed. He felt very strongly that if the possibilities of this service were more widely known, greater advantage would be taken of it.

The following Papers were read and discussed:—

1. "Non-Ferrous Metallography," by Mr. S. Glen Primrose.

2. "Some Notes on the Production of Cylinder Pig-Iron to Fracture and Analysis," by Mr. E. J. Yates.

3. "Chemical Reactions in the Cupola, with Special Reference to Fuel Consumption," by Professor E. C. Thompson and Mr. M. L. Becker.

During the afternoon the members and ladies visited a number of works in the London district and in the evening a banquet was given at the Agricultural Hall by Messrs. F. W. Bridges & Sons, Limited, organisers of the International Foundry Trades Exhibition. The banquet was in honour of overseas delegates and visitors, and officers of the Institute of British Foundrymen were also present.

FRIDAY, JUNE 18.

The day was spent in visits to various works, situated near London. A party of members and ladies visited the Letchworth Garden City and afterwards inspected several works in Letchworth and other parties of members visited works at Dunstable and Braintree.

SATURDAY, JUNE 19.

The last day of the Conference was devoted to an excursion by steam launch along the Thames. On the outward journey a halt was made at Windsor and the party disembarked for luncheon at the Bridge House Hotel.

The President, in a few remarks, expressed the gratitude of the whole party to Mr. H. G. Sommerfield, the Honorary Convention Secretary, for the excellent arrangements which he had made on their behalf and regretted that Mr. Sommerfield himself was unable to be present.

QUALITY IN QUANTITIES.

By Arnold Lenz, Saginaw Products Company,
Saginaw, Mich., U.S.A.

[American Exchange Paper.]

The production of articles in quantities is an outstanding feature of the present industrial era. It is the result of industrial evolution and a product of present civilisation.

The effect of this development in the various industries on the mode of living has been very pronounced. It has raised the standard of living and has given everybody more of the enjoyment of the better things of life by bringing within the means of the masses such things as better clothing, better heating and lighting of homes, improved sanitary equipment, telephones, books, newspapers and even automobiles. Luxuries of a few years ago have become commonplace and will be classed as necessities by the next generation. Quantity production is necessarily confined to the manufacture of commodities, enjoying a wide range of distribution and usefulness, whose application and use are to a certain degree only limited by its cost to the consumer and may vary from a match to an automobile.

This method of manufacturing has invaded every industrial field and has been equally successful in high and low quality articles. Although there is evidence of this on every hand, there are still a large number of manufacturers as well as consumers who refuse to recognise this truth. They persist in associating quantity production with cheapness, not only in price, but in quality also. This is erroneous and can only be attributed to a misconception or ignorance of the fundamentals of quantity production.

Since the price and the usefulness of a commodity are the controlling factors in its distribution, the quality is, as a rule, predetermined and fixed in advance. Production has therefore to adjust itself to quality and not quality to production. This is well illustrated in the textile

FIG. 1.—ONE OF THE QUANTITY PRODUCTION FOUNDRIES OF THE SAGINAW PRODUCTS COMPANY. HALF THE CARS SHOWN ARE THOSE BELONGING TO THE WORKMEN.

industry, one of the first industries to adopt quantity production. Here the efforts to produce goods in wool, cotton, linen and silk of a quality and price to satisfy the needs of people of humble circumstances, has not prevented that industry from producing, sometimes in the same institution, textiles of the finest quality that will satisfy even the most exacting taste. The automobile industry is another example. There are cars of a great variety in quality and price, and the few manufacturers who do not build on a quantity production basis are prevented from doing so, because their prices are restricting their market to a point where the application of quantity production is no longer practical or possible.

Quantity Production as Applied to the Foundry Industry.

There has been considerable criticism that the foundry industry has failed to keep pace with the general industrial development. While this criticism is not wholly unfounded, it has, in most cases, been offered by people who have little or no knowledge of the peculiarities and difficulties incident to the foundry industry and has, as a rule, been devoid of the practical and helpful suggestions which every progressive foundryman is eagerly seeking.

This is an age of specialization and it is leaving its mark on the foundry industry. Specialization has already removed from the jobbing foundry such castings as fittings, pipes, radiators, railway car wheels, sanitary equipment, bearings, bushings, automobile castings, etc., and there are many more to follow. Once a casting has entered the specialty field, price and uniformity of quality place it beyond the reach of the foundry producing a general run of castings.

The limited number of any one piece and the nature of the castings produced by the ordinary jobbing foundry makes the application or adoption of even some of the well established foundry devices and equipment impractical. It is only the specialty or production foundry that can take full advantage of all the modern mechanical, metallurgical and chemical developments and it is to these foundries that the foundry industry owes its rapid development of the past few years. In the manufacturing of castings, as in any other commodity, quantity is the only limiting factor in the application of production methods. Quality and intricacies of

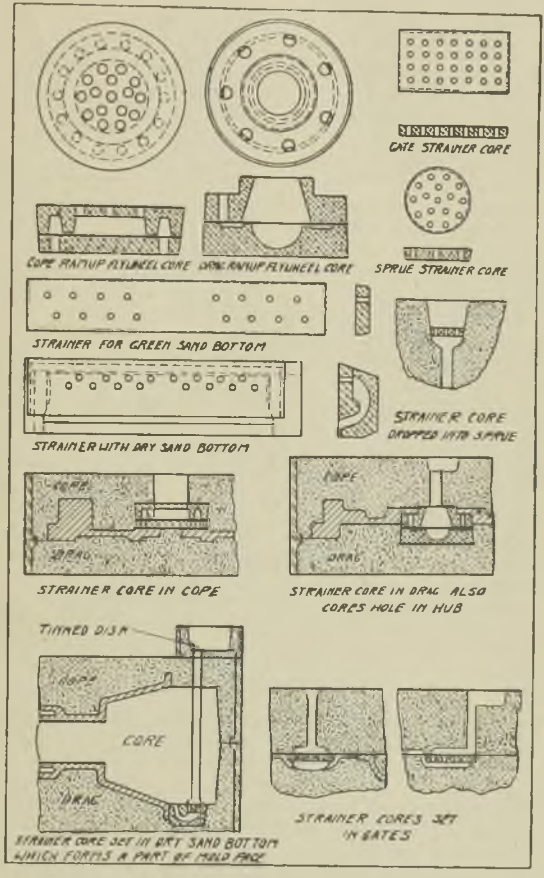

FIG. 2.—SHOWING THE APPLICATION OF STRAINER CORES.

design are only influencing factors as far as the selection of the equipment and method of manufacturing is concerned.

Judged from a standpoint of quality and intricacy of design, the automobile industry requires perhaps the highest grade of castings. That these castings cannot only be successfully produced, but that also a higher grade of quality is possible under quantity production methods, is a well-established fact.

Since, in addition to its own peculiarities, the automobile-casting foundry has also many of the problems and conforms in a general way to the production of other castings on a quantity basis, some of its main features will be set forth in the ensuing paragraphs.

A foundry producing automobile castings as a specialty differs from the specialty foundry producing radiators, car-wheels, pipes, etc., in that its general layout and equipment must have greater flexibility. With the exception of one or two well-known makes, there has been a constant changing in designs of motor-cars which, while perhaps not so apparent to the public, causes a seasonal readjusting and reorganising of the methods employed in the production of the necessary castings. In selecting core machines, moulding machines, conveyors or cleaning room equipment, this factor must be taken into consideration and a reasonable allowance must be made to take care of the changes of size, shape and weight of the various castings.

Labour and Management.

One of the outstanding features of a quantity production foundry as compared with the regular type of foundries lies in its working force. Instead of the trained and seasoned artisans which one would associate with the production of intricate castings of high quality, the staff is composed entirely of specialists, trained only in their respective operations which are reduced to the smallest unit and the simplest form possible. This, however, does not mean that such a force is a conglomeration of nondescript labour; on the contrary, some of these people become highly skilled and are able to perform their operation very accurately and with what is to the

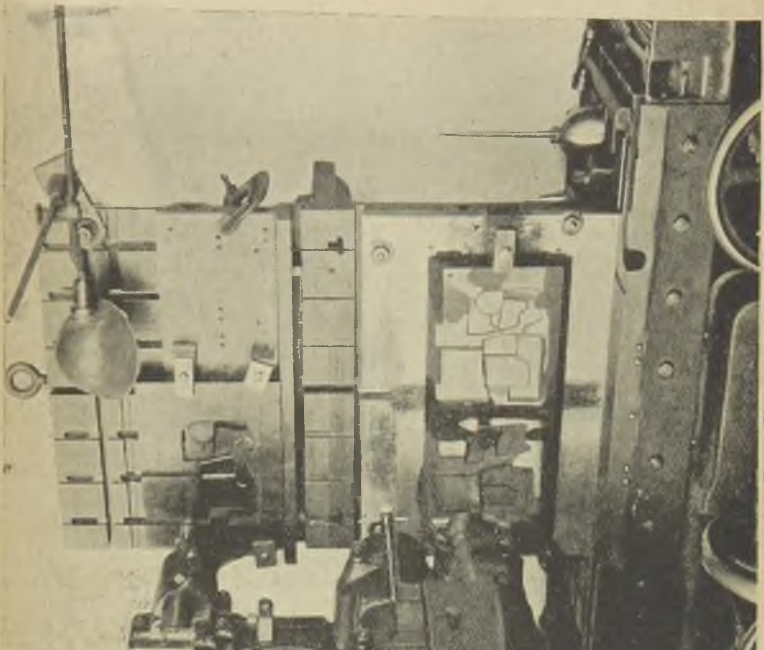

FIG. 3.—A PROFILING MACHINE PRODUCING CORE BOXES FROM A MASTER PATTERN.

uninitiated, incredible speed. Their performance compares well with the speed of a trained runner as against the speed of an all-round athlete.

A production foundry, employing about 2,500 men, may not employ over 10 full-fledged moulders and coremakers. The burden of supplying the necessary knowledge of the details involved in the manufacturing of a great tonnage of intricate castings falls, therefore, entirely on the management. For this reason, the successful operation of a production foundry, of this nature, depends largely on the ability of the management to choose the most effective methods, to standardise the various operations, to select the most efficient equipment and to maintain it, to design the necessary special appliances and to organise its force in such a way that the product will flow through the plant in a continuous uninterrupted manner. This is best accomplished if the executives are advanced from the ranks by merited promotion.

Although the chief aim of quantity production is toward lower costs, its introduction has, in some instances, been actuated by a shortage of all-round mechanics. Contrary to what certain short-sighted labour leaders would have one to believe, quantity production was never designed to lower the wages of the working man, nor was it designed to exclude trained artisans from these plants. The absence of union moulders and core makers is entirely voluntary on their part and must be charged to their reluctance to do repetition work and the restrictions of the unions as applied to production.

Piece Work as Wage Incentive.

A prevailing mode of wage payment is piecework based on time studies. A day's work constitutes what a man can do without injury to himself over a long period of time. It is based on an average man and does not represent the maximum of the exceptional worker. The time required by a new man to reach the specified rate of production may vary from one to two days on some minor operations, to one to three weeks on the more skilled. In the foundry, the rammers are usually recruited from the labourers and the finishers and core-setters from the rammers.

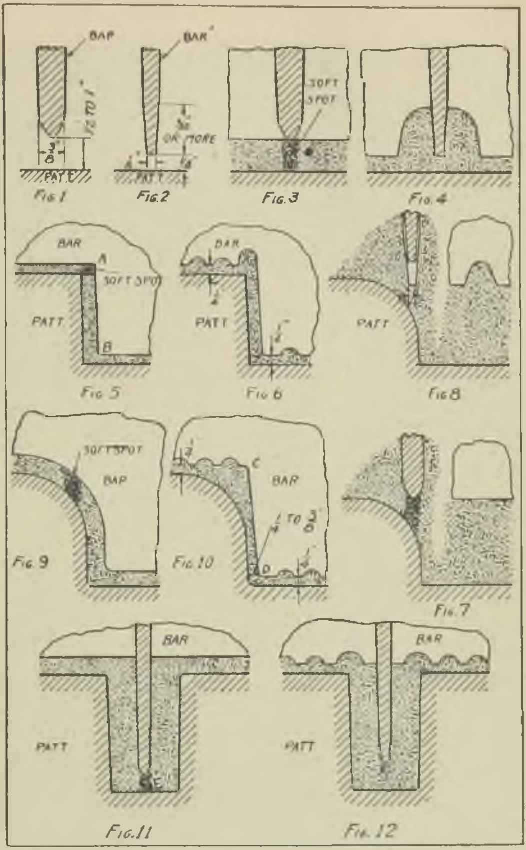

FIG. 4.—PROPER AND IMPROPER DESIGN OF FLASK BAR FOR JOLT MACHINE RAMMING.

Sketch 1 and 2.—Contrast of properly designed bar of Fig. 2 for machine ramming with common type of design, which does not give good results, as soft spot is usually left under bar, as shown in Sketch 3.

Sketch 4 shows proper design of bars at joining of two cross bars.

Sketch 5 and 6.—Sketch 6 proper design of bar in contrast with improper design of 5.

Sketch 7 and 8.—Sketch 8 shows proper design and spacing of bar contrasted with improper design of Sketch 7.

Sketch 9 and 10.—Sketch 10 shows proper design of bar contrasted with improper design of Sketch 9.

Sketch 11 and 12.—Sketch 12 shows proper design of bar for lifting sand from groove pocket contrasted with improper design shown in Sketch 11.

Fig. 5.—Gravity Conveyors for Continuous Pouring for the Reduction in Quantity of Box Equipment

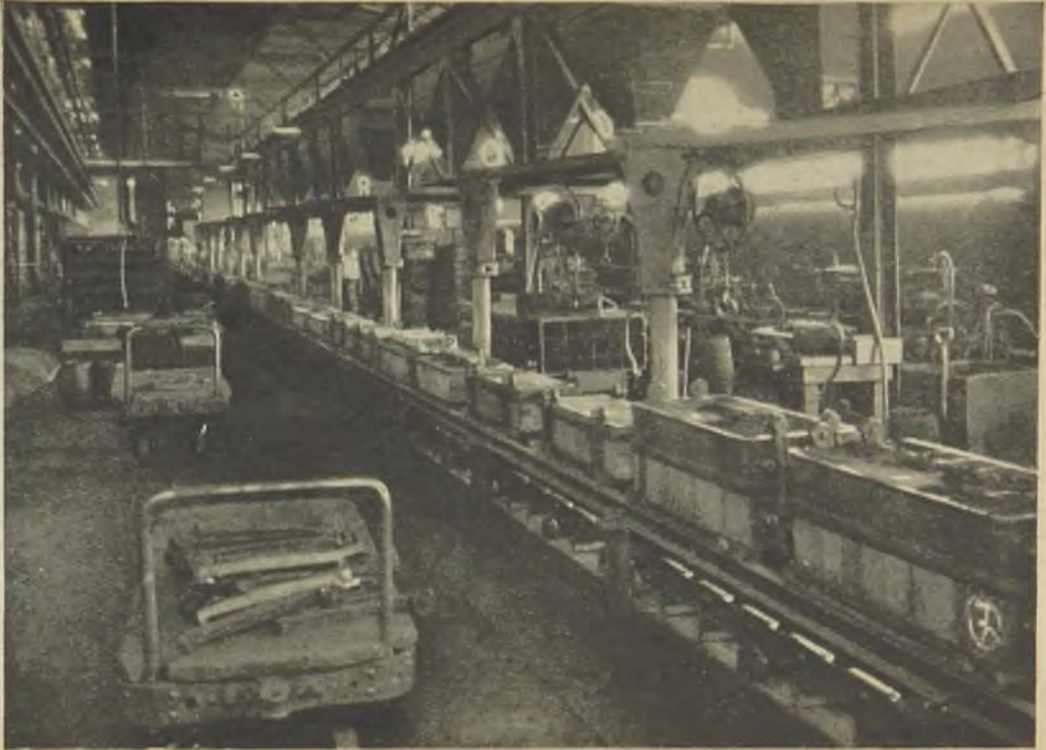

FIG. 6.—A POWER CONVEYOR UNIT FOR PRODUCING 2,100 CYLINDER CASTINGS IN NINE HOURS.

The beginner is usually guaranteed a certain day's wage which varies somewhat with the operation, but does in no case fall below the prevailing labour rate. The base rates, which are the amounts the men are to receive for 100 per cent. production, compare with the prevailing common labour rate approximately as follows:—

	Per Cent.
Moulders	180 to 200
Core makers and core assemblers (male)	150 to 175
Core makers (female)	150 to 200
Iron pourers	150 to 160
Shaking out of moulds (hot) ...	150 to 160
Melting	150 to 160
Cleaning department	125 to 150
Sand blasting	200 to 210

To what extent the workers prosper under this system can be judged, in a measure, from the photograph of the front yard (Fig. 1) of one of the production foundries with which the author is identified, which shows about 50 per cent. of the automobiles belonging to the workmen.

Materials.

The proper selection and control of raw materials are important factors in the production of quality castings, and the repetition of standardised operations presents an opportunity for checking and noting the effect of the various materials on the quality of the product, far beyond that possible by ordinary foundry methods. Therefore, a fully-equipped laboratory, in which the various materials and products are tested and analysed, forms an indispensable part of the production foundry.

While materials such as coke, iron, sand, limestone, corebinder, etc., are all closely checked in the laboratory, the effect of the physical structure and source are recognised as important factors. This is especially true with coke and iron as applied to castings calling for a high Brinell number, density, and high-speed machining qualities. Two brands of coke of practically the same analysis but differing in structure may produce iron with a difference in Brinell hardness of 25 to 30 points. The same is true of the combination of different brands of iron.

Special attention must be given to the variation between pigs in one truckload. Apart from an average analysis, the specifications should also call for a limit in variation. These specifications can usually be met at the blast-furnace by confining the iron loaded into any one truck to one tap, which is facilitated by the steady flow of deliveries required in a large foundry.

While a limit in variation is important in cupola practice, it is not so necessary where iron is melted and held in large quantities, as in an open hearth or in an air furnace, because it is much easier to maintain an average.

The large consumption and the adherence to a standard practice, not only in methods, but in materials also, enables the producers of pig-iron, coke, sand, corebinder, etc., to furnish these materials to very close specifications and the desirability of this business usually brings forth the fullest co-operation in scheduling and guaranteeing deliveries. This is especially true where the producers have the assurance of continued business relations which, however, does not necessarily mean long-time contracts.

Core sands are usually used in the natural state, but there is a growing tendency to have all moulding sands milled and blended to a specified bond at the pits, which eliminates the uneven and lumpy condition usually found in highly-bonded sands.

Among the corebinders, the greatest variation is found in core oils, which still constitute the chief binding material for intricate cores. While linseed oil is still considered the standard, some of the prepared oils are more economical, and because the tendency to gum-up the coreboxes is greatly reduced they lend themselves better to high-speed production. Core oil should only be bought from the most reliable sources, and great stress should be laid on uniformity, which is much easier obtained by buying in tank-car lots than in barrels. A quick and quite satisfactory way of testing incoming oil before unloading is to mix two small batches of silica sand, one with the new oil and one with a standard oil, such as pure linseed (kept in the laboratory for this purpose). A definite quantity of each is rammed into briquettes, placed on the same plate, dried at the

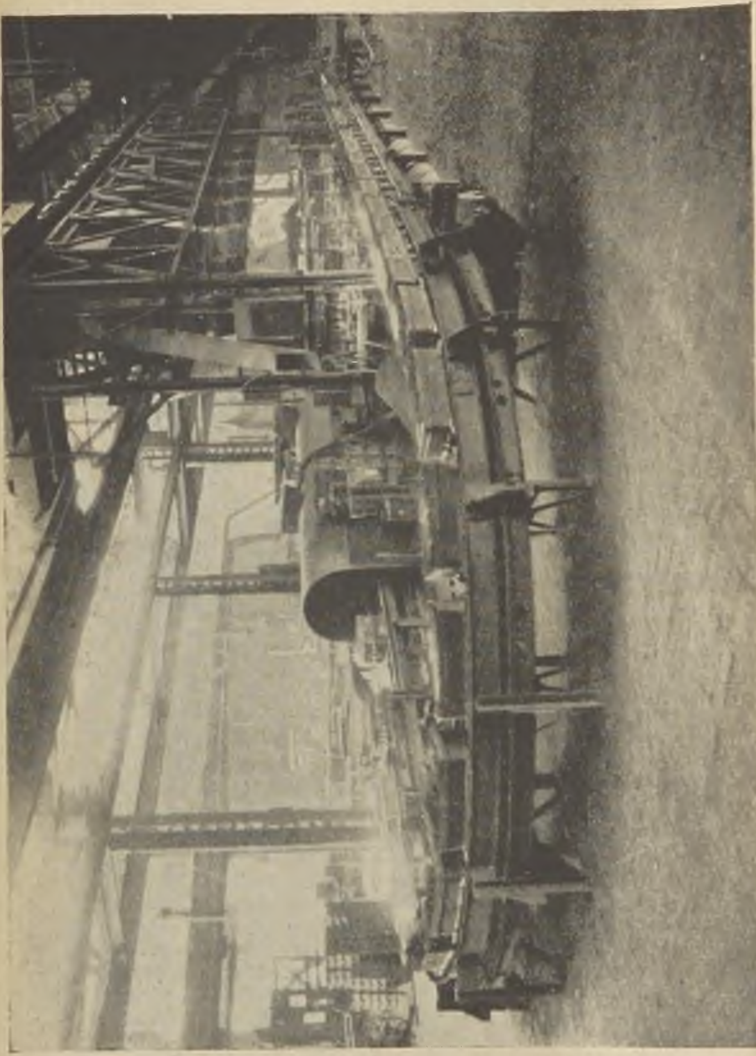

Fig. 7.—A Power Conveyor Unit for Producing 2,300 Cylinder Heads in Nine Hours.

customary temperature and tested for relative, rather than a given, strength. If, in addition to this, the colour of the oil matches a predetermined sample, it is quite safe to put into production. The iodine value, etc., can be checked later.

For best results, an oil that will withstand a fairly-high baking-temperature should be selected, and if the cores are inspected for defects before going into the ovens, even intricate cores requiring much handling in cleaning, grinding and assembling can be produced with a 3 to 4 per cent. loss.

Meeting New Demands.

The demand of the consumers for better quality, greater uniformity and closer dimensions is increasing with every year. The amount of metal to be taken off on finished surfaces by the machine shop is being constantly reduced until it is not uncommon to have an allowance of only 1/32 in. on even a good-sized casting.

Only a few years ago it was thought impossible to shake out thin-walled castings, such as cylinder blocks, before they had almost completely cooled. Any castings that were taken out of the sand whilst red hot were sure to develop a heat crack or a warp, and special precautions were always taken to avoid any premature shaking out. With continuous pouring and the necessity of conserving floor space came also the development of iron that will withstand sudden changes in temperature without ill-effects, and the shaking out of castings while red hot is becoming the rule rather than the exception. Incidentally, this solution has also produced a superior product by greatly reducing the danger of cracking in service.

Various expedients, such as hollow cores, etc., have been resorted to in the past to produce a uniform hardness throughout the full length of the bore, because the slow cooling condition in the region of the water jacket and the valve seats produced a softer iron. This soft section was usually located where the piston rings caused the most wear, and if the iron was made hard enough to counteract this condition, the flanges and thin sections were usually so hard that they could not be machined, even at ordinary speed. To-day, with only slight changes in the analysis, cylinder blocks can be produced with a uniform hardness in the bore, in which the thin sections can be machined at high speed.

Another vexing problem that confronted the foundryman in the development of quantity production was the placing of risers on castings for the purpose of feeding, either by gravity or churning, and this problem has been solved to a point where risers for any purpose can be eliminated on automobile castings. The greatest difficulties in this direction were presented by flywheels, which usually have a thin web and a heavy rim. Some foundrymen have met this situation by arranging the pouring basin so that it will also act as a feeder, but even this is not necessary if a properly designed strainer gate is used.

At one time it was thought impractical to let anyone but experienced moulders pour the iron, but with the advent of continuous pouring it was soon apparent that the efficiency of the moulders could be greatly increased by relieving them of this arduous task. Pouring crews which did nothing but pour iron were therefore formed. At first it was attempted to teach them to judge the proper pouring temperatures of the various castings and impress upon them the importance of skimming the iron; but during the hot summer months, when the labour turnover necessitates the constant use of new men, it was soon found that their knowledge had to be reduced to the simple operation of keeping the pouring basin, or sprue, filled to the top. This situation was met by placing tin discs over the sprue, and the application of strainer gates which skim the iron and regulate the pouring temperature. While they have not been generally adopted, they have definitely proved their value and usefulness in the making of automobile castings, because iron will more readily rid itself of slag and produce a more uniform quality if it is melted and poured at a high temperature. If convenient, the iron may be strained through openings placed in the regular cores, but ordinarily it is easier to make separate strainers for this purpose, and Fig. 2 shows a number of such cores and their application.

Pattern Equipment.

Since the machine shop does not check for dimensions before setting the casting for the first operation, there is need of very close checking at the foundry. The most satisfactory way to meet this condition is to guarantee certain locating points by which the castings are set into the machine. This gives the foundry a chance to build a similar fixture in which, by means of templates, slight variations can be adjusted at the locating points and greater variations can be rejected before the castings leave the foundry. In malleable iron, where the annealing may cause some warping, the castings can be run through heavy power presses which make them practically perfect as far as dimensions are concerned, but in grey iron these specifications have to be met without such recourse.

The first requisite in meeting these specifications is good pattern equipment, and a great amount of study and attention to details is required to build successfully a pattern and corebox equipment for complicated automobile castings.

In order to avoid delays and losses, not only in the foundry but in the machine shop as well, every item related to the production of a particular casting should be carefully planned and fully considered beforehand. In a production foundry this reaches far beyond the immediate pattern and corebox equipment, because it is necessary that machines and handling equipment be definitely located and the flow of the material through the plant be routed in advance.

A well-equipped pattern shop is a definite necessity, especially where intricate castings are made, and tool equipment for both wood and metal should include the latest machines developed for this purpose.

Some of the latest additions in labour-saving machines for pattern shops are the high-speed punches for making templates, filing machines, horizontal grinders with magnetic tables for grinding driers, and the automatic profiling machine. The profiling machine is proving especially valuable in the production of duplicate patterns and core boxes, because any number of patterns or core boxes can be accurately reproduced from either wood or metal models. Stripping plates and similar pieces can be produced from sheet metal templates at a great saving of labour. Fig. 3 shows a profiling machine producing a gang core-box from a single model.

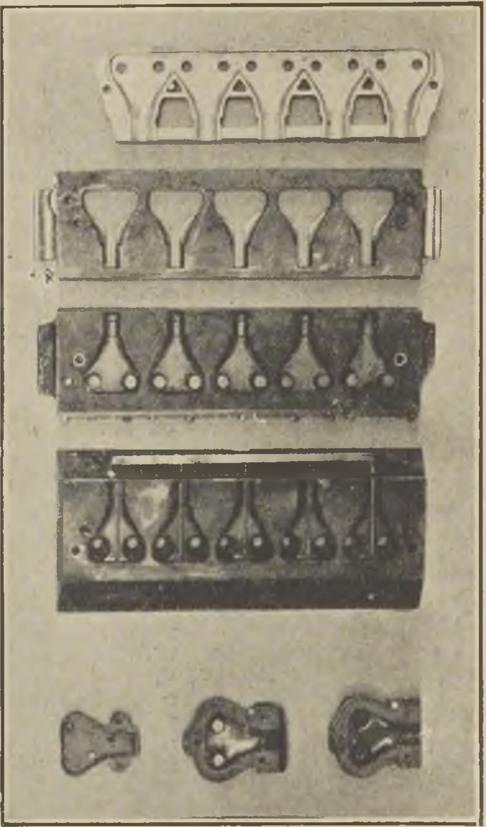

Fig. 8.—A Single Core Box for Bench Work (Lower), and a Multiple Box for a Roll-over Machine for the Production of the same Core.

Due to the excessive wear, metal is the only practical material for production patterns and core boxes. Double-face match-plates, and also some of the larger patterns and coreboxes, are made of aluminium. For small-gated patterns brass is the standard material, on account of the ease with which it can be soldered. For large patterns, and where great accuracy has to be maintained over a long period, cast iron is the most satisfactory material, and is therefore used whenever possible.

The double-face aluminium match-plate with vibrators is extensively used for small castings that have to be run intermittently, because the changing from one plate to the other is very easily accomplished, and it can be used on either a bench or a machine. They are usually used in connection with snap flasks and steel bands, or slip boxes. Very true castings can be produced by this method, because the plates are centred by the flask pins, and can therefore be rapped only by means of a vibrator, which affects the dimensions of the castings very little. The match-plate adapts itself to either ramming on a bench or a hand or power squeezer.

For greater quantities the so-called split pattern-plate is to be preferred. By this method the cope and drag are mounted on separate machines, and the combination jolt-squeeze stripping type of machine is the fastest for this purpose. The first, or match-plate method, requires a moulder of considerable training, while the second method can be successfully performed by labourers of average intelligence who are willing to exert themselves beyond the requirements of ordinary labour.

The cope and drag moulds of larger castings are always made from two separate plates, which are mounted on either a jolt roll-over or a jolt squeeze stripping machine. This practice has become standard, although quite a number of sand-slingers are being successfully used.

For accurate results, production patterns should be machined all over. Where stripping plates are used, they should be carefully fitted, and to assure a minimum of wear on the pattern and stripping plate, also to guard against inaccuracy through worn machines, the stripping plate should be provided with heavy guide pins which move in hardened bushings in the pattern plate.

Flask Equipment.

The flask equipment plays an important rôle in quantity production, and has a great influence on the quality of the castings. The flasks should be made of metal, have machined joints and accurately fitted closing pins. Flask bars should be designed so as to eliminate tucking of sand under the bars and setting of gaggers and nails.

There are definite rules which can be followed in designing a flask for production work, and there are few jobs in which gaggers and nails cannot be eliminated if these rules are followed. For instance, the moulding of a certain cylinder block required 78 gaggers and 42 nails, but by redesigning the flask, all of these were eliminated with the exception of eight nails. Since it also eliminated the tucking of sand under the bars, it can easily be seen that the ramming of the mould was reduced to a very simple operation, which could be done by any intelligent labourer. Special attention is necessary where hot flasks are rammed on jolt machines, and thoroughly tried rules for barring were described in a Paper * prepared by the author for the 1923 Convention of the American Foundrymen's Association. Fig. 4 illustrates some of the rules mentioned in that Paper.

Floor and Conveyor Moulding.

Aside from the machine, flask and pattern equipment, there are several methods of producing castings in the foundry. The moulds may be made and set on the floor during the morning and early part of the afternoon and shaken out by a night gang, who also prepare the sand for the next day.

If continuous pouring is practised, the moulds are usually poured by a pouring gang as fast as they are produced and shaken out as soon as they have sufficiently cooled. This method requires only from twenty-five to fifty per cent. of the flask equipment of the first method and reduces the required floor space by about fifty per cent. This reduced floor space can again be

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* Lenz, A. "Flask Equipment for Moulding Machines," Transactions. A.F.A., vol. 30, pp. 726-740, 1923.

FIG. 9.—AN EXTRUDING MACHINE FOR THE PRODUCTION OF TWO SIZES OF CYLINDRICAL CORES.

cut in two by the use of gravity conveyors, as arranged in Fig. 5. This has also the advantage over the second method in that it removes the pouring and shaking out from the immediate vicinity of the moulders, giving them better working conditions and the foundry a more orderly appearance.

The latest development in green sand moulding equipment is the power conveyor, which conveys the moulds through the various operations, starting at the drag machines and ending at the shake out. This same system also delivers the sand to a central tempering unit, from where it is returned to bins over the moulding machines. One such unit produces 2,100 cylinder castings weighing 126 lbs. each in nine hours, with a crew of eighty men, or 26 cylinder blocks per man, on a floor space of 260 ft. by 40 ft., including the necessary gangway and sufficient space for the storing of cores; while a smaller size produces 2,300 cylinder heads on a floor space of 120 ft. by 40 ft. Figs. 6 and 7 show two such units.

In the production of medium-sized castings the new sand and coal dust are added into the system so that no special facing sand is needed over the pattern. The same may be done on larger castings, but due to the cutting action of the metal or the burning in at some small projections a small amount of special facing may be used at certain points.

In moulding a casting of the nature of a cylinder block on a conveyor, the operations are very closely divided. Each moulding machine is usually manned by a rammer, labourer and a finisher. The first two produce the mould and the finisher patches or corrects any imperfections, wetting the core prints, dusting and brushing the graphite, and setting the mould on the conveyor. There may be a number of core setters, each one setting one or more cores, while the gauging of the cores may be done by a man stationed at the end of the core setting line. After the copes are set on, the operations are further divided into clamping, moulding of a pouring basin, setting of the pouring basin, pouring, taking off of the clamps and removing the pouring basins. On the shake out end the operations call for

Fig. 10.—A View of a Production Core Room in which all Cores are Machine Moulded.

removing and shaking the cope, taking out the casting and loading it, shaking out the drag, removing the bottom board and placing bottom board, drag and cope flask on the conveyor to be returned to the moulders. All these operations must be well timed, because congestion at any one point would hold up the whole line.

Core Department.

In some of the production foundries, especially in those producing automobile castings, the core department occupies an important place, and its force may exceed that of the foundry. A cylinder block, for example, may require as many as fifty or more separate cores, which, if stored in large quantities, would take up a prohibitive amount of floor space. To avoid this the cores are produced only far enough in advance to get them to the foundry in time to set into the moulds. Since at the end of the day there may not be one hour's supply in the core-room, expert routing through the various operations is required. To insure accurate records and balanced stock, all defective cores, found either in the core-room or foundry, must be turned over to a department created for the purpose.

Due to the intricate nature of the cores and the necessity of holding them to close dimensions, a core department of this nature requires the best of core box and machine equipment, besides a great number of gauges and fixtures. For best results, all cores should be made on machines whenever possible, and many ingenious core boxes and devices have been developed to make this possible. If small cores are arranged in gangs and mounted on machines, not only greater accuracy is possible, but production can be materially increased.

Fig. 8 shows a single box for bench work and a multiple box for a roll-over machine of one of the more difficult cores. The production in this instance compares with 500 to 600 cores on a bench, against 1,000 to 1,200 on a machine, both made by a girl in a nine-hour day.

Fig. 9 shows an extruding machine producing two sizes of plain cylinder cores. These cores can be made on a bench from a split box, rammed with a stick and rolled on a plate at a daily production of 400 cores, or the cores may be rammed in a split box on a small jolt machine and placed on driers, at a production of 580 per day per

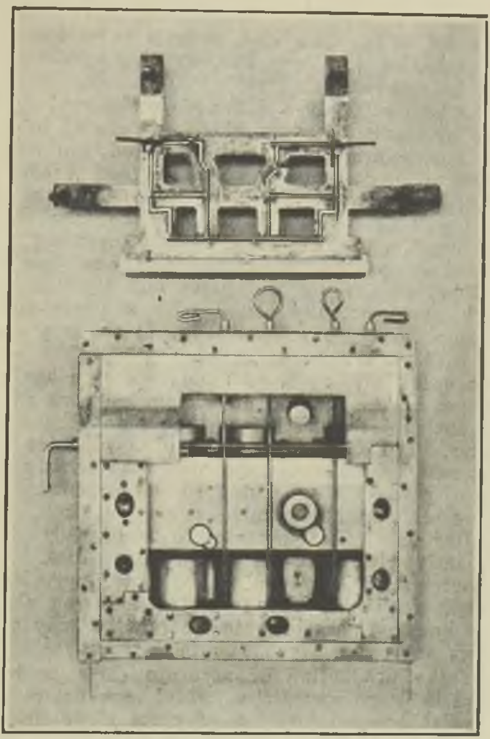

FIG. 11.—A CORE BOX WITH VENT WIRES IN POSITION.

man. If extruded on a machine, cut to the proper length by means of a wire-cutting attachment and removed on driers, the production will increase to 2,700 cores of each size per day for six men. In each instance the quality of the cores improves with the increase in production.

Fig. 10 is a view of a section of a production core-room, in which all cores are made on machines, either in single or multiple core boxes.

The operations involved in making a core should be reduced to the simplest form and follow a standard practice. The wiring and venting must be determined and definitely located, or indicated, in the core box, so that uniformity may be assured.

The best results are obtained if the venting is done by means of wires which are placed in the core box before it is filled with sand, and withdrawn after ramming. This method produces clean, positive vents, which can be checked by probing with wires. To prevent the iron from entering the vent system all outside openings not needed in passing the vent from one core to another, or leading the gases out through the mould, are carefully closed with a paste made of graphite or soapstone. Fig. 11 shows a core box with vent wires in position.

To speed up production and to insure against changes in the method of wiring, all core wires are cut and formed before they reach the coremaker. The forming is done in a separate department, which is usually equipped with automatic wire cutting and forming machines, or where only small quantities are required, the bending may be done quite accurately and efficiently with hand-operated forming dies. The importance of the above can be more appreciated if it is realised that a foundry producing about four hundred tons of auto castings per day consumes approximately 500,000 core wires.

In the production of accurate cores at high speed in large quantities, metal core driers are essential because bedding of cores slows up the operation, produces a rough surface, and unless done by an expert, destroys the necessary accuracy required in quality work. With the employment of modern machines, experience, and a thorough knowledge of the shrinkage or contraction of the metals to be employed, also the necessary clearances, these driers can be built very cheaply.

The assembling of cores, before they are delivered to the foundry, commands a great deal

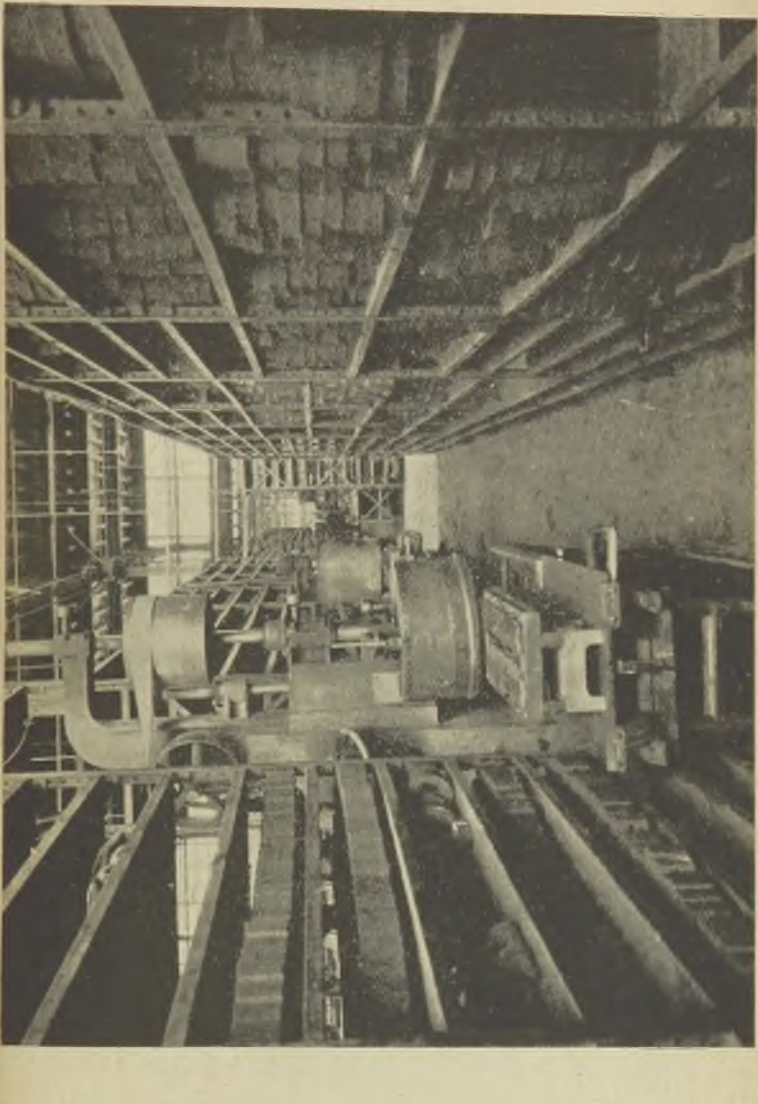

FIG. 12.—SURFACE GRINDING AND BORING MACHINE FOR CYLINDER WATER JACKET CORES.

of attention, especially if they are to be used on conveyors where each core must be a perfect fit. The old method, fitting by rubbing two cores together, is a thing of the past. To ensure accuracy, all joints are ground on surface grinders before pasting, and if the bores of cylinder water jackets are split on the centre line of the cylinder they are bored out on special grinding machines, which will remove all irregularities. This also establishes a definite centre line and removes all possibilities of an uneven wall thickness. Fig. 12 shows some of these grinders. Whenever possible, large core assemblies are put together on progressive lines, and Fig. 13 illustrates such an arrangement, in which the cores are moved along the line by means of gravity conveyors.

In any automobile foundry, practically all of this work can be done by girls, because the pieces that are beyond their weight limit are moved along on gravity conveyors. All assembly jigs into which the cores are assembled are accurate duplicates of the mould, and every bearing surface is lined with hardened steel, which can be easily replaced. Since the locating points correspond to the core prints and chaplets in the mould, there is very little trouble in the foundry from crushes or bad fits, and the moulders are therefore not permitted to file or otherwise fit a core.

Cleaning Quality Castings.

Along with closer dimensions and better metal has also come the demand for better appearances and absolute freedom from sand and scale. The tumbling mill, which has served so well in producing the much-desired burnished appearance, is no longer adequate, because it is not always possible nor practical to remove fused sand and scale from small depressions and corners. High-grade castings coming into contact with the oil of the lubricating system must therefore be sand blasted, or sand blasted and tumbled. Such castings must also be delivered free from rust, which is quite contrary to the theory of seasoning in the weather of a few years ago. Since the cost of sand blasting, like that of many other operations, was just another item that had to be absorbed by the foundrymen, they were forced to find more economical methods. The continuous sand blast room, through which the larger castings are carried on chain conveyors, and the continuous sand blast mill, which receives and ejects smaller castings in a continuous stream, are now performing this operation at a fraction of the former cost.

A few years ago practically all cylinders and similar castings were chipped with air hammers. With the increasing demand for this type of castings came also a shortage of high-grade chippers, which even high wages could not overcome. Electric swing grinders and small air grinders, which are easy to operate, were finally pressed into service, with the result that they have practically replaced the air chippers and improved the quality of work at a considerable reduction in cost.

Inspection and Control.

To control the losses incident to high-quality intricate castings requires constant checking, and a well-organised and well-equipped inspection department is a definite necessity. Unless defects are located, and promptly and accurately reported, the losses can assume disastrous proportions. This is especially true when castings are stored in large quantities by the consumer, in which case the foundry should insist that a certain number be machined on the arrival of each shipment. This will protect both producer and consumer.

On many castings it is necessary to build elaborate checking fixtures into which the castings can be set and the finishes inscribed with hardened steel points moving in hardened and ground bushings. On others, where visual inspection is inadequate, the checking can be done by means of gauges and templates.

A definite understanding should be had with the machine shop as to the extent of the foundry's responsibility, especially as applied to cracked castings. Harmonious relations can easily be maintained if, in addition to this, a capable representative of the foundry receives and inspects all rejected material at the machine shops and means are provided definitely to check disputes over lack of stock or errors in machining.

There is a growing tendency in progressive manufacturing institutions to operate with a

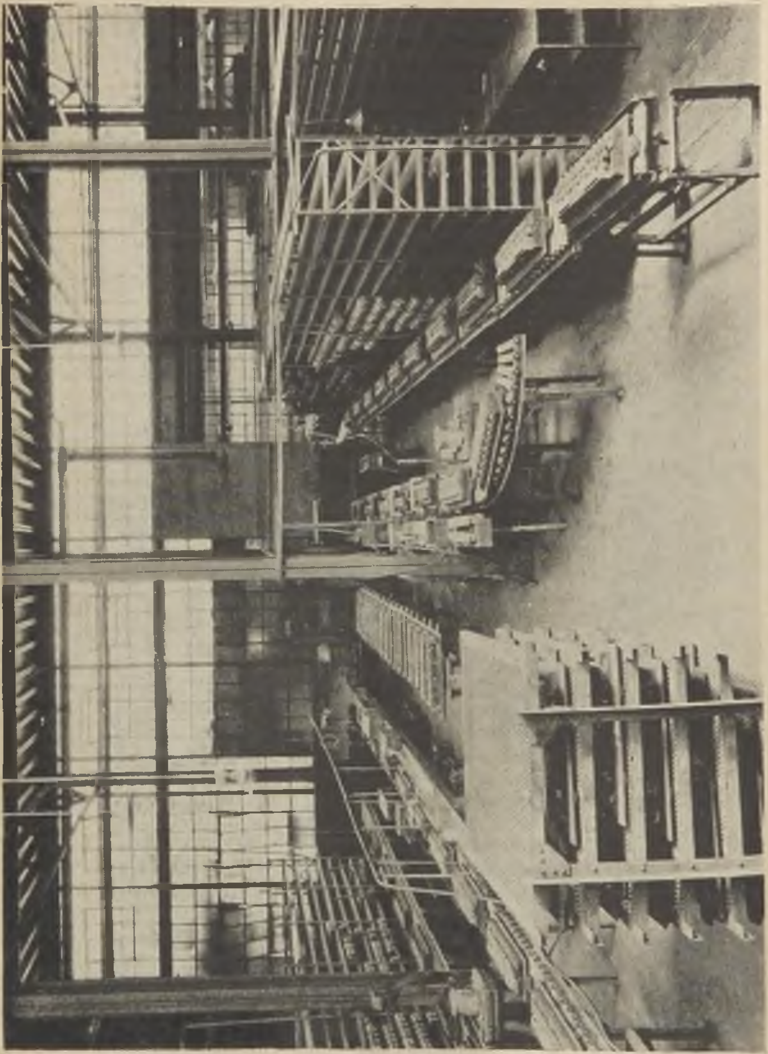

FIG. 13.—GRAVITY CONVEYOR INSTALLED IN CORE SHOP.

minimum stock of raw materials, and plants which a few years ago carried a sixty and ninety day surplus, and in some cases contracted for six months in advance, now operate successfully on a two to three weeks' basis, which at times may be reduced to an even shorter period. In a foundry producing castings under this condition, the work in process and the finished castings on hand may not exceed one day's production in the foundry. If, in addition, the shipments must synchronise with the daily production of the consumer, the scheduling of output and shipments must receive special attention.

Removal of Refuse.

The disposition of refuse in a large foundry is a considerable item and various means have been devised, such as belt and pan conveyors which take the refuse from hoppers placed beneath the floor line, from which the sand is raised to storage bins by means of bucket elevators. If the bins are placed across the railroad tracks, or arranged so that trucks, tramrails, monorails, cableways, or other means of conveyance can be placed directly under the hoppers, the sand can be removed very cheaply.

Perhaps the most economical and novel installation for removal of refuse is in operation in one of the foundries under the management of the author. In this case the sand is removed from the castings in a room situated between the foundry and the cleaning department, passed through floor hoppers on to a belt, one end of which is equipped with a magnetic pulley which removes the iron from the sand. The belt feeds the sand into a crusher, which pulverises all included cores and discharges into a tank of water from where a centrifugal pump removes the mixture of sand and water and conveys it, by means of a pipe line, to a swamp located back of the foundry. Since the water used for plant purposes is taken from a river bordering on this swampy area, the cost of transportation reduces itself to the power of running the pumps and the investment in the pumps and pipe line.

Since this refuse consists almost entirely of burned core and moulding sand, and is deposited clean and well pulverised, there is a possibility of reclaiming it, because, from all appearances, the oil in the core sand is weathering out very rapidly.

Application of Handling Equipment.

According to an analysis* of Mr. Sklovsky, of Messrs. Deere & Company, the handling of 168 tons of material is required to produce one ton of good castings in the ordinary foundry. Since, in most foundries, handling of material is still done by laborious hand methods, it is safe to predict that the greatest development in the foundry industry in the next decade will be in reducing the handling of materials to a more mechanical basis. A great deal has already been accomplished in this direction, but as in other labour-saving devices, the adoption of existing and the development of new means for this purpose has been largely confined to the production foundry.

How one development may lead to another is well illustrated by an instance that happened in a malleable foundry with which the author is identified. Practically all the high-grade malleable iron produced in America is melted in the air furnace, which does not adapt itself to continuous pouring unless a number of furnaces are arranged so that one of them is always ready for pouring. This has prevented the malleable-iron industry from taking advantage of the benefits derived from putting the foundries on a continuous production basis. Knowing definitely the savings that could be affected by more modern methods, thoughts were turned toward the development of some melting process that would make this saving possible. This has now resulted in a new cupola-electric furnace process which not only meets, but exceeds the specifications for high-grade malleable iron. It has made possible the building of a series of mould, sand-handling, and casting conveyors, and, together with continuous mills and continuous annealing ovens, marks a definite step forward in the production of malleable-iron castings.

It might be of interest to point out a few of the performances achieved by the application of labour-saving devices. By means of a crane and

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* "The Foundry" April 15, 1921.

magnet it is possible to move all incoming pig-iron and steel scrap from cars to stock piles, and at the same time supply the charging deck with all the iron, including foundry returns and limestone required for a 600-ton melt, with four men. By the use of mechanical sand-conditioning and distributing equipment, two men are conditioning and distributing approximately 400 tons of moulding sand every nine hours. In addition to the large output per man-hour, the sand is cleaned of all iron and has a texture and uniformity of bond and moisture that cannot be consistently reproduced on the floor even by the best moulders. On a conveyor, one man sets 4,200 cores weighing 45 lbs., and six men pour 160 tons of iron into 2,100 castings.

Great savings are possible by the use of electric lift trucks for moving platforms on which material is loaded, and electric and gasoline trucks and tractors. The most efficient means of transportation, however, is found in the application of conveyors, and the tendency in the production foundry to adjust its principles to this type of transportation is growing with every year. The specialty foundry producing such castings as pipe, carwheels, radiators, fittings, etc., has the advantage in this respect, and it will only be a matter of a short time until the more progressive of them will have a continuous flow from raw material to the finished product. The foundry producing a greater variety and more intricate castings will find a combination of the continuous and intermittent type of equipment the most economical, especially in the application of continuous core ovens, core delivery, and cleaning-room equipment.

In concluding, the author wishes to state that his convictions in regard to the production of quality castings in quantities is based on a varied experience in both jobbing and production foundries, as practical moulder, core maker, melter, foreman, superintendent and manager. He recalls not a single instance where the application of quantity-production has not improved the quality of the product, improved the status of the workmen and resulted in great benefits to the producer as well as to the consumer. He is a great believer in the exchange of ideas among manufacturers and competition by individual efficiency. His belief is perhaps strengthened through his close contact with the automobile industry, which has immensely benefited by practising this policy in the most liberal manner. He realises that the great consumption and distributing facility of the United States, within its own borders, presents a condition especially favourable to the application of these manufacturing methods, but having spent his early life and received his early training on the Continent of Europe, he knows that there is a great deal of room, if not an actual need, for more specialisation and the economical benefits derived from the application of the principles of quantity production.

DISCUSSION.

Mr. E. Longden, discussing the application of handling equipment, pointed to the statement that four men could handle a 600-ton melt, and said that it was very ambiguous. On the face of it, that would be a wonderful performance, and there must be a great deal more behind it. He asked how many men were employed in the handling of the material on the charging platform other than those on the electro magnetic, because it appeared to him that there were a great many more men required for handling and putting into position for the electro-magnets, so that what was gained on the swings might be lost on the roundabouts.

Mr. A. Harley (Coventry) agreed cordially with the thesis put forward in the Paper, that quantity production did mean quality, and said it was obvious that where every operation was separated in the manner indicated in the Paper, the results must be better than those obtained in the ordinary jobbing foundry. Commenting on the warning given by Mr. Arthur Henderson in welcoming the members and delegates that morning, as to the danger of men becoming merely routine workers, he said the problem was a difficult one. Under modern conditions we could not very well get away from that. At the same time, it must not be ignored by the workmen to-day that there were still fields for the exercise of their intelligence in the design of equipment and in the metallurgical problems associated with foundry work; that while the skill required in moulding and core making was being reduced to a negligible point, there were other problems in the solution of which the brains of the workers could be well exercised. One of the chief problems to-day in large foundries was the handling of material, and he prophesied that in the near future many of the large foundries here would have to adopt mechanical means of conveying material, such as were dealt with in the Paper. The difficulty about adopting quantity production methods in this country was that of disposing of the products made. Recently he had laid out plans for a foundry for a very large output, and with every mechanical convenience that could be employed, but was up against market conditions. Such a foundry was definitely dependent upon a selling organisation that would clear the production quickly, but the conditions in this country gave us pause, because it would be disastrous if any hitch occurred either in production or in disposing of the castings produced due to spasmodic demand. There was another side to the picture, however, namely, that such methods certainly reduced costs, and that in itself would probably create the necessary market.

Mr. Horace J. Young, F.I.C. (London), in a denunciation of intensive price cutting, referred to a foundry which was turning out 100 to 120 tons of castings weekly without making a profit. The question would arise in the minds of his hearers whether that foundry made castings at a competitive price, and he could state that the castings in question were manufactured at a cost of 8s. to 10s. per cwt. Something more than economical mass production was involved. In his opinion our foundry troubles in this country were due partly and mainly to the cut-throat trade that existed. There were a number of founders in this country willing to make castings at a loss, thus deliberately ruining the industry. He knew of foundries which could not get work save at a loss, and when a foundry produced castings at less than 10s. per cwt. and yet could not make a profit it proved there was something radically wrong at the core of the foundry trade.

THE PRACTICAL UTILISATION OF APPARATUS FOR MEASURING THE PERMEABILITY AND COHESION OF MOULDING SANDS.

By R. Lemoine, Paris.

[French Exchange Paper.]

INTRODUCTION.

Although no precise information is available as to the intimate constitution of moulding sands and their behaviour in service, the experiments made in recent years have resulted in the design of apparatus for measuring the gas-permeability and cohesion at ordinary temperature with any given percentage of humidity.

In the present state of our knowledge of these sands, the methods outlined by the "Committee for Testing Sands" of the American Foundrymen's Association must be regarded as most nearly approaching the object in view. This does not, of course, imply that the principles adopted in these tests are the only ones capable of being applied to the measurement of certain complex properties of sands, because it would be quite possible to evolve other methods and devices for the purpose; but as a choice has to be made and the methods referred to above have the advantage of having been widely used for some time, and the results have been found to be sufficiently accurate and inter-comparable, at least where the necessary precautions are taken, it is the methods of the A.F.A. that have been considered in the present paper.

As stated above, these methods enable the permeability and cohesion at ordinary temperatures to be measured, while, actually, what it is necessary to know is the value of these properties at high temperatures, or, at least, those properties that have a direct bearing on foundry conditions. Nevertheless, a knowledge of the properties at ordinary temperature is of great interest to the foundryman, especially if applied in accordance with specific directions. It is the object of this Paper to explain broadly what the rules are.

The questions to be settled in foundries in connection with moulding sands fall into the following three categories:—(1) The careful selection of the mixtures intended for use for a specific purpose, both as regards their composition and the method of preparation; (2) a proper method or methods for checking the uniformity of the raw materials used in the preparation of the mixtures: and (3) a proper method or methods of checking the mixtures prepared, with a view to securing the regularity of the operations they have undergone, and constancy of properties.

I.—Control of the Mixtures.

Composition.—To enable the mixtures to be prepared quickly, considerable knowledge of the raw materials themselves is necessary. Experience of this kind is difficult to acquire, and in addition to its immediate interest, it ought to be sufficiently comprehensive, enabling subsequent problems to be tackled, especially those coming into the second category above mentioned.

It is common knowledge that the action of the metal at high temperature, or at any rate the action on the surface layers of moulds, generally consists of a drying or baking of the bond and fragmentation, more or less pronounced, of the grains. Sand, when it has been acted upon in this way, loses its cohesion and permeability, owing to the loss of some of the bonding constituents and the increased percentage of fine particles.

One of the functions of new sand which is added to old sand in order to form a mixture, consists in supplying to the whole, grains which aerate it, and fresh bonding material which, after being suitably prepared, restores permeability and cohesion to sufficiently high values.

It will thus be seen that, for a given type of output, a sort of balance must be established by means of which the composition of the mixture (proportion of new sand to old) and the preparation maintain at a constant the permeability and cohesion of the mixture during subsequent operations.

Obviously, the very existence of this balance depends upon the fresh sand available and the branch of foundry work involved. It may, however, be impossible to ensure this, especially if very complex properties are involved dependent on the intimate nature of the sands used and which are impossible of investigation in regard to such points as refractoriness, its effect on the skin of the castings and abrasion by the metal, etc.

If one examines what takes place in practice, it will be seen that it is quite possible to proceed by comparison and start from a basis that has been experimentally established. Sand control therefore amounts to adapting the composition of the mixtures and their preparation, or, in a word, to the sole determination of the equilibrium factors outlined. This should certainly be carried out in many foundries, even in those which insist that they are satisfied with their moulding sands, but which, periodically and because wasters increase, reject a portion of their old sands to be distributed in new material.

This general control is simple to achieve: it amounts to assuring constancy of permeability and cohesion, by controlling the composition of the mixture, or its preparation, as will be shown further on. The properties are, of course, measured with the aid of certain apparatus.

The question is more difficult where a new product has to be tested. It is not usual to start entirely with new sand and allow it to age in service, but this would certainly be the best way of following the evolution of the properties of the sand, and of the efficiency with which it was prepared—in a word, of studying the factors that go to make up "balance."

It would be extremely interesting and would reduce experimental work if it were possible to compare simultaneously a new material with those which are being used already and whose practical properties were, of course, known. Foundrymen are unable at present to measure directly all the factors that control the behaviour of sands in service; the chemical, mechanical and other special methods of analysis and tests are still insufficient, probably due to the part played by the intimate constitution, nor can these methods enable one to compare two sands in a practical way. It is possible, however, that the variation of certain measurable properties under the influence of a known factor forms a valuable guide. Moreover, one may conceivably do without the individual knowledge of all these elements of the intimate constitution and content oneself, for practical purposes, merely with the effects of their variation under definite conditions.

Among the discoveries made, there are one or two special features of interest, *e.g.*:—

(1) When investigating the variations in permeability and cohesion of a number of sands in terms of humidity, it is found that the resultant curves plotted are of different shape. In many cases, working with, say, from 4 to 10 per cent. of water, each of the properties passes through a maximum. In rarer cases, the maximum is only reached for higher percentages, and, for the cohesion in particular, it may only be attained at towards 15 and even 20 per cent.

The slope of the curves and the position of their maxima are points of importance. As regards the shape, the branches may be at a greater or lesser distance from the horizontal, which means that the permeability and cohesion of the corresponding sands are more or less sensitive to humidity. As regards the maxima of the curves, three cases may arise: the permeability and cohesion are the same with the same percentage of water; or the permeability is reached with a lower or a higher percentage of water than that of the cohesion.

All these characteristics unite in the effect to produce factors that cannot be distinguished individually, such as quality, plasticity, capacity to absorb bond, its distribution in relation to the grains, the behaviour of small particles which do not play the part of an active bond.

The very few experiments that have been carried out on these points furnish an insight into the practical interest which may be expected from the minute study and comparison of one sand with another in these respects. An example of this will be given later on.

(2) Simple and studied use of the American device for moulding the permeability test specimen shows that all sands do not behave alike

when rammed. The reduction of volume they undergo under the same stress is variable. They attain, more or less rapidly, a maximum compactness, after which the blows of the rammer do not appreciably reduce their volume. Again, for the same humidity and the same ramming stress, the hardness, measured by means of the ball device designed by Mr. E. Ronceray, is just as variable as the permeability.

Here again the size of grains, their shape and all the properties of the bond intervene.

(3) By applying the hardness test indicated by Mr. Dietert,* supplemented by curves showing the variation of the permeability and cohesion after heating, in terms of moisture content, and comparing these results with those found before heating, information of a highly practical nature may be obtained.

There is hardly any need to dilate upon the measurements that might be thought out for comparing the behaviour of sands in service with properties that could be investigated before using the sands, with a view to comparing the materials against each other.

In each special case the experiments most likely to be useful should be taken, bearing in mind that those in which the moisture is the variable factor are often best, in view of the part played by moisture.

Generally speaking, the methods only involve measurements, in the cold state, of the permeability and cohesion. Sometimes special experiments are made when elaborating moulding sands, especially in the case of sand for steel foundries, where the refractory properties, with their complexities, play a part.

Although the author has had occasion to make a few tests covering these questions, it would be clearly beyond the scope of this paper to outline them, and a single example will be given later of what is possible.

Of the two parts which go to make up a moulding sand, viz., the grains and the bond, the former is generally sufficiently refractory for steel foundry purposes; but this is not the case with the latter, the function of which may be extremely

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* "Commercial Application of Moulding Sand Testing." Trans. A.F.A., Vol. xxxii, Part II.

variable. A sand cannot be considered as a homogeneous substance in respect to its refractoriness, and while it is true that, most of the time, the two parts cannot be regarded as behaving in distinct ways at high temperature, a certain measure of independence does exist. The bond, in particular, undergoes attrition (grésage) and in certain cases assumes a consistency such as to strengthen cohesion without altering the permeability, or, conversely, it ruins cohesion and permeability at high temperatures.

In a problem of this kind, where a lack of permeability or cohesion in the hot state was exhibited by special defects in the castings, the following experiment was made:—

Permeability test samples were prepared and heated to different temperatures by a method that had been thought out beforehand with a view to preventing the breakdown of the cylinders. The permeabilities were then measured in the cold state, as it must be remembered that the constitution at high temperature must be maintained on cooling. In practice, there is merely a difference in the volume of the gases to be removed, this volume being a function of the temperature, and although it was impossible to do this, the difference in question could be calculated and taken account of, and this would, of course, still further accentuate the alterations found. The figures found are plotted in Fig. 1, which exhibits a very appreciable diminution in permeability at a certain moment, and, reaching a minimum towards 1,150 deg. C., afterwards increases. With a view to linking up these results with the behaviour of the bond, the sand was investigated separately after washing. This investigation showed that the part AB of the curve gives the attrition (grésage) of the bond, this phenomenon being accompanied by considerable expansion of the material, terminating in its melting and gradual contraction from about 1,160 deg. C.

It may be mentioned, incidentally, that this action of the bond on the properties of sand at high temperatures does not only depend upon its nature and refractory properties, but also apparently to a considerable extent on its distribution and adherence to the surface of the grains. What is termed the "fixed bond" apparently plays an important part in this connection.

For a given product, at all events, the higher the properties in the cold state, *i.e.*, the more perfect the distribution of the elements, the better the properties at high temperature.

This is perfectly logical if it is borne in mind that the action of the bond is always expressed by the same diminution in the properties in whatever way it may be distributed. In the light of initial experiments made in this matter this hypothesis seems superfluous, the better the bond is distributed around the grains, the less its tendency to act separately at high temperature to produce the deleterious effects mentioned.

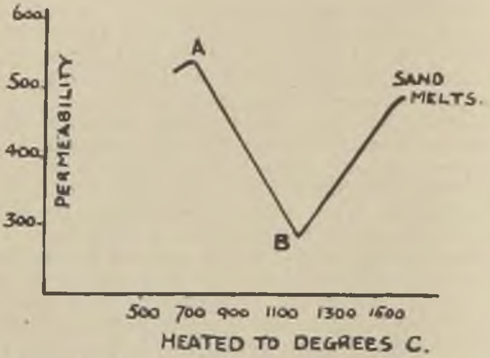

Fig. 1.—Permeability of Washed Sand.

Preparation.

Assuming the existence of old and fresh sand, the preparation of the mixtures consists in distributing as uniformly as possible around the grains the bond and the small particles that adversely affect permeability and which cannot be eliminated. This operation is generally followed by a separation of the grains that have been covered in this way, this action being produced by means of the disintegrator.

It is well known that by properly preparing a mixture, its permeability and cohesion when cold. and also when hot, are augmented. The proper control is just as important, therefore, as the composition, and it may easily be carried out by means of apparatus for measuring these properties. In a given foundry the machines available in the sand shop are generally pretty much the same, and attention should therefore be directed particularly to the method of preparation.

In practice there are two processes for getting the distribution of the bond and the sand grains; the first consists in thoroughly mixing the old sand and the new in the dry state, and then wetting the mixture; the other consists in wetting the mixture first and then subjecting it to mulling in order to get the desired distribution.

The first advantage of permeability and cohesion tests is to show that, in the majority of cases, the second of the two above methods is preferable to the first for natural sands. The reasons for this are pretty simple. but the following are a few of them:—

(1) Except in special cases, it is undesirable to crush the grains, because, as mills are generally used. this fragmentation is considerable when working in the dry.

(2) If it be desired to distribute the bond in the form of a layer around the grains, then the bond must be plastic, *i.e.*, moist, because if dry, merely mixing and not distribution is effected.

(3) The plasticity of a bond, which is a clayey material, depends, apart from its own nature, on the amount of water it may absorb colloidally. It is better therefore to leave its natural water, because it is impossible to say ever whether it may reabsorb it after drying.

(4) It is a common notion that kneading a moist clay increases its plasticity—another reason for working the sand with water.

There are, however, raw materials which are difficult to incorporate in used sands without previous drying. Such products are those in which the bond is naturally very badly distributed and forms nodules of clay distributed over the mass. These nodules become covered with all the dry powder of the old sand, assume the consistency of rubber. and are no longer able to cover the grains, whereas, if previously dried, they disintegrate.

It is sometimes possible with these materials to obtain good results by proceeding as follows: Pure new sand is mulled by adding the necessary water for moistening the mixture. The nodules become very plastic and are distributed around the grains. The old sand may then be added. In other cases it is of advantage to mull the fresh sand simply with the natural water it contains in it, and to add to it afterwards the old sand suitably moistened.

The Addition of Clay to Sand Mixtures.

A certain percentage of clay is sometimes added to a mixture to increase, say, its cohesion. The results differ greatly according to whether this clay is added in the powdered form or in the form of a thin paste prepared in advance with the aid of the water that must be incorporated in the mixture. In the course of an experiment carried out by the author, the additional quantity of clay necessary to obtain the same cohesion was cut down by half by means of the second process, with considerable benefit to the permeability.

These examples have been mentioned to show the importance of moisture in all these questions; for it must be remembered that this factor plays an outstanding part through the plasticity of the bond.

If the work of a muller be carefully studied, and curves be plotted showing the variation of the properties of sand in terms of time of muller, it will generally be found that: (1) Permeability begins to diminish more or less appreciably, afterwards increasing and reaching a value that is practically constant after a certain time, this latter being variable, and (2) cohesion also tends towards a kind of limit.

The initial diminution in permeability is due to the fragmentation of the grains at a time when they are not sufficiently protected by the bond. This protection is really good distribution of the bond, or, put another way, the maximum good properties are more quickly reached when, other things being equal, the plasticity is very high.

As time is an important matter in the sand preparing shop, it is sometimes regarded an advantage to carry out the mulling operation with an excess of moisture, allowing the mixture to dry slightly before using it. *En passant*, it is desirable to examine in this connection sands which, in the crude state, exhibit maximum permeability, and, more specially, cohesion, for high percentages of water.

In this respect the following experiment may be mentioned: Three parts of the same mixture were worked up in exactly the same way, but with different percentages of water, viz., 5, 7 and 9 per cent. The percentage moisture was then standardised at 7 per cent. (the sand with 5 per cent. moisture having been wetted by 2 per cent. and the sand with 9 per cent. moisture dried in air for a sufficient length of time). The permeability and cohesion after this operation were not the same. For the portion of sand mulled with 9 per cent. water these properties were higher than the others by 15 and 20 per cent.

This case is probably not general, but it shows the importance of studying these questions where the products actually available have to be used.

From the standpoint of the preceding remarks an attempt might be made to draw up a programme for the preparation of a definite mixture with a view to obtaining the highest possible properties in a time compatible with the necessities of production.

Assuming, for instance, a sand mill with constant characteristics (weight of runners, width of runners, speed of rotation of the pan), then three related factors should be investigated: (1) Thickness of sand placed in the pan; (2) time of mulling; (3) moisture. The thickness of sand plays an important part relatively to the crushing of the grains and the extent and intensity of mulling.

The time of mulling is related to the percentage of moisture in view of the properties to be obtained, and governs with the thickness of sand the production of the apparatus. Moisture, of course, plays the part already mentioned.

It is convenient to determine first of all. according to practical requirements, the time of mulling and the moisture; information on this latter point being obtained, as already stated, by curves showing the variation in the properties of sand in the raw state. The effect of the thickness of sand is then investigated by permeability and cohesion measurements. When the two other factors have been determined, the time of mulling and, finally, the moisture, should be studied.

Sufficiently accurate information will then be available in order to determine the conditions under which the operations are carried out. It is not meant to imply that the investigation should be systematic, because this would mean varying highly complex and closely related factors; but the rough-and-ready method suggested may be extremely useful in the process of sand control.

A great advantage of this method is that it gives information as to the effects of daily variations in the percentage of water in the mixtures, and enables the limits of such variations to be fixed. Certain products are more sensitive than others to these fluctuations, and so require greater care and attention. Since these experiments are not made in the laboratory, but in the sand preparing shop it is necessary to be able to determine the moisture, as well as the other properties, very rapidly and, if necessary, at some expense of accuracy.

An apparatus of the kind suggested by H. Dietert* is very satisfactory in this connection. It may be formed of a tube (A) (Fig. 2) closed at the top by a plug (B) containing an electric heating wire and containing inside a compressed air pipe. The bottom of the tube (A) contains a small sieve (D) supported on legs. The electrical part of the device comprises a rheostat and an ammeter.

After having inserted the sieve (D) containing, say, 10 grams of sand, the current and flow of air are adjusted so that the temperature on the sand is 200 deg. C. Perfect drying is therefore effected in a few seconds. The loss of weight gives the quantity of water contained in the sand under investigation, this quantity being expressed as a percentage of dry sand by means of a chart prepared in advance. To accelerate operations it

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* H. Dietert. "Commercial Application of Moulding Sand Testing." Transactions, A.F.A., Vol. xxxii, Part II.

may be possible to add a weighing device which would directly indicate this percentage.

Obviously, once the adjustment has been made, it is not necessary to do it over again for each determination. It will be seen that the sieve has been adapted so as to give very quick drying. A small disc (D) collects the portions of sand that may have been forced through the sieve by the compressed air. Once an apparatus of this kind is hot, it enables a humidity determination to be made in three minutes, and only five minutes are required for heating up.

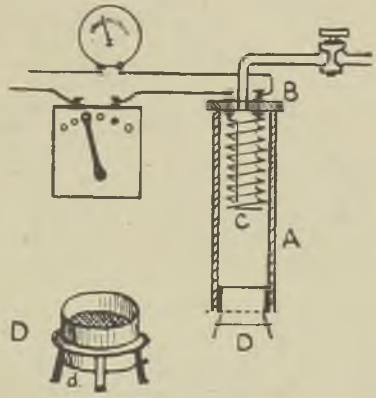

Fig. 2.—Permeability Apparatus of the Dietert Type.

II.—Controlling Raw Materials.

With a view to obtaining the continuity of results that is desirable in manufacture, new sands reaching the foundry must be checked with a view to recording any variations they may exhibit before an increase in wasters calls attention to them.

This control is difficult to organise, and among all the methods of investigation that have been examined, the foundryman must ascertain which of these should be adopted in his case. The strata in sand-pits are rarely uniform and homogeneous, but one might assume that, apart from a few differences in chemical analysis and mechanical properties, the products obtained when of the same geological origin must be practically constant as regards their intimate constitution.

This is not always the case, however, and although the question has not yet been investigated to any great extent, differences have been found. The following example may be quoted.

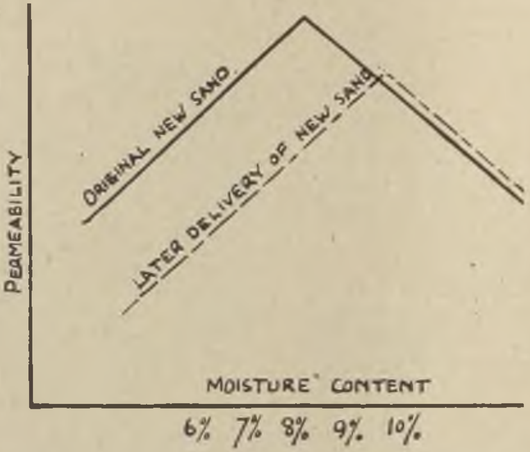

FIG. 3.—MOISTURE PERMEABILITY CURVES OF SANDS GIVING GOOD AND WASTER CASTINGS.

A new sand used in a steel foundry and 50 per cent. of which was used along with old sand to form the mixture, was giving satisfactory results, when, a further consignment having been delivered, the percentage of waster castings began to rise rapidly. The mechanical and chemical analyses carried out on the fresh product did not reveal any appreciable difference compared with the sand previously used, but an investigation of the variations in permeability in terms of moisture showed a marked difference. The curves obtained are shown in Fig. 3. They take the same form, but exhibit a deviation from the horizontal corresponding to about 2 per cent. of moisture. The percentage of water used in preparing the sand and moulding is 7 per cent., so that, in view of the slope of the curves, the difference in permeability is considerable.

The control of the preparation was resumed according to the broad outlines given above, with a result that the dotted line was displaced and sufficient permeability obtained. The percentage of wasters then decreased rapidly. The cause of the difference in behaviour of the two products was never known, but it is none the less true that the knowledge of this difference, had it been gained before using this fresh sand for moulding, would have prevented the rejection of a number of castings.

This is a fairly typical example, and shows what may be done by careful investigation with a view to controlling these methods, which have been mentioned as a supplement to the ordinary analysis to ensure practical comparability of two natural sands.

Among the methods that may be used, a choice must obviously be made, because it would take too long to apply all of them, and, moreover, they are all related to each other, and in the case quoted it is highly probable that the curves showing the variation of cohesion would have revealed the same kind of difference.

It is very difficult to give in this Paper precise rules, because it only deals with the subject in a general way; but it is certain that, where the arrangements at the quarries enable a definite check to be made of the uniformity of their products, it will be useless and ineffectual to make chemical analyses on material from each consignment; it will be preferable to rely upon the help of apparatus for measuring permeability and cohesion rather than on special measurements of the kind that have been discussed.

III.—Controlling Prepared Sand.

The thing here is to know at what moment these control operations should be exercised. If one examines what takes place when mixtures are utilised it will be found that, for moulding operations, a material is used which comes from the sand preparing plant. It is rammed by some means or other, and the decrease in volume which it undergoes, assuming the force applied and the product to be the same, depends upon the moisture in the sand at that moment. When casting in green sand the surface layer dries more or less during the time which elapses between the making of the mould and the arrival of the metal. If the mould is stoved, it dries completely, and is even baked sometimes. Finally, during casting, the qualities of the mixture undergo unknown variations. In the whole of this cycle the permeability and cohesion undergo changes, but their successive values are correlative and interconnected.

The methods of preparation govern the values A of the properties of the mixture. The moisture at the moment of moulding governs the ramming and leads to other values B. The subsequent treatments to which the moulds are subjected give fresh values C for the properties, which finally assume still further values D during the operation of casting. Obviously it is these last values that have the greatest influence on the results, but they cannot be measured, especially for control purposes. The values that it is most important and convenient to control are the values B, and they must be kept in mind in any daily investigation. Their measure forms a kind of specification test of the products supplied by the sand department of the foundry. Once these methods are properly defined and controlled, an apparatus for determining moisture will be a sufficient guide in its work.

As regards this evolution of permeability and cohesion, it may be mentioned that the values C corresponding to stoved mixtures often do not differ greatly from the values B, at least in respect of the first of these properties. But this does not prove that stoving is useless, but shows that it simply acts by greatly decreasing the quantity of gas that has to be liberated, because it takes a great deal of the water from the sand.

Conclusion.

The author has attempted to show that apparatus for measuring permeability and cohesion in the cold state, when employed according to certain methods, may be of great service in the foundry. They enable the best way of utilising the products to be determined, and the uniformity of such products to be controlled day by day with a view to obtaining uniformity of results in manufacture.

Except as regards the question dealt with in the last paragraph, in the light of what has been said isolated measurements of the properties of sands should not be undertaken, as very often they signify nothing, whereas curves of variation plotted according to a fixed method and with a definite purpose in view are generally productive.

DISCUSSION.

Mr. W. H. Poole said there was no doubt that foundrymen would have to pay more attention to sand in the future than they had done in the past. Generally speaking, the condition of the sand did not receive the attention it warranted until some definite trouble arose, and usually there was no system adopted for the maintenance of definite sand conditions. During the last twelve months at his foundry each section had been entirely cleaned up at regular intervals of a month or six weeks, the sand being re-conditioned and put back again. The results were astounding from the point of view of the quality of the casting and the skin obtained, and, incidentally, from the point of view of the saving of sand. It was surprising to him that those responsible for the supply of sand did not pay more attention to grain selection, because the variation in the quality of the sand from the same pit month by month was astonishing. A firm supplying sand would be amply repaid if they made periodical tests with a view to keeping sands in a definite condition, irrespective of whether they were having trouble or not. He mentioned the case of one foundry which, when trying new sand, obtained remarkably good results for the first week or two, but after a month or more the whole condition of the foundry floor altered. By comparing the previous sand conditions to the new sand conditions they had come to a new understanding of how to change the mixtures and keep them in good condition. In connection with steel moulding they made it a practice to test the moisture content of the batches of facing sand all round the foundry, and in green sand steel moulding the number of wasters produced as the result of bad sand conditions was reduced to an absolute minimum by that simple moisture test.

Mr. J. E. **Fletcher** (Consultant to the British Cast Iron Research Association) dealt with the questions of the mixing of sands and their permeability. He believed that many sand research workers lost sight of a very practical point concerning sand in a mould. When metal was poured into a mould only a very short interval elapsed before shrinkage began; immediately shrinkage set in, and the metal surface contracted from the mould face—except, of course, where the casting was resting on its base—our ideas about the permeability and conductivity of sands began to be disturbed. Between the metal and the mould there was a space through which cold air was rushing at a speed very much higher than we might perhaps at first imagine. The heat was not taken up by the sand at the rate we often imagined; at the actual contact surfaces at the bottom of a casting the heat was being conducted at one rate, whereas in those parts where the sand had left the casting there was an undoubtedly different rate of heat conduction. He did not think that point had been sufficiently stressed. In many cases he had dealt with, where large steel castings were shrinking to the extent of $\frac{1}{4}$ in. to the 1 ft., and where, in a short time, there was a space of $\frac{1}{4}$ or $\frac{3}{8}$ in. between the sand and the casting, these questions concerning the permeability of sands assumed quite another aspect. After all, however, it was the permeability during the contact of the molten metal and the sand that mattered. While in America last year he had had an interesting conversation with Mr. Dietert, and with Mr. Harrington, his collaborator. They were trying to evolve a gas permeability test on the mould in actual contact with the metal—the apparatus being not unlike that sketched in the Paper—so that the gases could actually be drawn from the face of the mould. The question of the mixing of sand affected the permeability question functionally in a most important way. He had seen sands taken repeatedly from the bottom of a certain measure which had never given trouble, but as soon as he had received deliveries from the same sand pit under certain conditions, sand from the top and the bottom being mixed together, a great deal of trouble was experienced. Referring to the curve in Fig. 1, where M. Lemoine had drawn attention to the permeability of washed sand, he asked if it were possible to give a comparative curve of the same sand before being washed, because he had found such a comparison to be very useful. It was most difficult to get a permeability value which one felt was a practical one, and although the papers which were coming before the Institute in connection with sand were most valuable, it must be remembered that all these workers were dealing with the subject progressively and had not settled anything yet, but they were on the way towards solving some of the most difficult problems in sand research. The British Cast Iron Research Association very much valued every contribution of this sort, because they were a very great help to those who were trying to get some little knowledge of this big subject.

Mr. Colin Gresty (Newcastle), referring to Fig. 1, said that the curve gave its permeability of sand heated to different temperatures, but no indication was given of the permeability at normal temperatures. It was to be assumed, apparently, that from the peak at the point A the curve would go down towards the left, but he asked if that could be confirmed, because it rather indicated that from ordinary temperatures up to about 700 deg. the permeability of the sand was gradually increasing.

Mr. Horace J. Young, F.I.C. (London), was exceedingly glad to hear that the British Cast Iron Research Association were taking up the attitude indicated by Mr. Fletcher. At the Glasgow Convention he had got into hot water for pointing out that many tests then being applied to sands were of little practical use so far as he could see, particularly in relation to permeability to gases. There seemed to be a misconception among foundrymen that the gases and the heat from the casting rushed through the sand, but, so far as he had observed, nothing of the kind occurred and in the hot mould process one obtained very much evidence to the contrary. He had observed that about an hour after a large casting had been poured a pyrometer which was placed an inch or so away from the metal had not altered, and he believed that had the hot gases been passing through the sand the pyrometer would have shown it. Actually they came out where there was a vent or joint. He agreed with Mr. Fletcher that we must alter our methods of investigation of sand, particularly on the question of permeability. A core might be permeable, but he did not think the sand outside the casting was permeable except it was thoroughly burned. One factor which had to enter into this investigation was that of conductivity, and it would be found that, while we were now using chills, which were not permeable at all, we should in the future—perhaps after many years—be using sands of different conductivity, which would give the effect of a partial chill at those points where the metal needed to be densest. Therefore, he hoped the British Cast Iron Research Association would investigate sands not only from the permeability point of view, but also from the point of view of conductivity.

Mr. J. G. A. Skerl (B.C.I.R.A., Sheffield) pointed to the variables occurring in sands, and urged the necessity for first investigating thoroughly one particular sand, and then gradually to apply the knowledge so obtained to a group of sands. That was the plan adopted by the British Cast Iron Research Association. There were two variables which were most important in the investigation of sands, namely, the degree of ramming and the degree of moisture present. In America and on the Continent, up to the present, ramming had not been taken into such great account as it should have been, and one found that the results obtained by investigators could not be correlated. American methods, which Mons. Lemoine seemed to half advocate, were not suitable for British sands, because the latter were generally of finer grain and stronger. Also fully half the British sands were red sands, which were unknown on the Continent and in America, and which had well-known characteristics of their own. Referring to the reference in the Paper to the need for a knowledge of the behaviour of sand at high temperatures, he said he had done a certain amount of work in that direction, but the difficulty was to maintain the high temperature necessary. He assured Mr. Young that research on conductivity and specific heat of moulding sand was being undertaken.

RESULTS OBTAINED IN THE IMPROVEMENT OF THE QUALITIES OF CAST IRON.

By Louis Piedboeuf.

[Belgian Exchange Paper.]

High-tensile cast irons generally have a structure that is almost entirely pearlitic, though sometimes high strengths are obtained with cast irons having a pearlitic and ferritic structure, provided the graphite is distributed in sufficiently fine lamellæ.

Maurer's cast iron diagram may be very useful for classifying and comparing the various high quality cast irons. This diagram subdivides the cast irons according to their texture, in terms of carbon and silicon content. It was suggested for the first time by Engineer Maurer, of the Krupp Works, in a Paper on high-tensile cast irons as produced by Krupp. He was dealing, of course, with good machinery castings, having a phosphorus content usually below 0.60 per cent., with 0.50 to 1.0 per cent. manganese. In cast irons of this kind, the structure depends on the carbon and silicon contents, assuming, of course, that the speed of cooling is kept within certain limits.

The diagram (Fig. 1) is plotted by giving the carbon contents in terms of silicon. The horizontal line HH′, at 1.7 per cent. C., shows the limit between cast iron and steel. The point **B** is determined from the assumption that steels containing 2 per cent. of silicon may be cast without graphite forming. The point C, with 7 per cent. silicon, is derived from Guillet's researches on silicon steels. The point **A** corresponds to the eutectic containing 4.3 per cent. of carbon.

B is projected to B′ on the line HH′; and D, which is the intersection of AC with HH′, is projected on the abscissæ, when it will be found that

CAB = the region of white cast iron.

BAD = the region of pearlitic cast iron.

Above AD is the region of ferritic and graphitic cast irons.

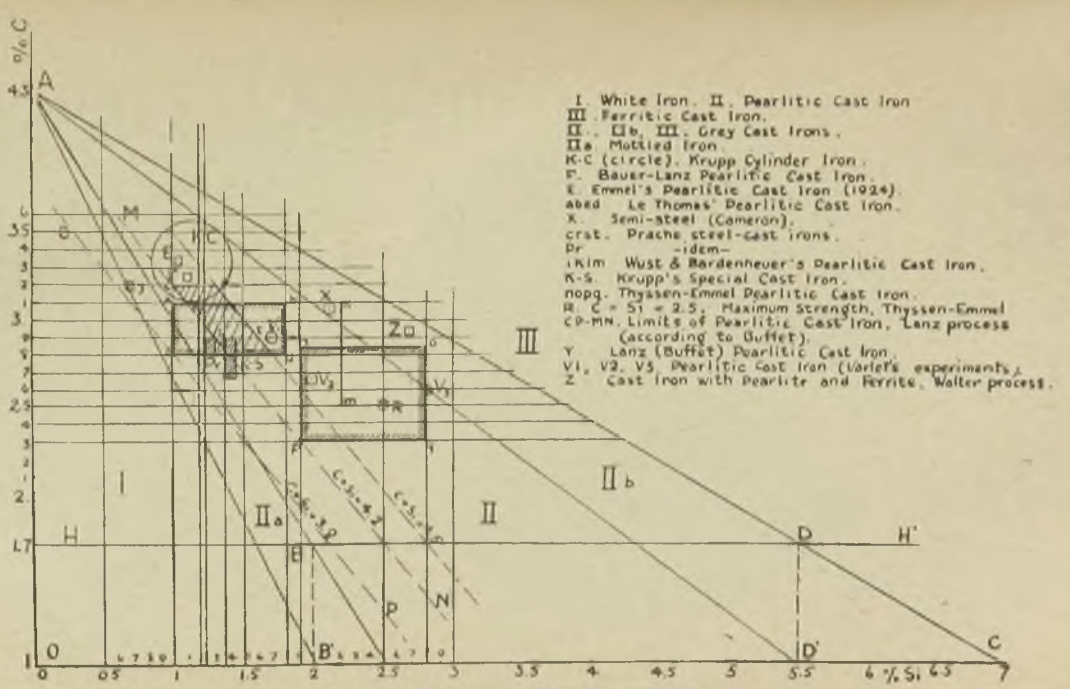

FIG. 1.—MAURER'S CAST IRON DIAGRAM.

BAB′ = region of cast irons intermediate between white and pearlitic cast irons—those which contain pearlite and cementite, *i.e.*, mottled irons.

DAD′ = the region midway between pearlitic and ferritic cast irons, *i.e.*, those containing pearlite and ferrite.

B′AD′ = the region of pearlitic cast irons.

This diagram, plotted from theoretical considerations, has been verified by numerous examples in practice, nearly all of which have confirmed the correctness of it. The diagram may be checked by any laboratory having available the results of chemical analyses and micrographic investigations.

Maurer included in his diagram cylinder cast irons and Krupp special cast irons, as also the results of laboratory tests carried out by Wüst and Bardenheuer. The appended diagram has been supplemented by points showing a whole collection of special irons, pearlitic irons, and semi-steels.

The point F (see Fig. 1) corresponds to information given by Bauer in 1923 to characterise (distinguish) pearlitic cast irons obtained by the Lanz process. Not much data has been published on this method. In a Paper published in "La Fonderie Moderne," August, 1925, Monsieur Buffet, engineer of the Société Alsacienne, gives as the distinguishing feature of the Lanz pearlitic cast irons: C + Si = 3.8 to 4.2 per cent. The corresponding zone in the diagram is that included between the two parallel lines OP and MN. Part of it comes within the space occupied by the mottled irons, *i.e.*, those with an excess of cementite. This is quite as it should be, because, in the Lanz process, the pearlitic structure is obtained by heating the mould.

The circle KC circumscribes Krupp steam engine cylinder irons, and the zone KS the special high-tensile irons of the same firm.

Point E is derived from data published in 1924 by Emmel for pearlitic cast irons as produced by the Thyssen Company. These cast irons are distinguished by Si = Mn = 1.

The one *crst* included between the lines C + Si = 4.2 and C + Si = 4.5, and the zone marked

Pr differentiates two types of semi-steel cast iron as suggested by Lieut.-Col. Prache.[1]

Point X indicates the composition of a special semi-steel cast iron used for aerial bombs, and suggested by Cameron.[2]

The zone included within the rectangle *abcd*

FIG. 2.—SPECIMEN V3 AT 200 DIAS. ETCHED WITH PICRIC ACID.

T.C., 2.61; C.C., 0.77; Si, 2.82 per cent.; and Brinell hardness, 206 to 214.

is that of the pearlitic irons as produced at the Indret works, and as given in a very interesting Paper[3] published by Monsieur le Thomas.

The rectangle *iklm* is derived from the laboratory researches of Wüst and Bardenheuer.

The zone *nopq* is the region of cast irons produced by the Thyssen-Emmel process. These cast irons are said to give the best results from the point of view of evenness of texture and strength.

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[1] Liege Congress, 1922.
[2] Birmingham Congress, 1923.
[3] "La Fonderie Moderne," Feb., 1926.

The points V_1, V_2 and V_3 indicate the results of a test kindly made, at the author's suggestion, by M. Varlet (Vice-President of the Belgian Association) at the foundries of the Société Espérance-Longdoz. It is due to his courtesy that the author is able to present some interesting specimens of high-tensile cast irons. A photomicrograph of the cast iron V_3 is shown in Fig. 2.

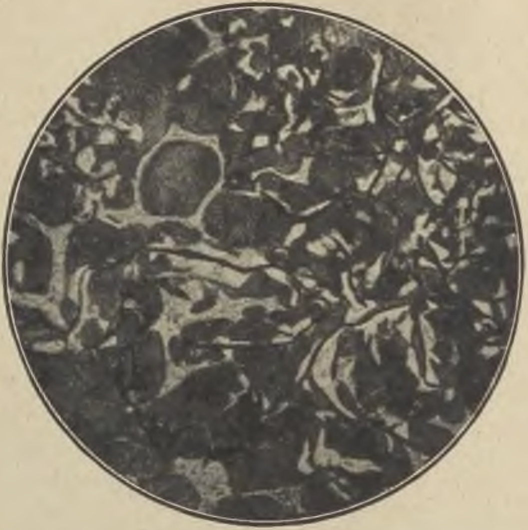

FIG. 3.—FERRITIC-PEARLITIC CAST IRON WITH THE GRAPHITE IN FINE NODULES.

Tensile strength, 15.8 tons per sq. in.; Brinell hardness, 170 to 180; Gr., 22.51; C.C., 0.42; Si., 2.73; Mn., 0.41; P., 0.87, and S., 0.04 per cent. x 200 dias.; etched picric acid.

In order to distinguish the cast irons of zone 2*b*, there has been noted, at Z, a cast iron containing pearlite and ferrite, the analysis and micrograph of which are shown in Fig. 3.

It may be presumed that the researches carried out by the Société Alsacienne tend in the same direction, since, in his Paper quoted above, Monsieur Buffet mentions the production of cast iron containing 2.3 and 2.5 per cent. carbon.

Maurer's diagram clearly points out the advantage of low carbon-contents. The lower the carbon content, the wider the zone of pearlitic structure. There is thus greater certainty of getting the pearlitic structure without the risk of encroaching on adjacent zones. By keeping at an equal distance from the cementite and ferrite zones, there is a greater chance of getting the pearlitic structure without heating the mould.

For the cast irons included in the zone *abcd*, Monsieur le Thomas states that an endeavour should be made to keep a slight excess of cementite so as to be sure of attaining the pearlitic structure. With low carbon contents that is not necessary, and there may even be a slight excess of ferrite without fear of modifying the structure and the tensile properties, as will be seen from the results obtained with the V_3 cast iron. In this case, there is the added advantage of a lower hardness and better machining properties.

Another advantage of the low-carbon one is that, in this zone, the pearlitic structure will be attained much more independently of the speed of cooling.

As a matter of fact, the effect of rapid cooling (by chill-casting or in light castings) may easily be represented by a displacement to the right of the zones I and IIa; and slow cooling (by casting in a hot mould, or in heavy castings) by a displacement to the left of the zones III, IIb and II. It will readily be seen that the points situated towards the middle and bottom of the rectangle *nopq* will be least affected by these changes.

The test-piece 220 mm. square, cast with the cast iron represented at V_3, has an even texture throughout its cross-section. In the higher-carbon machinery cast irons, a considerable increase in the graphite lamellæ will always be found towards the centre, even where the diameters are smaller. With low-carbon and high-silicon pearlitic cast irons it is possible to obtain an identical texture in the thin parts and the thick parts of the same casting.

This regularity of texture may be explained as follows:—The primary graphitisation persists for a certain time and takes place during a definite interval of temperature, after solidification. As in the case of secondary graphitisation[4], we may assume that its rate will be proportional to the silicon content. At the same time, owing to the lower carbon content, graphitisation will be completed more quickly. In the case of cast irons of the Thyssen-Emmel type, graphitisation would be extremely rapid and practically complete before the effect of the walls has had time to make itself felt and cause appreciable cooling of the thin parts of the casting.

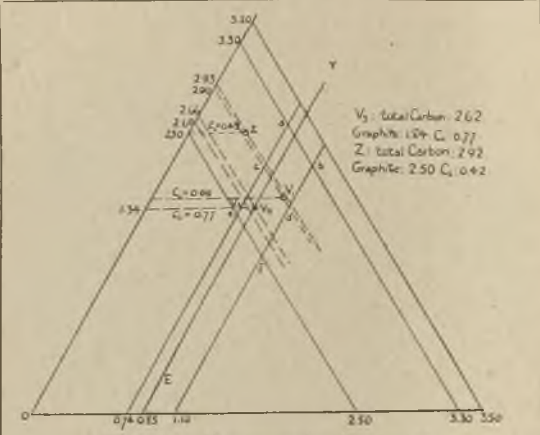

Fig. 4.—Portevin's Diagram.

Maurer's diagram classifies cast irons according to their carbon and silicon content, without taking into account the percentage of combined carbon. Referring to Portevin's diagram (Fig. 4), it will be seen within what limits this content may vary for pearlitic cast-irons and semi-steels. Assuming the carbon content to be the same, the percentage of combined carbon will be inversely proportional to the silicon content. For each composition of cast iron, there is only one percentage of combined carbon corresponding to the ideal pearlitic structure (C = 0.90 per cent. for pure pearlite).

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[4] Researches of Charpy and Grenet.

The corresponding percentages of combined carbon for cast irons the total carbon of which varies between 2.5 and 3.3 per cent. are situated on the line EY of Portevin's diagram. Adding to this diagram the points corresponding to samples V_1, V_2 and V_3, it will be seen that V_1 has an excess of cementite, V_2 comes practically on the line EY, and V_3 has an excess of ferrite.

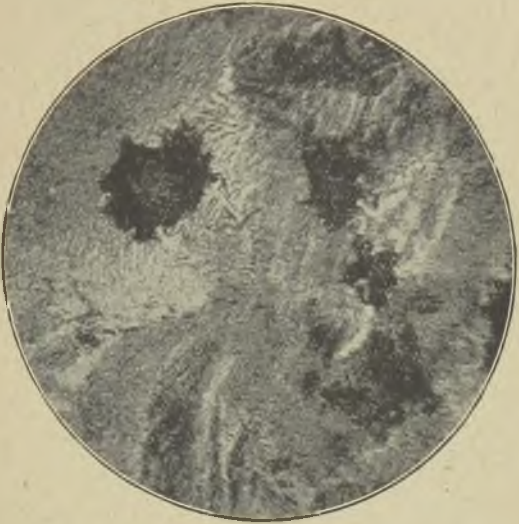


FIG. 5.—THE CENTRAL PART OF A MALLEABLE CASTING SHOWING THE GRAPHITE TO BE IN NODULES, AND PEARLITE. × 200 DIAS., ETCHED PICRIC ACID.

Finally, the cast iron characterised by the point Z comes on to Z in the diagram, *i.e.*, the pearlite *plus* ferrite zone. Contrary to what Monsieur le Thomas states in his Paper read at the Liege Congress, it is possible to get high-tensile cast irons even in this region of Portevin's diagram.

The zone *abcd* distinguishes more particularly the so-called semi-steels, and *cdef* pearlitic cast irons proper.

TABLE I.—*Mechanical Properties of Various Special Irons.*

Bauer (Lanz System).						Krupp.			Remarks.
Test piece.	38/42 mm.	32/28 mm.	42 mm.	32 mm.	% increase.	15 mm.	36 mm.		
Transverse strength tons/sq. in. . .	32.3 (25.3)	34.2 (28.4)	27.2 (19.6)	31.7 (24)	20	40.8 (31)	38.9 (22.8)		
Deflection, mm. . .	13 (12)	17 (16)	10	13		8.8 (300)	18 (720)		
Tensile strength, tons/sq. in. . .	15.7 (12)	17.6 (13.8)							
Brinell hardness . .	160 (147)	173 (160)				230			
Thyssen-Emmel.						Kerpely.			Kerpely iron cast in electric furnace. Distance between supports for deflection: (a) & (b): 300 mm. (c): 600 mm. (d): 720 mm.
Test piece.	(a) 15 mm.	(b) 15 mm.	(c) 30 mm.	(d) 36 mm.		30 mm.			
Transverse strength tons/sq. in. . .	40.3	41	38.3—42.9	41—42		30.4 —32.9			
Deflection, mm. . .	4.8—4	8.6—6	11—10	16.8—17.4		10—10.5	(On length of 600 mm.)		
Tensile strength tons/sq. in. . .	20.2					19 to 22.1			
Brinell hardness . .		240 to 310							

TABLE I.—*Mechanical Properties of Various Special Irons.—Continued.*

Test piece.	Le Thomas.					Varlet.			Tests made on Frémont machines. In transverse test load was applied until specimen broke. (Figure is "total breaking load.")
	8 × 10 mm. sq.	Breaking load.	25 mm. diam.			8 × 10 mm.	Breaking load.	25 mm diam.	
Transverse strength tons/sq. in. ..	31—33.6	700—750 kg.				41.8	935 kg.		
Shearing strength tons/sq. in. ..			15.8 to 17					29.4	
Tensile strength, tons/sq. in. ..	13.89 to 15.20					Elastic limit—731 kg.			
Brinell hardness ..	230					210—230			

TABLE II.—*Composition of Various High Tensile Irons.*

		C.	Si.	Mn.	P.	S.
1922	Wüst et Bardenheuer	2.5 to 3.10	1.20 to 2.20	0.70 to 1.20	0.30	0.00
March, 1923 ..	Bauer, Syst. Lanz	3.25	1.90	0.79	0.40	0.15
April, 1924 ..	Emmel	3.35	1.00	1.00	0.30 to 0.50	0.06 to 0.15
Nov., 1924 ..	Krupp	2.67 to 2.90	1.40	1.00	0.68	—
April, 1925 ..	Buffet, Syst. Lanz	C.+Si.=	3.80 to 4.20	0.80	0.10	0.10 max.
Jan., 1926	Kerpely	2.95 to 3.05	1.00 to 2.30	0.85 to 1.00	0.25 to 0.80	—
Feb., 1926 ..	Varlet	2.60 to 2.90	1.70 to 2.80	0.80 to 0.90	0.12	0.07 to 0.09

The pearlitic texture alone is not sufficient to ensure high mechanical properties. There is another important point, *viz.*, the diminution in the size of the graphite lamellæ. Numerous researches have been carried out in this direction, as a result of which the size of the lamellæ has been considerably reduced by treating the metal in an oil or an electric furnace. According to Piwowarski's researches, it is principally by superheating the liquid iron that the finely distributed graphite is formed. The results obtained by Kerpely, and which are given in Tables I and II, show what is possible in this connection by treatment in the electric furnace.

From the practical point of view, there is another important factor contributing to the production of high strengths, and that is, to get sound castings. As Monsieur Ronceray has very rightly observed, it is soundness of the castings that should be primarily aimed at.

It would not be much use trying to reduce gaps caused by faulty distribution of the graphite lamellæ, if other discontinuities were allowed to persist in the shape of blow-holes, segregations, or internal stresses. In this connection, it is interesting to note that the cast iron represented by point Z of Maurer's diagram gives a tensile strength of from 15.7 to 17.6 tons sq. in., in spite of a phosphorus content of 0.8 per cent. This result was obtained by a purifying treatment carried out in the fore-hearth by alkaline substances. This cast iron is close-grained and the graphite in fine lamellæ. By protracted treatment in the fore-hearth, in the absence of the impurities contained in the cupola slag, a considerable improvement in mechanical properties is attained. This case is all the more interesting because the metal is a cast iron with pearlite and ferrite, Brinell hardness 170 to 180, easy to machine, and produced with a cheap flux and normal working conditions in the cupola.

The photomicrograph, Fig. 5, shows the middle part of a malleable cast iron made by the European process. The texture is entirely pearlitic, the graphite being in nodules. It is this kind of texture that should be aimed at with a view to getting maximum strength. It seems doubtful whether it is possible to succeed without a heat treatment subsequent to casting. However, the researches of Piwowarski and Matsusiro Hamurami show that the dimensions and shape of the graphite particles of the melt can be considerably modified.

This contribution on high-tensile cast irons was written primarily with the object of giving the members of the " A. T. F. B." a summary of what has been done recently to improve the quality of cast iron.

Since the Committee of the Belgian Association have kindly suggested that the author should give a Paper on the same subject to the Institute of British Foundrymen he was glad to do so, although he realised that there will be very little that is new in it to numerous British foundrymen, who have already investigated these questions. Fresh results may have come to light in this country, where foundrymen are actively engaged on research work connected with the improvement in the strength properties of cast irons.

DISCUSSION.

This Paper was introduced by Mr. G. Masson (President of the Belgian Foundrymen's Association).

The President, welcoming Mr. Masson, said he believed that this was the first time for four years on which the Institute had had the honour of welcoming the President of a foreign association.

Mr. Masson, addressing the meeting in French (his remarks were interpreted by the President), apologised for his inability to speak English, and also for the absence of Mr. Piedboeuf. The Paper, he said, was the result of the action of the Committee of the Belgian Foundrymen's Association. Its object was to give the results of tests made during recent years in the direction of improving the qualities of cast Iron. Mr. Masson produced a fracture of Varlet's special iron, which exhibited quite a pearlitic structure, together with two photographs of Varlet's iron.

The President reminded the members that Mr. Varlet had read a very valuable Paper before the Institute at Birmingham four years ago. He also thanked Mr. Masson for having introduced Mr. Piedboeuf's Paper.

Mr. Horace J. Young, F.I.C., said that in Table II reference was made to a Lanz iron in which the carbon + silicon = 3.80 to 4.20 per cent. As one who had practiced the Lanz process, he could give his assurance that that total could be anything one liked. The mould was heated according to the composition of the iron. Mr. Young also referred to the statement on page 4 of the Paper that the pearlitic cast irons produced by the Thyssen Company were "distinguished by Si = Mn = 1," and asked for an explanation of that. As to the suggestion in the Paper that if composition were altered one need not take into consideration the temperature of the mould, he said that all scientists would agree that all metals during cooling were affected by their cooling rates, no matter what their composition was. Grain size as well as structure must be taken into consideration. One of the things that mattered most was the stability of the pearlite, and that stability depended largely upon other things in the iron. For instance, when it had to resist repeated heatings; a large content of silicon was most undesirable. We must have the quality of steel as well as soundness of castings. If soundness of castings mattered to the extent suggested in the Paper, then very many steel castings, if not nearly all, would be rejected. However, engineers still used steel, and put up with the fact that many steel castings had defects. The same remarks applied to cast iron. As to the statement that the cast iron represented by point Z of Maurer's diagram gave a tensile strength of from 15.7 to 17.6 tons per sq. in., in spite of a phosphorus content of 0.8 per cent., by a purifying treatment carried out in the forehearth by alkaline substances, although he knew little about that treatment, which was very interesting, the same tensile strength could be obtained without that treatment in iron with 0.8 per cent. phosphorus. The tensile strength of cast iron was a very debatable point. He had made a great many Diesel castings by the hot and the cold mould processes which had given high tensile strengths, but there were other properties which were of greater importance. Therefore, he wished the author had given more data upon the growth, impact values, and so on, of these irons as stated casting thicknesses and weights.

WRITTEN CONTRIBUTION.

Results Obtained in the Improvement of the Qualities of Cast Iron.

Mr. J. G. Pearce (Director, B.C.I.R.A.) wrote that he suggested that it would be advantageous if the author would give in greater detail the construction and use of the diagram prepared some years ago by M. Portevin. This diagram is not at all well known to British readers.

It is perhaps necessary to bear in mind that a complex system like cast iron contains so many constituents that it can never be completely represented on a diagram. Such diagrams may conveniently be considered as a means of comparing one iron with another, and constitute a kind of metallurgical shorthand. Apart from composition, the properties of grey iron are governed by the rate of cooling. This factor is not taken into account in any of the diagrams mentioned by the author. He does not refer to a recent attempt to take this factor into account by Greiner and Klingenstein, whose diagram from the Gusseisen-Taschenbuch, 1926, is reproduced on page 18 of the Cast Iron Research Association's Bulletin. In this case the sum of carbon and silicon is plotted against thickness, and is compiled for cupola-melted metal having a total carbon content not less than 2.8 per cent. The diagram shows, for example, that an iron containing 3.2 per cent. carbon and 1.8 per cent. silicon would be white if cast $\frac{1}{8}$-in. thick, while $\frac{1}{8}$-in. to 3-10th in. would give a mottled iron. Beyond this, to 1.1 in. thickness it would be pearlitic, and above 1.18 in. thickness free ferrite would appear in the structure, increasing in quantity as the thickness increases. When such diagrams are published it is highly desirable that those founders who have access to results, including analyses and micros, going back over a period of years should test their previous results against the diagram and see whether the diagram is reasonably correct.

NON-FERROUS METALLOGRAPHY.

By J. S. Glen Primrose, A.R.T.C., A.I.M.M.
(Member.)

INTRODUCTION.

Since the writer drew attention to the importance of "Metallography as an Aid to the Ironfounder" at the British Foundrymen's Association's Glasgow convention in 1911, there has been an increasing use of the microscope as an adjunct to foundry work, and the wide scope afforded by its application to control and investigation work in the non-ferrous field has been dealt with by noted writers in the Institute's proceedings.

There are so many aspects of the case—whether pure research into new properties, pathological investigation of failures, or examination to ensure compliance with rigid specifications—that it is not possible in limited space to deal fully with all of these; and the present object is to draw attention to the results of some slight practical experience in all of these fields, which may prove of value to practical workers endeavouring to establish standards of comparison to follow or avoid. The general tendency lies in the direction of illustrating only ideal structures and those representing exceptional conditions or strengths, whereas it is often more valuable to be able to recognise the appearance of defective structures in order to assign the proper cause to them, and thus know the direction to go in order to avoid a repetition of the trouble. Another common failing is to resort too soon and too frequently to excessively high powers of magnification for the particular structure under examination, and thus the general appearance of the structure is apt to be overlooked. Wherever possible, a three-fold record should be taken showing first the simply polished surface to indicate size and distributions of inclusion or blow-holes at low powers, then the same spot suitably etched, and finally a definite central area at a higher magnification to reveal the minute arrangement not seen at low power.

Apparatus.

A review of the micrographic outfits available for various classes of workers during the last two decades clearly shows the reasons for the great advances made in the technique of practical metallography. For purely visual work, the simple vertical mounting of the microscope tube has been greatly simplified from the original model resembling the petrological stand, and to-day there are several exponents of the compact tripod mounting due to the late Dr. Stead.

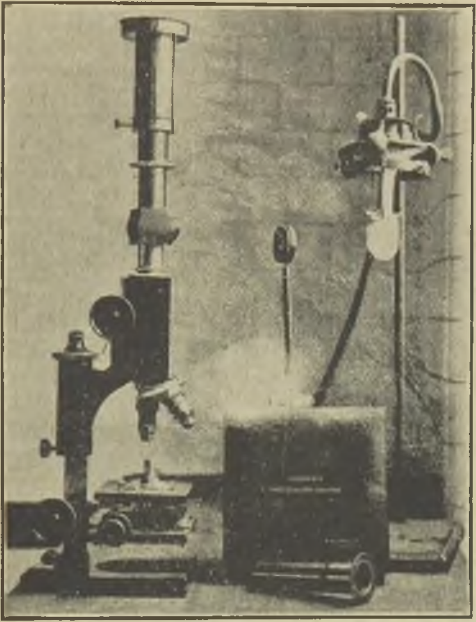


FIG. 1.—REJTO VERTICAL STAND, WITH GORDON MICRO CAMERA.

Perhaps the earliest attempt at making the purely laboratory instrument available for the workshop also was the Rejtö stand[1] shown in

Fig. 1. In this the wide body tube carried the eye-piece in an elongated form of vertical illuminator, placed in this case near the top of the mounting. The lower end of the microscope tube carried two or three objectives in a revolving nose-piece, which greatly facilitated the transfer from one power to another whilst retaining the same spot of the specimen for inspection. Between the horse-shoe base and the pillar carrying the fine adjustment screw of high accuracy, which even with prolonged wear developed no appreciable back-lash, there was fitted a removable object-stage with a long-reach rack and pinion motion for accommodating a wide range of specimen sizes. This mechanical stage could not only be levelled accurately by means of two screws and a fixed-length third leg, but could also be made to traverse horizontally in two directions rigorously at right angles by two fine screw spindles mounted co-axially, which was of considerable service in operation by touch instead of after visual finding. Two set screws at the base of the pillars enable this intermediate section carrying the stage to be readily removed, leaving the microscope available for direct setting upon any large object in place,

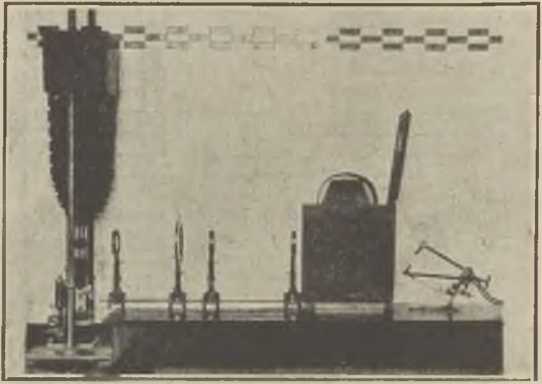


FIG. 2.—REJTÖ MICROSCOPE, VITH ARC LAMP AND OPTICAL BENCH.

without the need of removing a section to be examined. The illustration shows the inverted gas-mantle source of light and the small Gordon photo-micro camera over the eye-piece. This small attachment was sufficiently portable to enable it to be loaded with a plate in the dark room, and it was placed over the microscope and the exposure made by a small slotted disc above the lens. A focussing magnifier the same length as the camera enabled very clear images to be obtained in a very simple fashion. For more elaborate work, the use of an electric-arc source of light was deemed advisable, and for varying magnifications the various condenser combinations of the optical bench was a great help when accompanied by a large aperture iris diaphragm. This arrangement is shown in Fig. 2, in which case the photographic attachment consists of a vertical bellows camera sliding upon two fixed uprights after the Nachet principle. The upper box portion, with the plate carrier grooves, could be clamped in any desired position, but the lower connection was a simple light-tight one resting on a ring concentrically covering the microscope eyepiece.

Fig. 3.—Reichert Inverted Microscope, with Optical System Attached.

The inconvenience of either having to place the microscope very low down to have the camera top at a convenient height, or else having to mount an elevated position to focus the image on the screen if the microscope was placed at a convenient working level, was overcome by another arrangement, and this consisted of having the microscope tube capable of pivotting backwards through a right angle, whilst still resting upon its base, and thus the camera attachment could be connected horizontally after the visual examination had been performed with the microscope tube in either a vertical or in a suitably-inclined position. This still necessitated the very careful mounting of the micro-specimen, and if no levelling device was attached to the stage, then some form of stepped base-plate or the sliding tube device of Stead was a great boon to workers who required to get through a number of examinations in a limited time.

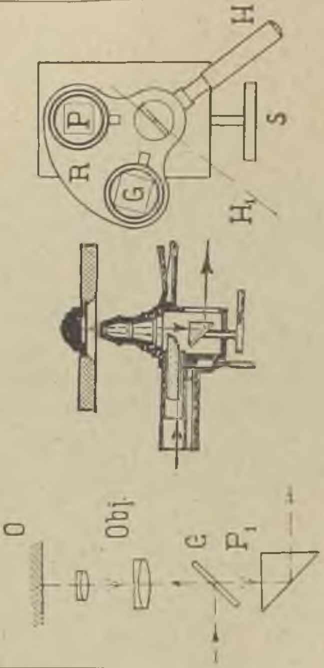


Fig. 4.—Diagram of Illuminating Arrangement in Reichert E.M. Microscope.

The greatest advance came with the idea of the inverted stand[2] introduced by Le Chatelier, in which the objective pointed upwards, and the customary difficulty of levelling the specimen was overcome by the simple expedient of placing it, polished face downwards, upon a little circular tripod stand, the legs of which rested in a grooved ring capable of rotation for final focussing, and the length of the legs was selected to suit the varying focal length of the objective. This improvement by Dujardin over the original Pellin method of adjusting the focus by means of screwing a tube with the necessary perforation in the base, up and down on the sub-stage continuation of the body tube, was a great advantage in changing objectives to secure different magnifications.

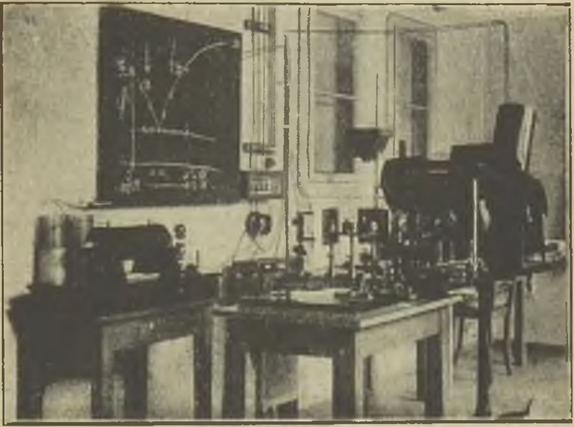


FIG. 5.—MARTENS' HORIZONTAL STAND, WITH ULTRA-VIOLET LIGHT ILLUMINATION.

Many modifications of this Le Chatelier design have been elaborated and put upon the market, such as the overhanging arm type, which soon gave place to the four-column arrangement of Guertler, and finally the most substantial form now embodied in the E. M. I. Reichert[3] stand as shown in Fig. 3. A very full description of this has already been published, but passing reference should be made to the ease in manipulation where large numbers of specimens have to be examined and also photographed with the minimum of trouble and time expended upon them. Thus five photo-micrographs of the same spot, both unetched and etched, can readily be made within a period of five minutes. One of the most important features is that the position of the mechanical stage and also the illuminating prism can be set for the correct focus of any objective without the presence of any specimen, suitable graduations being provided to enable this preliminary setting to be made without reference to the image of the object. Another great facility in rapid manipulation is the ease with which the prism can be withdrawn into its carrier tube, the arm swung over into a second definite position, and a suitably inclined cover glass brought into position for the reflected type of illumination instead of the transmitted form when the prism is used. The mechanism of this arrangement is worth illustrating in the three accompanying sketches, Fig. 4, which shows the path of the light rays, and how readily the change can be effected, without disturbing the microscope or

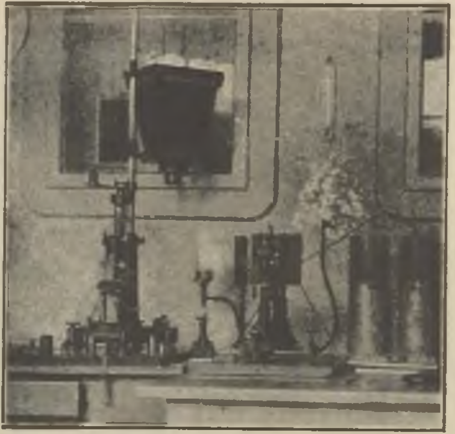


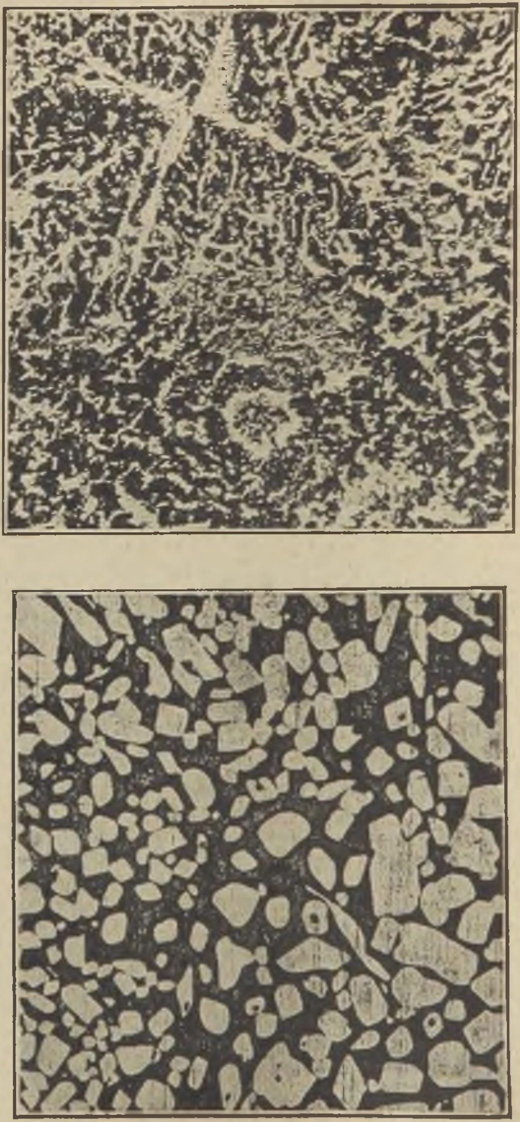
Fig. 6.—Zeiss Vertical Camera, Used for Ultra-Violet Light Research Work.

specimen in any way. The Prism P_1 can be rotated through a right angle, thereby allowing of either direct visual observation of the object, or the projection of the image for photographing into the camera below. The objectives are provided with a simple bayonet catch, whereby they can be changed in the minimum of time, since they carry no screw to fasten them. The author has found that exceedingly high-class work can be done with this instrument, which represents the greatest possible saving of time in both visual examination and in taking photographic records for comparison.

Illumination.

Just as great advances have been made in regard to improved sources of illumination, as have been effected in metallurgical microscope construction. The ordinary microscopist's oil lamp was early replaced by some form of incandescent gas mantle, the inverted type offering certain advantages. The incandescent electric lamp was less satisfactory, especially as it has to be used in a frosted glass bulb to prevent the filament image being projected on to the screen, and the simplest expedient of directing a small oxygen-coal-gas blow-pipe flame on to the upturned end of a porcelain mantle-stem was one for long in use in the laboratory of Doctors Martens and Heyn at Lichterfelde. The Nernst lamp had a short vogue, but was soon superseded by the more suitable Pointolite, which gives excellent results for most purposes of observation, and is also available for photographic work. The author's preference has always been in the direction of an arc lamp, and several types of automatic-feed carbon arc have proved satisfactory, these usually being of the inclined electrode form. The neatest and now almost universal form is the small carbon right-angle arc, which usually does not take more than 5 or 6 amperes to incandesce.

In the E.M.1 type of microscope stand above referred to, it is of considerable advantage to have the light-condensing system all mounted on a small attachment to the miscroscope stand, and to obtain concentricity of the beam of light from the arc, flexible connections to two quadrant

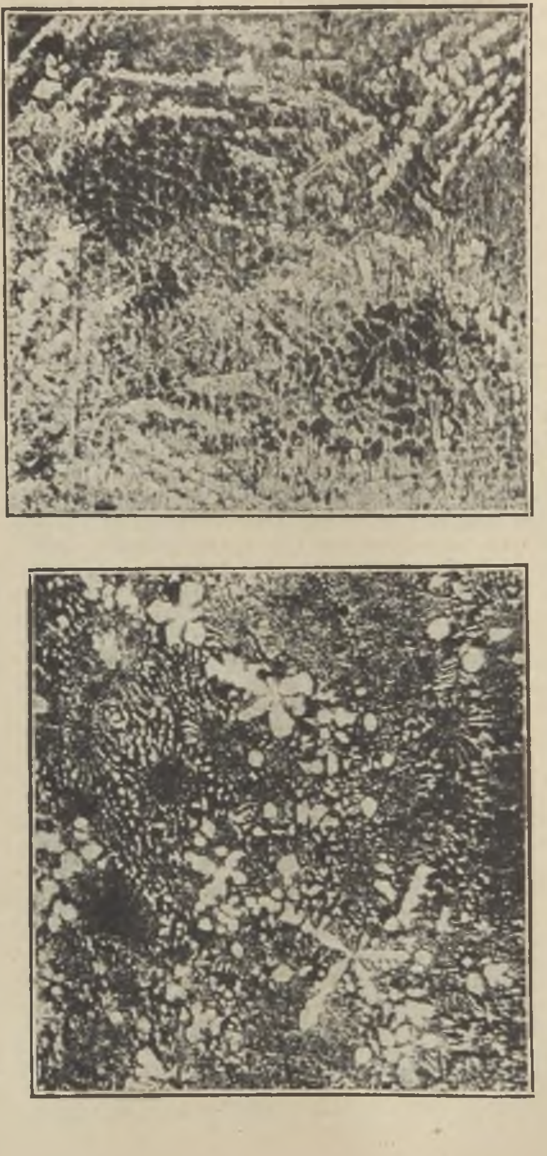


FIGS. 7 AND 8.—(V—50—X.)

adjustments enable the arc to be brought easily into the best position.

When using arc-lamp illumination, the great tendency is to overexpose the photographic plate, even with such slow speeds at H. and D. 45, if the fine-grain ordinary variety is used, and a screen is employed partly to counteract this, but also to sharpen the image by elimination of the various light wavelengths which are not correctly registered by achromatic objectives and huyghenian eyepieces. One of the most generally useful is the K.10 yellow screen, which can be secured either in glass or as a gelatine film, but for other purposes the green filter is frequently used. The disadvantage of liquid filters is that they are difficult to keep clear of bubbles, and even the cooling trough presents the same feature unless potassium-alum is dissolved in it to form a concentrated solution. Special light filters are required when panchromatic plates are used, and also in the case of recording the various shades of colour produced on polished specimens by suitable heat-tinting or oxidation etching, by the aid of the auto-chromatic plates successfully introduced by Lumière.

When particularly high-resolving power is required from a microscope lens-system, it is found that this advances in direct proportion to any decrease in the wavelength of the light used. Thus for very high powers, when research is being undertaken into the inner structures of eutectics, or of microscopical constituents the exact shape of which is not revealed by ordinary white light, it is possible to make use of ultra-violet light. By utilising the special objectives known as "monochromats," designed from the formulæ of Dr. M. von Rohr, which are corrected for ultra-violet light having a wavelength of $275\mu\mu$, the resolving power is double that of a similar numerical-aperture ordinary lens. These lenses are made of quartz which has not been fused, as this destroys their refractive index, but simply rendered plastic by heating in an oxy-hydrogen flame, and then moulded to the approximate shape required. The polishing to the correct shape requires special care, and they can, of course, only be used with this light, being quite useless for light of different



FIGS. 9 AND 10.—(V—50—X.)

wavelength, particularly daylight. The 6-mm. objective is used dry, but the two higher powers available for magnifications between 3,000 and 5,000 diameters, and having numerical apertures of 0.85 and 1.25 respectively, are immersion systems, in which the fluid used is a mixture of pure glycerine and distilled water in the proportions calculated to give a definite refractive index.

Fig. 11.—Alpha Brass—Specification A (V—50—X).

The eyepieces, for projecting the image on to the photographic plate, are also made of quartz, and similarly the necessary condensers in the illuminating apparatus are made of the same material. So, too, are the two right-angle prisms used on the optical bench for reflecting the light emitted by a nearly continuous series of sparks, produced by the Leyden jar and large induction coil, between the points of the cadmium electrodes. The photographic apparatus recommended for use with this outfit is the vertical form of camera attached to a steel upright which can be swung about its bottom pivot, and thus alternately bring into position over the microscope eyepiece, first the searcher, consisting of a fluorescent screen of uranium glass to render the otherwise invisible image capable of being focussed by a powerful

FIG. 12.—ALPHA-BETA BRASS—SPECIFICATION B (V—50—X).

magnifier, and secondly, the camera itself, which, if approximately 30 cms. extended, permits the exposure to be made without further inspection.

In working with this arrangement whilst conducting some research work for Prof. K. Friedrich at Freiberg Bergakademie in 1907, the writer overcame the inconvenience of the vertical camera arrangement, which at high powers did not record a sharp image even after the searcher had done so, and therefore a final focussing was needed on the full-sized fluorescent screen. To do this the Martens' horizontal stand was selected, and after the desired spot had been photographed by ordinary white light emanating from the right-hand side, the sliding objective changer and prism were exchanged for the quartz set, and the same spot was examined and photographed by the pencil of ultra-violet light coming from the special illuminating table placed on the left-hand side, as

FIG. 13.—ALPHA-BETA BRASS—SPECIFICATION C (V—50—X).

shown in Fig. 5, Fig. 6 showing the original arrangement used. The structures examined were chiefly of non-ferrous alloys from the famous series of arsenides and sulphides investigated by Friedrich, and in several cases structures and shapes not previously revealed were made clear by the aid of the ultra-violet light photo-micrographs[4], some of which have already appeared in "Metallurgie," Vol. V., Heft 20, of Oct. 22, 1908, p. 593. That the microscope fitted with ultra-violet light apparatus is an instrument of greater precision and power than any other available for micro-metallography is only now being appreciated in some quarters.[6]

Microstructures.—In the scope of non-ferrous metallography there is a very great variety of known types of structure, and an even richer vista opens before the practical worker in this field than in the general run of the ferrous metal-structures.

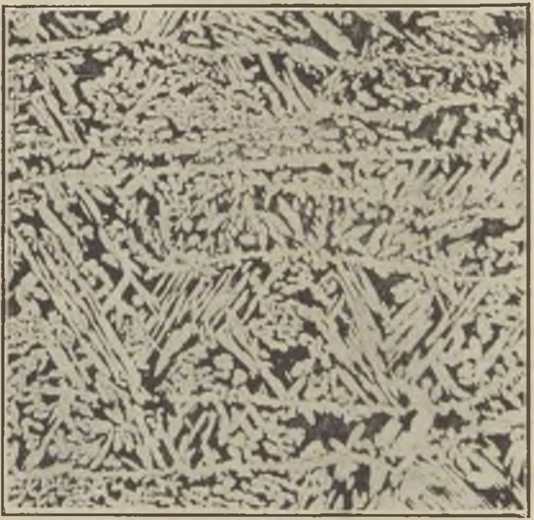


FIG. 14.—ALPHA-BETA BRASS—SPECIFICATION G (V—50—X).

To the research student there is an even greater possibility of variations, and the careful development of these by suitable polishing means and selective etching reagents is a very interesting and instructive range of work. Numerous lists have appeared from time to time of special agents of limited application, but it is surprising what generally useful application can be made of the old ferric chloride solution in the majority of practical working cases.

Referring to a series of zinc-base alloys, quite remarkable types of structure can be revealed in these by proper etching. The simplest is the well-known cubic or rhombohedric formation when a definite compound is formed and has but little solubility in the matrix. The size of the separated particles reflects accurately the rate of cooling attained by the mass, and Fig. 7 shows how, in the case of hard spelter in accretionary form, it can

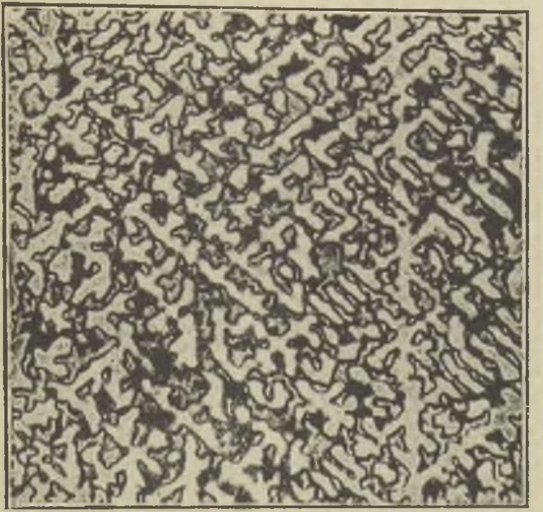


Fig. 15.—Well-Cast Phosphor-Bronze (V—50—X).

quite suddenly change the size of the crystal grains separated. The average analysis of this dross showed 3.5 per cent. of iron (which was practically all united with the zinc, forming the higher melting-point crystals which were the first to separate as the mass cooled), and 1.5 per cent. of lead, not visible in the zinc-rich matrix etched black in the photo-micrograph taken at 50 diameters.

The " onion " type of freezing suggested by Professor Howe[5] is an almost ideal form of structure for certain purposes, but it is very rarely met with in practical experience, about the only example known to the writer in his small amount of nonferrous metallography work being the Prana alloy

No. 4, shown in Fig. 8 at 50 diameters magnification. In this view, the alternate layers of light and dark etching constituents are distinctly arranged in concentric formation, except where two or more crystallisation centres mutually interfere, and produce a double right-angled appearance shown at the bottom of the figure.

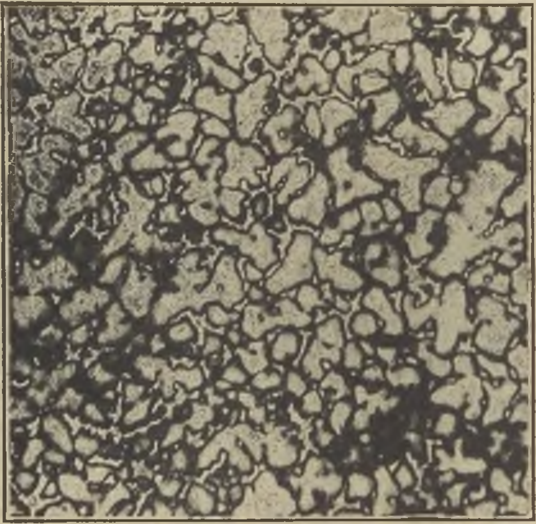


Fig. 16.—Phosphor-Bronze Cast at too Low a Temperature (V—50—X).

Needle-shaped spines and conglomerates of these into stars are common non-ferrous alloy formations, and these show up the more clearly when the matrix containing them is eutectiferous, and thus of much lower melting point. Thus Figs. 9 and 10 show two zinc-base alloys to which both aluminium and copper have been added in the following percentages, in the endeavour to secure a suitable fuze metal to meet the specification called for and detailed in the table (page 123).

Fuze Metal.	Zn	Cu	Al	Pb	Tensile.	Compression.		Hardness.
						El. Lt.	Ul.	
					Tons.	Tons.	Tons.	
Fig. 9	92	2	6	tr.	6	21	56	105
Fig. 10	90	5	4	1	15	33	58	—

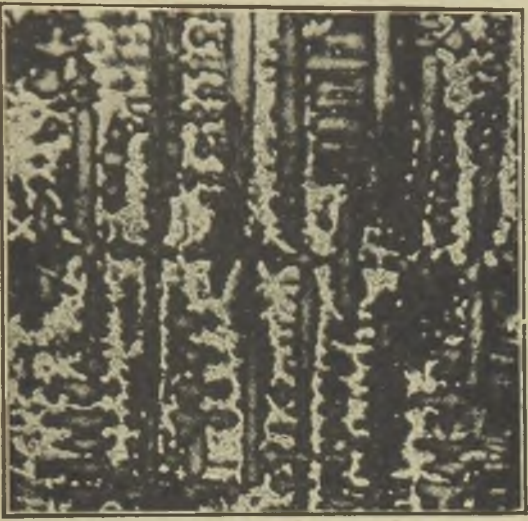


FIG. 17.—BRITTLE PHOSPHOR-BRONZE (V—50—X).

The specification called for a compression breaking load of not less than 60 tons per sq. in., whereas the above did not quite come up to this. The elastic limit in compression, well over 20 tons for both above samples, was not definitely called for, but after a load of 8 tons per sq. in had been applied, the cylindrical test piece must not show a reduction in length of more than 1 per cent. As a measure of ductility and ability to forge, the specimen should not show any signs of cracking after it had undergone a 35 per cent. reduction of length. In making the tensile test, the ductility, as measured either by percentage elongation or reduction of area, was not deemed sufficient, being only 1 per cent in each case. The alloy containing lead was still less ductile, and only recorded 0.5 per cent. elongation on the standard 2-in. gauge length. Although these alloys were understood to be forgeable at 250 deg. C., it was generally found advisable to take them up to about 400 deg. C., but it was necessary to heat them up slowly, first to about the 250 deg. C. in an oil bath, and then for a few minutes at the front of a gas furnace, before being stamped in the screw press, to get the rough forging suitable for subsequent machining.

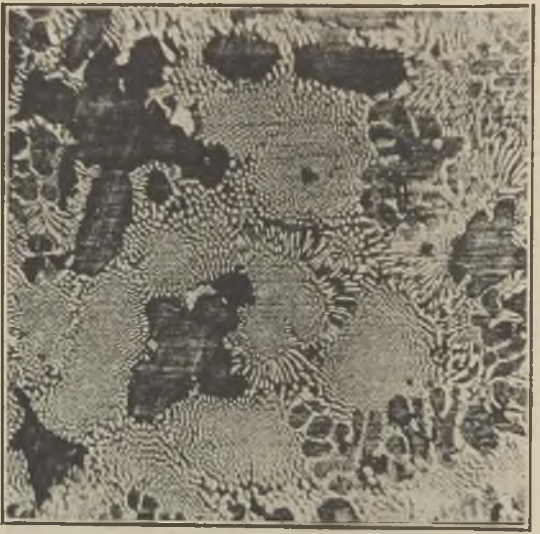


FIG. 18.—" SWEAT " FROM PHOSPHOR-BRONZE (V—50—X).

Brasses.

The foregoing zinc-base alloys were never able to replace successfully the forging brasses for the purposes of fuze metal, and four micrographs

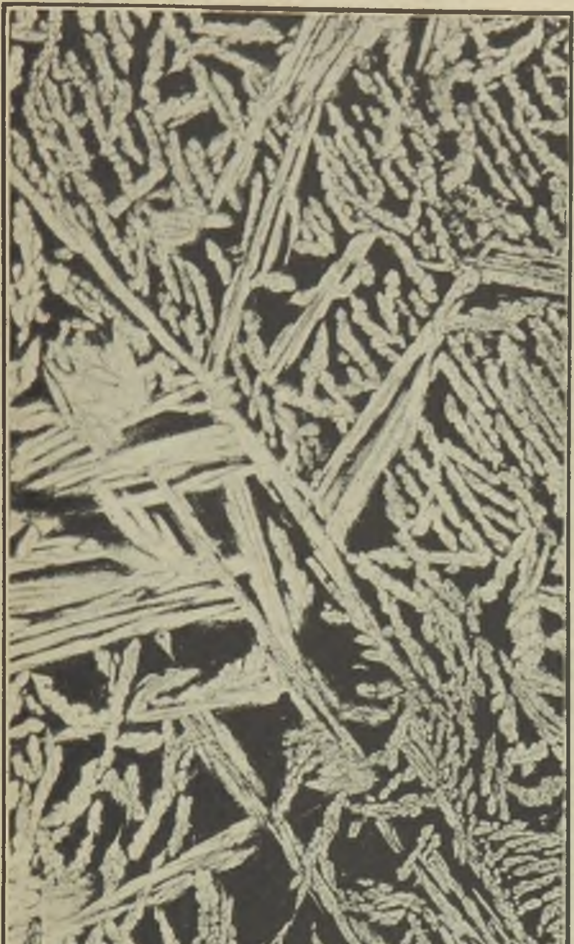


Fig. 19.—Aluminium-Nickel-Bronze at 50 dias.

Fig. 20.—Aluminium-Nickel-Bronze at 200 dias.

(Figs. 11 to 14) at 50 magnifications clearly show the differences between the grades of alpha-brass and the several grades of alpha-beta brass around the 60:40 composition, all of which were forgeable but which possessed different degrees of machinability. Table I serves to compare the specified strengths of the several classes with the actually attained physical characteristics corresponding to the four different structures shown.

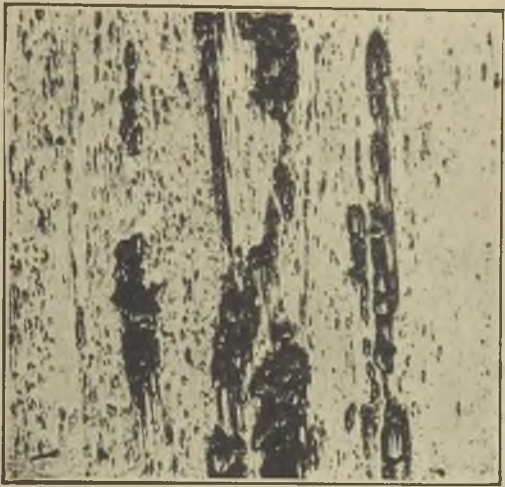


Fig. 21.—Copper and Copper Oxide (V—100—X).

In the case of detent parts, the necessary physical properties could rarely be attained in the plain casting, and the necessary forging, after heat treatment, was needed to reach the high values shown under class "A." Both "B" and "C" could best meet the requirements if the metal were carefully melted, without stewing, before being cast into chill moulds. With moderate care the requirements of "C" could be met without this precaution, but as common scrap materials were often utilised in its manufacture, sufficient care was not often expended in keeping

TABLE I.—*Correlating Mechanical Properties of Specified Brasses with the Micro-structure.*

Fuze Metal.		Class.	E.L. Tons/sq. in.	T.S. Tons/sq. in.	E. per cent.	R.A. per cent.	Brinell hardness.
Alpha brass	(Specif.) ..	A	20	30	20	—	—
	(Fig. 11) ..	A	20.4	40.2	23.5	23.1	170
Alpha-beta brass	(Specif.) ..	B	12	20	30	—	—
	(Fig. 12) ..	B	13.2	30.8	32.1	27.2	110
Alpha-beta brass	(Specif.) ..	C	6	12	10	—	—
	(Fig. 13) ..	C	10.8	29.2	16.8	19.0	120
Alpha-beta brass	(Specif.) ..	G	8	20	20	—	—
	(Fig. 14) ..	G	9.4	23.2	29.0	32.9	105

In compression (Fig. 11) .. A 22.2 62.7 13 on 1in. at fracture; and only 10 per cent. reduction in length after the application of 40 tons per sq. in.

TABLE II.—*Correlating the Chemical and Mechanical Properties of Bronze with the Micro-structure.*

Fig. No.	Analysis of bronze.			Physical tests.				Brinell hardness.
	Copper.	Tin.	Phos.	E.L. Tons/sq. in.	T.S. Tons/sq. in.	E. per cent.	R.A. per cent.	
15	86.6	12.2	0.06	10.0	15.2	5.3	4.9	90
16	85.6	11.2	0.29	3.0	10.0	1.8	1.2	70
17	85.0	14.3	0.18	2.5	6.0	2.0	1.0	105

the melt free from dross. The "G" metal used for the forging proper was usually best cast in a chill mould, and in many cases the subsequent forging or press-stamping operation in the hot state imparted an elongated form to the constituents, similar to that often observed in extruded metal.

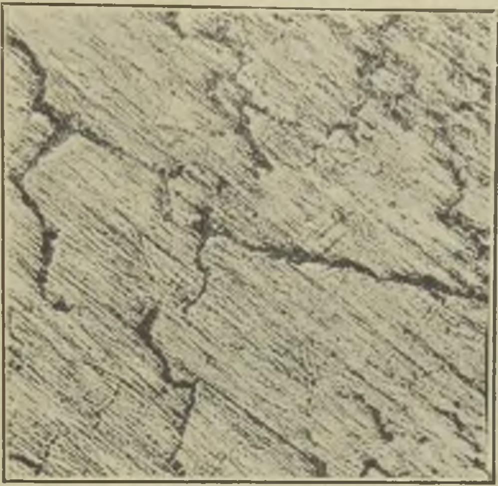


FIG. 22.—GASEOUS INTERGRANULAR PENETRATION RENDERS COPPER ALLOYS BRITTLE (V—200—X).

Bronzes.

In the tin- and phosphor-bronzes which are most commonly used for bearing metals, one of the most important matters is to ensure, apart from their soundness and freedom from blow-holes, the proper structural arrangement of the primary copper-rich crystallites, which should form the interlocking type of arrangement, and have the inter-special delta material in small, uniformly distributed, and, if possible, isolated patches. Figs. 15, 16 and 17 show, with the accompanying physical tests (Table II), the effect of attaining or losing this desired structure.

The structure shown in Fig. 15 is that of a well-cast metal, the temperature having been suitable for the size of article involved. By contrast, the metal shown in Fig. 16 has evidently been cast at too low a temperature, and resulted in the suppression of the dendritic growth of the primary crystals, whilst the eutectoid has formed an almost continuous network in spite of the lower tin-content than No. 15. In addition to being deficient in strength, this bearing would not stand up to such prolonged wear as the first. An exceedingly brittle arrangement of the constituents is the rectangular one shown in Fig. 17, which metal was not chill-cast, as it might appear to have been. Such a bearing metal might stand up fairly well if put into service where no serious shocks were likely to be encountered, but even then the large amount of delta-eutectoid present

FIG. 23.—NORMAL ANNEALED STRUCTURE OF HIGH MAGNETIC PERMEABILITY FERRO-NICKEL (V—400—X).

would be apt to promote scoring of anything less than a hardened journal.

When large percentages of tin are present, either alone or along with some residual phosphorus, there is a great tendency for some of this delta-eutectoid to exude or ooze out of the casting, particularly from the riser and runners, as the metal cools and contracts. The erroneous idea that this "white" metal is purely tin is not only clearly proved by analysis, but also, when the particles are too small for this, by the microstructure they show. Fig. 18 indicates the complex nature of this "sweat," since, in addition to the ternary eutectic of copper-tin-phosphorus, there are quite an appreciable number of the dark-etching copper-rich dendrites present. Naturally, such pellets are exceedingly brittle, and indicate the extent to which segregation can occur within drawn places inside the casting.

Aluminium Alloys.

So many of these have now been utilised in the foundry and fully described recently that it is not necessary to recapitulate those of the low specific gravity end of the diagram. There are still many avenues of the copper-aluminium alloys to be explored, and a very interesting case of the remarkable property some of these have of self-annealing themselves in the process of casting came to the writer's notice. A very heavy-duty bevel-wheel of over 3 cwts. had been tried in several alloys, until a mixture was finally recommended and tried which contained copper, 83; aluminium, 10; nickel, 6; and zinc, 1 per cent. A separately-cast test-bar was found to be similar in strength and structure to the risers of comparatively small section. It was not, however, until the machine was being scrapped in which the actual wheel was used that portions of it were examined for structure, and the comparison is shown in Figs. 19 and 20. In the former at 50 diameters the structure is of the simple alpha-beta type, due to the comparatively rapid cooling. The larger mass, which had cooled more slowly, showed the complete change possible in this type of structure due to self-annealing, whereby the beta constituent can break down into either a gamma or delta eutectoid which forms the interspacial matrix around the primary crystals rich in copper, and in this case containing most of the nickel in solid solution. The minute nature of the particles in the eutectoid will be realised from the greater magnification of 200 diameters required to resolve it in the photo-micrograph, Fig. 20.

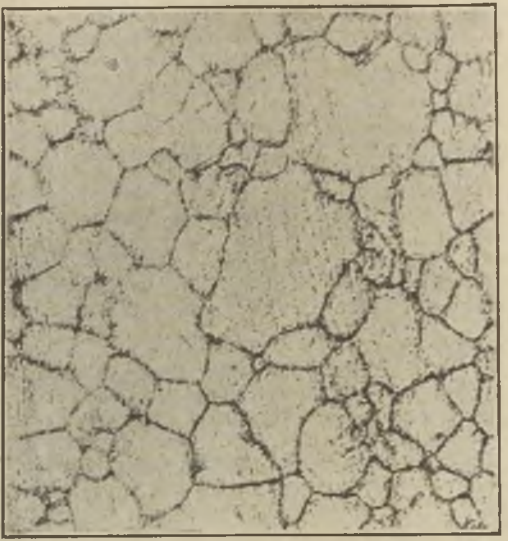


FIG. 24.—SHOWING INFLUENCE OF GASSING THE ALLOY SHOWN IN FIG. 23 (V—400—X).

Copper.

Apart from the harmful amount of oxygen sometimes taken up by copper when remelted from ingot form, there has recently been a crop of obscure troubles in refined copper, chiefly of American origin, which has been put down to "gassy" copper. A considerable amount of research work has been expended upon this matter, and the result points to two causes; one of which is an excessive amount of oxygen present in the form of cuprous oxide, and the second cause to copper with a more moderate amount of oxygen which very readily became brittle on being heated in a reducing atmosphere. When copper is being refined, or even when electrolytic copper is being melted to cast it, cuprous oxide forms rapidly, and is soluble to a slight extent in the molten copper. It should be almost completely removed by the poling operation, and only sufficient left to control the "setting" of the open-mould cast-bars to produce the required level surface in the common "crimped" form. If too long a time elapses during casting and before poling is again resorted to, there is a danger of an excessive amount of oxygen being taken up, and this commonly shows itself in a layer near the top skin of the ingot or bar, and in certain cases it even exudes as small pimples on the ingot surface. The analysis of such metal may be all that is desired, apparently, as it is somewhat difficult to estimate oxygen content, especially when so completely segregated, but the microscope reveals the harmful effect very clearly. Thus Fig. 21 at 100 magnifications shows not only the easily-recognised eutectic structure of copper with cuprous oxide in the copper ground-mass, but also considerable masses of free oxide in slightly globularised strings occurring near the surface even after the copper has been reduced in size, and any possible excess-scale given every opportunity of being removed. The only cure for this fault is better casting conditions and care in obtaining the correct casting temperature.

The other trouble caused by gassing in a reducing atmosphere has long been known as the effect of reducing the copper oxide, which occurs in less highly-enriched copper as pearlitic patches of eutectic at the grain boundaries. This produces spongy material around the grains of copper and causes pronounced brittleness, as the fracture always occurs between the crystal grains. A very useful form of heat-treatment has recently been devised to overcome this possibility of brittleness, the explanation for which is clearly shown in the photo-micrograph, Fig. 22, revealing the intergranular nature of the gaseous penetration. It has been found[7] that by a proper annealing, followed by slow cooling, the cuprous oxide meshwork can be spherodised just like pearlite, and balled up into tiny patches located throughout the copper matrix, without being in the grain boundaries. The gassing or heating in any reducing atmosphere no longer had any harmful effect upon the ductility of the metal, because where the cuprous oxide had been there only remained tiny

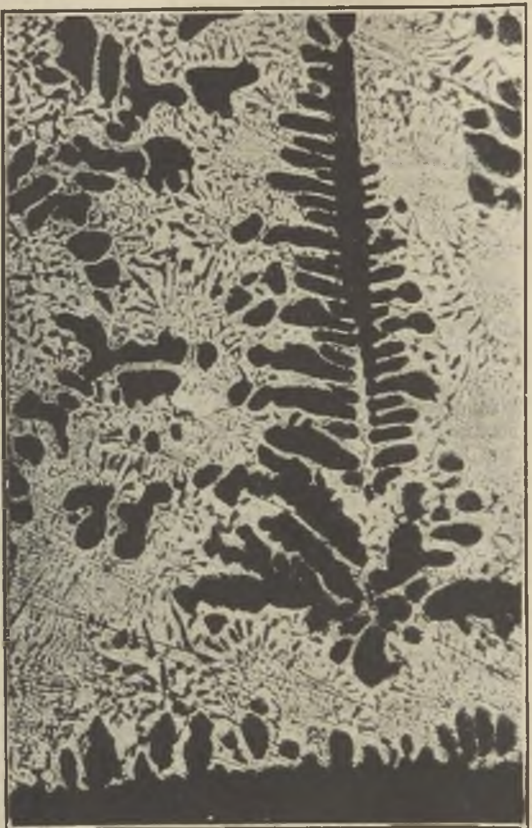


Fig. 25.—Silver Solder—the Normal Structure (V—500—X).

holes in the metal lined with spongy copper. Since these blow-holes were scattered through the metal in disorder, no brittle grain boundaries were found to exist, and the trouble was eliminated.

Nickel Alloys.

The extent to which nickel and its alloys can be rendered non-malleable by oxygen is only slight compared with the astonishing effect which sulphur has in this respect. The former idea that the addition of magnesium had the effect of removing the oxygen has now been dispelled, and the true case for the expulsion of the sulphur by magnesium has been demonstrated.[8] A remarkable similarity has recently been found in the working of some of the nickel alloys with that of copper, in regard to its ready embrittlement when being annealed, a structure exactly resembling that of "gassed" copper resulting. One of the new alloys of ferro-nickel renowned for high magnetic-permeability, shown in Fig. 23, illustrates the normal structure of tough and ductile metal when it has been properly annealed. Whenever the temperature is sufficiently high, and gassing conditions prevail, then the surface is converted into a mass in which the grain boundaries are embrittled, and differ considerably from the normal metal. Such a state of affairs is shown in Fig. 24, which deleterious effect can only be removed by strong chemical or mechanical means when the unattacked portion retains its customary properties.

Silver Alloys.

One of the most useful applications of this semi-precious metal to engineering purposes is in the preparation of the so-called silver solder, which consists of a brazing metal to which a varying proportion of silver has been added. This series of alloys gives rise to some of the most interesting forms of eutectic structure, which is capable of numerous modifications. In the usual variety for high conductivity work, the percentage of silver added is usually 8 per cent., and when used in conjunction with copper the initial copper-rich crystallites to form are generally well-marked and contiguous to the joined surfaces. Further in, as shown in Fig. 25, the tree-like forms of these crystallites have free scope to develop in the silver-zinc eutectic, which can form beautiful patterns, most of which are highly-ductile for such

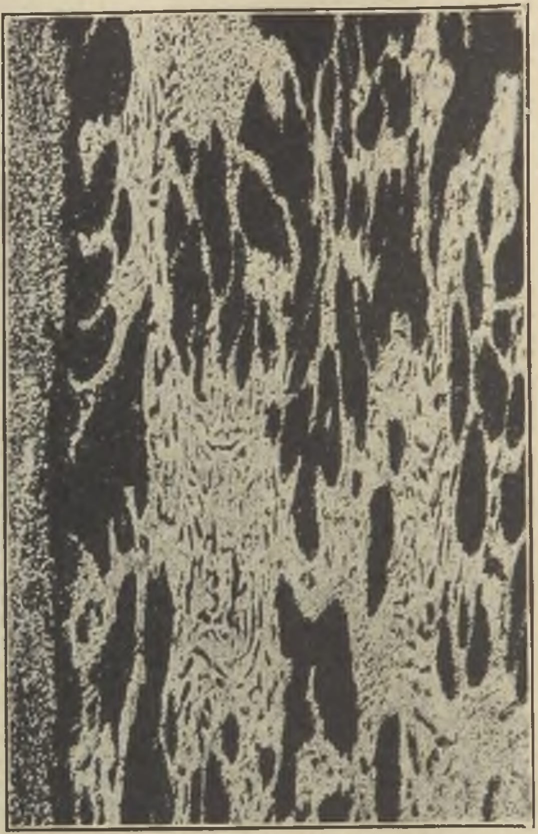


FIG. 26.—SILVER SOLDER IN A BRAZED JOINT (V—500—X).

a material. Thus when the cross-sectional area of the braze has been considerably reduced, the deformation figures of the copper-rich crystallites and the surrounding eutectic are often grotesque, but indicative of strength and non-liability to parting company, as seen clearly in Fig. 26, which, like the former photo-micrograph, has been taken at 500 diameters magnification, and shows the copper base with the solder attached.

Conclusion.

The enumeration of cases in which the microscope can prove of inestimable value to the non-ferrous metal worker is almost endless, but it is hoped that the present selection of instances and illustrations will serve to assist those who have not yet seriously contemplated the installation and continuous application to practical purposes of a reasonably good microscope, and wherever possible a serviceable photographic outfit, in making a step in that direction, since the knowledge gained in this way cannot be equalled by that obtained in any other direction, and is most fruitful in attaining better results when applied in common-sense manner.

The writer desires to express his indebtedness to Mr. H. S. Primrose, M.I.M., for assistance in connection with the analyses quoted, and also to the numerous firms whose products have been investigated and reported above.

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[7] S. B. Leiter, "Annealing of Commercial Copper to Prevent Embrittlement by Reducing Gases," American Institute of Metals, February, 1926.

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DISCUSSION.

Dr. H. **Hyman**, Ph.D., said that the Paper was of the usual high standard associated with Mr. Primrose. The only criticism he had to make was with reference to the alloys in Table I and the corresponding micro-photographs. In connection with specifications A and B, the Alpha brass was made to give a higher tensile and elongation than the Alpha-beta brass, but that was not in accordance with the general custom. Usually, Alpha-beta brasses gave high tensiles and low elongations and Alpha brasses lower tensiles and correspondingly higher elongations. He asked whether it was not possible that the photograph illustrating the Alpha brass was really a Beta structure. Perhaps the analyses representing classes A and B would help to clear the matter up.

Mr. E. **Longden**, referring to the remarkable micro-photographs showing the effect of the rise of casting temperature, said it would be very illuminating if Mr. Primrose would carry out some experiments on the use of hot moulds. There had been some wonderful results with the Lanz process, and modifications of it in connection with cast iron, but he did not know whether similar results would be obtained with non-ferrous metals.

Mr. P. A. **Russell** thanked the author for the Paper, and particularly for supplying what he had called standard micro-photographs for purposes of comparison. His (Mr. Russell's) firm ran both an iron foundry and a brass foundry, the latter being only a small part of the foundry concern, and they had found the microscope of enormous advantage in investigating the troubles that arose, and which seemed to be even worse in brass founding than in iron founding, particularly with regard to casting temperatures.

Mr. **Fletcher** thanked the author for emphasising the necessity for examining one particular area of a specimen instead of moving about. He himself had adopted that particular practice for 25 years. Some of those who had not had very long experience might benefit greatly by what the author had said, and they all thanked him for his usual wonderfully clear work.

Mr. A. **Logan** said the author had rightly emphasised that very high magnifications were not really required, and that applied to the iron foundry as well as the brass foundry. In the majority of cases it was not necessary, for works practice, to go beyond 150 diameters. The point needed emphasis because the microscope was looked at by some folk with feelings of awe, and some were rather discouraged to adopt the microscope on account of the skill and manipulation required. With regard to the use of screens, mention was made of the K.10 yellow screen as being the most generally useful. He asked if this was a misprint. He was very interested in the author's description of the use of ultra-violet light for high resolving powers. Although ultra-violet light was of very great practical use for pure research work, he was inclined to think that it would be some time before it would come into general use in works practice. There were many difficulties and troubles attendant upon its use. The self-annealing of certain aluminium alloys was also a very interesting point. He believed most types of Alpha-beta structure showed this phenomenon, given suitable conditions. The same thing occurred in connection with alpha-beta manganese brass. In fact, in the production of such castings as propellers automatic annealing of the casting in the mould was purposely arranged.

Mr. N. D. Ridsdale (Middlesbrough) asked what colour process the author considered to be the best for colour photography through the microscope. He understood that the "Lumiere" process generally gave rather a dense picture, which was too dense if one wanted to use the colour transparency through the lantern for lecture purposes. He asked whether the author had ever used the Paget colour process, and whether he considered it to be more suitable on account of the more transparent picture produced.

Mr. Wesley Lambert (London) expressed his appreciation of the paper, and suggested that, being now in possession of this paper, which covered the general ground of the apparatus used in the laboratory in connection with the examination of the microstructure of metals, we should not require any more papers of this kind. This paper should be regarded as a text-book so far as the apparatus is concerned, and what was now wanted was papers dealing with the microstructure of particular foundry alloys. The analysis should be clearly stated, together with the conditions under which the alloy was compounded, the size of the sections from which the pictures were taken, and so on. The specimens to be cut from castings produced both under ideal conditions and improper conditions, and the photomicrographs should be clearly interpreted, so that a student could familiarise himself with the micro-constituents and also the defects of any particular foundry alloy. His experience was that the young operator had considerable difficulty in correctly interpreting what he saw under the microscope. He would like to impress upon the younger members who were taking up the use of the microscope for the the investigation of alloys, that it was on the lines he had suggested that they might do valuable work. What he had in mind was that brief papers should be presented to the Institute giving photomicrographs obtained from castings made in any one of the commonly used foundry alloys, from metal in both the normal and abnormal conditions.

AUTHOR'S REPLY.

Mr. **Primrose**, replying to the discussion, said that the alloy A, in Table I, compression was found to give a percentage of elongation of 13 on 1 inch. Referring to Dr. Hyman's remarks as to the physical properties of the Alpha and Alpha-beta brasses, he said he could assure Dr. Hyman definitely that the A specimen of Alpha brass came within the 70/30 range. He could quite understand the doubt as to its physical properties being as stated in the table, because the " A " metal brass had had to be forged in order to attain the values given. The brasses in Figs. 12 and 13 were as cast, and that in Fig. 14 was forged. That might be the reason for the slight difference in physical properties that Dr. Hyman had commented upon.

In reply to Mr. Longden, he said he had not tried specially hot moulds for casting non-ferrous metal. It was obvious, of course, that the mould must not be in such a condition that moisture might condense on it; slight heating of the mould was found to be advantageous, but when it became too hot, troubles such as segregation arose.

In reply to Mr. Logan, he said he certainly had considered that a K.10 screen was one of the most generally useful. It was a fairly dark yellow. On one occasion he had used two of them as two screens of gelatine which alone were not quite dark enough. He believed they were equivalent to a K.10. He had not used the green filter much, but the yellow one he had found to be very useful for non-ferrous and even for some ferrous metals. With regard to the suggestion that 150 diameters was the highest magnification necessary for works practice, he said he had sometimes slightly exceeded that, especially where very small grain size was involved. As a rule, however, he liked to work in multiples of the lowest power obtainable with the ordinary lenses of the microscope. In many microscopes the lowest was 50, and could be worked up to 100, 200, 400 or 500 and 1,000 in simple multiples. He used a graph which had been prepared by micrometric measurement, and by looking at that graph he could see to what distance he must extend the camera in order to get a magnification of 200 or 500, as the case may be, instead of selecting a suitable place to photograph, and finding afterwards that it was 197½ or some such figure, whereas by a slight movement of the camera he could have got exactly 200 diameters.

The use of ultra-violet light might come into use to explore some of the points which even yet we were not certain about.

It was all very well to regard his Paper as a text-book, but he was afraid that it was subject to revision as progress continued; he had merely given what he had found up-to-date.

Replying to Mr. Ridsdale, with regard to colour photography, he said he had experience only of the "Lumiere" plates, and had found that after he had used them in the lantern a few times they became so dense as not to reproduce the colours on the screen. Mr. F. Law seemed to have got over the difficulty of colour transparency, and had exhibited some admirable examples of colour photographs, but whether they had ultimately become dense after continued use he did not know.

Finally, he thanked Mr. Lambert for his inspiring suggestions.

SOME NOTES ON THE PRODUCTION OF CYLINDER PIG-IRON TO FRACTURE AND ANALYSIS.

By E. J. Yates, B.Sc. (Met.).

The object of this Paper is to outline some of the difficulties and experiences on the production of cylinder pig-iron from the metallurgical and technical points of view. The task may be defined as an undertaking " to produce a cylinder iron of constant dense grey and close fracture to the following characteristic analysis: Total carbon under 3.2 per cent. and the silicon varying between 1.2 and 3.0 per cent."

The writer's experience has been at the Goldendale furnaces. These furnaces are peculiarly suited for this work, the output being small and the driving very slow, with a low-blast temperature; obviously the cost of making is far higher than with modern furnace practice based on large outputs.

Undoubtedly both the fracture and analysis are necessary for a complete definition of an iron, coupled with a very important proviso, *i.e.*, the type of furnace used. The iron produced in a small, slowly-driven furnace is of very different type from that produced from a large and more rapidly driven one.

These factors of furnace design, blast temperature and slow driving at the Goldendale furnaces are responsible for the low total-carbon iron produced, which is definitely suited to cylinder-casting manufacture.

Most careful attention is given to details of furnace working, both as regards quality of product and also the percentage produced. These factors are to be borne in mind during the subsequent part of this Paper.

There is on view at the Exhibition a dual series of fractures of this pig-iron. One series shows how the fracture can vary progressively from open iron to white iron, the silicon content of the series falling between 2.26 and 2.06 per cent., for all intents and purposes a uniform figure. The other series shows how the cylinder fractures are indistinguishable, with the silicon varying progressively from 1.4 to 4.6 per cent. It must be emphasised that these pigs have been normally cooled in the pig beds, the cooling conditions changing only with the seasonal variations.

These specimens show how the fracture and the most important element of the analysis, which is usually regarded as the controlling criterion of fracture, are not necessarily related at all.

It is usually taken for granted that the more open the grain the higher the silicon, and up to a point that is true; but by varying the operating conditions of the furnace, however, the whole range of silicon contents may be altered. So one gets the apparent anomaly of an open-grain iron containing 2 per cent. silicon and a close-grain cylinder iron with 4.6 per cent.

It is as well to digress for a moment. These terms "open" and "close" are difficult to define. The usual way is by numbers—No. 1, No. 3, etc., but this is a purely arbitrary one, and it is generally found that the grading of pig-iron is in the hands of the senior piglifter. This is not as it should be. The size of the graphite flakes varies over the face of a pig in a No. 3 iron, for instance, and together with the relative amounts determine the class into which the iron is to be placed. These fracture numbers from different plants bear a general analogy, but the only way would be to measure the average size of the graphite plates.

The phosphorus-content of the iron is entirely dependent on the amount present in the furnace burden, and all the phosphorus goes into the metal. Consequently, it is a serious matter to alter the phosphorus, necessitating a radical alteration in the burden, with consequent changing of supplies of raw material.

The manganese content is dependent on the furnace. Of all the elements, this is the least under control in cylinder iron. A partial reduction only takes place, and whilst the proportion of the manganese thrown into the iron remains tolerably constant for open irons, it dwindles rapidly as the furnace changes "colder," and a much smaller proportion passes into the iron when the furnace is comparatively cold and producing white iron. Cylinder irons are on the border line between white and open irons, and this results in a very variable amount being reduced.

Sulphur is always the *bête-noir* of the blast furnace, and it is advisable to carry a fair proportion of manganese to keep this within bounds —particularly when using coke high in sulphur (1.3 per cent.).

But there is another point of view. A high-manganese pig is desirable in the foundry. There it again helps to cure the equally important and pernicious problem of sulphur in the cupola. The sulphur in ordinary small proportions exists in high-manganese iron as manganese sulphide, which is innocuous compared with the iron sulphide in low-manganese irons. The manganese sulphide shows a tendency to slag off in the cupola, and a fair proportion of manganese in the cupola charge is an almost automatic antidote to sulphur. Manganese has no deleterious effect when present in amounts insufficient to cause brittleness, say under 2 per cent. to be on the safe side.

It must be understood that whilst a great measure of control is exercised in a blast furnace by very careful attention to the many variable factors, the only way finally to grade is by analysis.

Thus there is the twin specification of fracture and analysis as a complete description. Both are of great importance, but neither is complete in itself.

The fracture is a guide to the internal structure of the metal, which is, after all, the main consideration in the finished casting. Remelting an iron does not destroy its original structure, though it may be modified due to varying cooling rates, but as ordinarily cast, the structure obtained is the same as in the original pig.

The fracture shows the macro-structure of the pig, and this is a physical test which, roughly speaking, gives a clue to the micro-structure. The size of the graphite flakes bears a very close relationship to both the total carbon and the combined carbon, irrespective of the other constituents. These two, perhaps, form the most important factors in the properties of the finished material.

It will be seen that up to a point the fracture is an adequate guide. It shows the main properties of the material. The chemical analysis alone is no guide to the fracture. Given any particular analysis, it would take a very bold man to state the fracture. The fracture shows immediately the size of the graphite plates which have such an important effect on the physical properties, but the chemical analysis gives no clue whatever to this.

How can analysis reconcile the difference between two similar fractures of close cylinder iron from two different plants, one with 3.2 per cent. total carbon and the other with 2.9 per cent.? This is bound up in the question of manufacture, and each blast-furnace plant, under its own individual conditions, despite the similarity of ores used, etc., produces a distinctly different product.

Yet, as has been seen, the fracture gives no real clue to the micro-structure. The fundamental difference between 1.4 and 4.6 per cent. is enormous, and yet the two fractures on view are indistinguishable. The "fracture diviner" is here at an utter loss, as is likewise the chemical analysis by itself. Whence lies the difference? It is solely in the differing operation of the blast furnace itself.

The analysis gives the final key to this structure. The analysis, *per se*, is useless; it must be translated into the terms of the structural analysis. From the foundryman's point of view the analysis is important, but it is only of real service if he knows the analysis of the scrap used and the required analysis of the finished casting.

The structure of a cylinder iron produced in a slowly-driven furnace is much more uniform, and a more even and regular distribution of the micro-constituents is found. The distribution of the micro-constituents, apart altogether from their incidence, plays a very vital part in the physical properties of the finished casting. In practice, for some inexplicable reason, such iron mixes more readily and easily with the other proportions of the cupola charge, and produces a stronger iron.

The vital factors in the fixing of a specification are—the type of iron desired and the limits to which the manufacturer can reasonably keep in supplying the iron consistently.

A close specification is possible for small amounts of material for special work, but where consistent supplies are demanded, it proves very awkward to get such supplies consistently. The terms of a specification should not be too rigidly fixed. On one occasion it may be possible to meet it, but on another no material may be available.

What are the possible permutations and combinations amongst fracture, total carbon, combined carbon, silicon, manganese, and phosphorus? Pig-iron is not like steel, where the operation is under excellent control. Each one cannot be strictly specified to small limits.

The silicon limits usually worked to are with a 0.5 per cent. allowance, say from 1.5 to 2.0 per cent.; 2.0 to 2.5 per cent.; 2.5 to 3.0 per cent., and so on. It is only in very special work that any closer limits are any use to the foundryman. His own scrap must indeed be above any suspicion if a closer specification is to be of any benefit at all.

An important factor in the supplying of pig-iron to analysis is the sampling. Special steps are taken at the Goldendale furnaces to ensure the greatest possible homogeneity throughout each cast, but it must be remembered that the pig-iron from a blast furnace is liable to slight variations in composition. Three pigs are sampled for drilling—one from the commencement of the cast, one from the middle, and one from the end, and the average of these is the average analysis of the cast.

Some standard method of drilling the sample pigs is desirable. Slight variations occur over the surface of the pig, particularly with regard to the combined carbon and the sulphur. A fair way is to drill the pigs through from bottom to top, omitting, of course, the skin by a previous skimming and rejection of the drillings. The skin of a pig is invariably high in sulphur, and if included is liable to upset the estimation of sulphur and silicon.

With regard to the variations in analysis obtained between one chemist's determination and another's, these can, in the majority of instances, be traced to variations in the method of sampling.

On a given sample the results do not, as a rule, vary appreciably. Varying methods of analysis do occasionally cause dissension. Standard methods of drilling for sampling and analysis are urgently required, and a very useful purpose would be fulfilled if these could be settled. One of the technical bodies now existing could serve a very definitely useful purpose by so doing.

When ordering pig-iron it saves much trouble if the question of the specification is thrashed out beforehand. In the first place, an open discussion as to requirements will clear the air and enable the definite requirements of the foundry to be formulated.

Different foundries attach quite special importance to portions of the specification, which others almost ignore. If such points are cleared up it saves expense. For instance, it is quite absurd to specify combined carbon which cannot fit in with the fracture desired. Yet such occurrences do happen. A frank discussion with the supplier always repays itself, particularly with regard to the fracture desired.

The suppliers are always open to giving the correct material desired, and are anxious to avoid that almost, in practice, water-tight division between the blast furnace and the foundry. No specification is universal, and it is apparently, as yet, hopeless to fix one. Requirements differ very much.

In conclusion, it is hoped that these few notes have given some idea of the complexities confronting those engaged in the supply of pig-iron to specification of fracture and analysis, and the writer would plead for a greater co-operation between supplier and user in the many problems and details which arise.

DISCUSSION.

Mr. J. Shaw (Sheffield) said that while he had always held the view that the ordinary analysis was not always a key to the physical properties of the iron, he must protest against the misleading statements of the author, while quoting one (silicon) constituent only. A glance at the content of the open and white samples gave an immediate explanation. To compare irons which in one case contained T.C. 3.68, Mn 2.11 and S 0.046 per cent., with another that contained T.C. 2.49, Mn 0.37 and S 0.32 per cent. simply because the Si was roughly 2.13 per cent. in each case was futile. The relation of the Mn to the S was quite as vital as silicon on their effect on the structure. The question of FeS had been mentioned in the Paper later on, and he (the speaker) would be pleased to learn if the author had ever identified FeS in cast iron even when the S was in excess of the Mn. This had been done in steel, but so far he (Mr. Shaw) had met no one who had seen it in ordinary grey iron. He was quite in agreement that some standard method of sampling should be devised, but what was of much more importance to the ironfounder was that the furnaceman should keep his casts separate and not fill an order from two or three casts. Recently four pigs were taken from a wagon and a certain mixture for some experimental work based on the figures obtained. On completion it was found that the Mn was just double that obtained from the four pigs sampled and the whole of the work was wasted. He had not been alongside a blast furnace for 15 years without some knowledge of the difficulties of the blast furnace manager, and he thought if he would submit separate casts that did not quite meet the specification, most foundrymen would be willing to consider them and help him. Mixed casts could only lead to loss of custom.

Mr. H. Field said there were two points in the Paper which called for attention. One had reference to the varying content of manganese in the so-called high-manganese pig-iron. He gathered that the North Staffordshire pig-irons—and he referred to these in the general sense—were in demand particularly because of their high manganese content. To the Midland ironfounders they were often exceedingly useful, but only in so far as their high manganese content was maintained, and he voiced the complaint, therefore, to the makers of these high-manganese irons. that the manganese content was most unreliable. During the last five or six years he had been all round the North Staffordshire furnaces in an endeavour to obtain abundant supplies of manganese irons containing always over 1.5 per cent., and often over 2 per cent. manganese—according to the makers. For his own purposes he had prepared a graph showing the variations in pig-iron, and in the present year the manganese content had varied from 0.6 to 2.9 per cent. in the North Staffordshire high-manganese pig-iron. It must be more reliable if it were to retain its reputation. Dealing with physical properties, he asked Mr. Yates whether he really had evidence that when two irons, of similar analysis but of different fracture, were cupola melted, they possessed different physical properties. Was the structure of iron maintained with equal conditions in the cupola?

Mr. Colin Gresty (Newcastle) said he had found difficulty in understanding the contradictory statements in the Paper with regard to analysis and fracture. First it appeared to be the author's view that fracture and analysis must go together, but later he suggested that one of these was useless. It was difficult to know exactly what was meant, but it appeared to him that the author had made out a very good case for analysis only, and had proved that fracture did not matter. However, he asked for more direct evidence on the point The question was wrapped up with that of whether there was any difference in the properties when re-melted of two irons of the same analysis but different fracture. He himself had never discovered any difference, and at the works where he was engaged they had never, during the last fifteen years, to his knowledge, paid attention to the fracture of any pig-iron, but had worked entirely to analysis. Consequently, he did not think there was a great deal in fracture. To the blast furnace manager or blast furnace chemist, who knew the conditions of the furnace, the fracture might be a guide in manufacture, but it appeared to be of little importance to the user. A statement made by Mr. Yates, in the Paper, that the size of graphite flakes bears a very close relationship to both the total carbon and combined carbon, irrespective of the other constituents, appeared to be somewhat ambiguous. He asked, therefore. for a definite statement as to that relationship, and whether it was really irrespective of the other constituents, because in other parts of the Paper it would appear that silicon was the vital constituent.

Mr. F. J. Cook (Past-President) disagreed with Mr. Gresty's point that it was sufficient to work to analysis alone, and said he thought that Hailstone and himself had broken that idea down some years ago, when they obtained irons, the chemical analyses of which were so near as to be almost unbelievable, the physical properties of the castings produced varied widely. Therefore, they concluded that there must be some relation between fracture and analysis, and he considered it dangerous to suggest that satisfactory results could be obtained by working to analysis alone. If, for instance, he were given an iron with an analysis which he considered to be satisfactory, but on examination of the fracture he found it was white iron, whereas he wanted a thin grey-iron casting, he would not accept it.

Mr. W. Jolley congratulated the author upon having contributed the Paper, and assured him that there was no need to be despondent as the result of the adverse criticisms made. It was far better to do something which aroused criticism than to do nothing at all; indeed, it had been said that the man who never did anything wrong never did anything at all. He believed that the best method of testing pig-iron was to analyse it, and then to follow up the daily casts by using the Keep method. Fracture also must be taken into consideration; otherwise one would sometimes produce castings which, though in every way correct according to analysis, would fail physically.

Mr. N. D. Ridsdale (Middlesbrough) supported the author's remarks as to the necessity for a standard method of sampling pig-iron, and considered that that was even more important than a standard method of analysis. A reasonably accurate method of sampling was to drill from the top to the bottom at a point midway between the centre and outside of the inverted pig. One method, which was not too tedious, was to place a broken piece of pig-iron 6 or 8 in. long in a lathe, where it was held by a chuck, and to take side shavings right across the section with a side shaving tool. The fractured face must first be sawed off level, and then a complete slice could be turned off the pig and the turnings carefully collected while it was revolving in the lathe. This method was much more practicable than the ordinary method of planing. As to the alleged practice of some pig-iron makers, of mixing unsuitable material with casts of suitable material, in order to work off some of the former, he agreed that such a practice was very mischievous, inasmuch as chemists could seldom sample a large number of pigs from each batch.

Mr. E. Longden agreed that it was necessary to consider both analysis and fracture. In illustration of this he referred to a heavy casting in No. 4 Derbyshire iron, the boss of which was almost unmachinable, whereas the rim could be machined fairly easily. The analysis had conveyed nothing in that case. He also expressed the view that the orthodox analysis was not sufficient, and that it should be extended to include the gases present in the metal.

Mr. A. Logan said there was doubt in his mind with regard to the particular pig-irons which were referred to as being on view in the Exhibition, and which both contained silicon in the neighbourhood of 2 per cent. One was a white iron and one an open iron as Mr. Shaw had stated. The analyses of these showed that one contained high sulphur and low total carbon, and the other contained low sulphur and high total carbon. Then he himself believed that that was the explanation as to why one was white and the other open; the whole thing was explained by analysis entirely, in which case the paper was really very misleading. It appeared completely to make out a case for analysis only. He confirmed Mr. Gresty's remarks with regard to working to analysis only, and was of opinion that pig-iron fractures were immaterial. He took exception to the paragraph which stated that "The fracture is a guide to the internal structure of the metal, which is, after all, the main consideration in the finished casting. Re-melting an iron does not destroy its initial structure, though it may be modified due to varying cooling rates."

Mr. J. E. Fletcher, referring to the author's question as to what were the possible permutation and combinations amongst fracture, total carbon, combined carbon, silicon, manganese and phosphorus, said that a consideration of the points mentioned in that question lay at the root of what had been attempted to be said that morning with respect to the influence of either one or two special constituents in cast iron. Though we were getting nearer to the truth gradually, we should realise even now that we knew very little indeed as to the results of these combinations and permutations. That was one of the directions in which any research association or scientific body had to work in connection with cast iron. We had not yet reached the point at which we could say that the manganese-sulphur relationships were the most vital, or that the silicon, total carbon and graphite were the most reliable indices as to what an iron really was. The statement that fracture had nothing to do with the ultimate results in the casting could not, he believed, be verified. There were those who used portions of white iron in their mixtures, giving certain results which were not obtained unless that white iron were used. Such points as that had not yet been solved in any satisfactory sense, and yet we could, after a certain amount of experience, choose our mixtures by chemical analysis and fracture and obtain results in accord with what we might expect. But unless, under such circumstances, we took care to examine the fracture of certain ingredients put into our cupola charges, trouble might occur, and he did not think we could depend entirely upon chemical analysis. He thanked Mr. Yates for having brought this subject forward; it was one which came forward almost every year in one way or another, and many foundrymen, especially those engaged in making the stronger types of iron, were finding already that analysis alone did not provide a sufficient safeguard. He had found, in the course of many years' work, that the structural composition of a cast iron, when worked out, would give some very useful information, but something more was necessary. In addition to the points already mentioned as influencing cast iron, there were questions such as temperature of fusion and melting, mass effect, casting conditions, and the condition of the mould; those were quite sufficient to make one wonder which of them was the most vital in co-relation with the chemical and micrographical analyses as determining the desired properties of a cast iron.

AUTHOR'S REPLY.

Mr. Yates replied to the discussion. Dealing with Mr. Shaw's remarks as to individual cast analyses, he said that every hundredweight of pig-iron that was sent out, so far as he had anything to do with it, was supplied out of one individual cast. If there were two individual casts in a consignment, the analyses of both were provided, and no pigs out of one cast could possibly get into another cast except by the merest accident. Each cast was stacked individually, and that meant considerable trouble for the pig-iron producer. One point he had noticed with regard to manganese sulphide was that it would most persistently segregate to the top of an iron, whereas iron sulphide did not show any such tendency.

Mr. Shaw asked how he knew that it was iron sulphide.

Mr. Yates replied that he appreciated what Mr. Shaw was getting at, but must refer him to the papers on the subject. It was too much for any one man to go into all these points, and we must take so much for granted from other people's experiences.

Replying to Mr. Field, he said that the high manganese content was a characteristic of the North Staffordshire iron, but the variation from 0.6 to 2.9 per cent. was a very wide one, and he would like to know why Mr. Field experiences such a wide variation. In blast-furnace practice, whilst one could not control the manganese content within small limits, one could control it within limits closer than those mentioned, and if Mr. Field cared to put forward a specification of limits which a blast furnace could work to with that particular product, no doubt he would find that he would get the material he wanted.

With regard to the different physical properties of irons with different fractures, on remelting, he said that iron was supplied both to analysis and fracture, and in a good many cases even to-day it was supplied to fracture alone; the users did not seem to bother about analysis so long as the fracture was given. He would be glad to meet Mr. Gresty at some time when he was buying pig-iron, because it was very much easier for pig-iron producers to supply to analysis only than to supply to analysis and fracture.

The President asked if both analysis and fracture were specified in any case.

Mr. Yates replied that analysis and fracture were specified in 50 per cent. of the cases. The various fractures were shown on the stand, and they represented the ordinary shades to which the iron was graded. Some buyers asked for one particular fracture, some would give the alternative of one or two, whilst some asked that the iron should not be too close or too open. The fracture was important in 50 per cent. of the cases, and if the fracture were not of the type usually received the producers usually heard about it very quickly.

Replying to Mr. Gresty's question as to the relationship of the graphite flakes to the total carbon and combined carbon, he said that the size of the graphite flakes made a distinct difference in the ordinary way between the fracture of a No. 1 Cleveland and the ordinary No. 4, and it was well known that the combined carbon rose progressively from the more open to the closer fracture. Incidentally, the total carbon fell. The fractures shown on the Cast Iron Research Association's stand illustrated the point with regard to total carbon, although the combined carbons were not given.

In reply to Mr. Ridsdale, he said that what was wanted more than any rigid scientific method of sampling was a method which could be applied conveniently in works to give consistent samples. It should be possible to drill pigs in the same way and get the same results with the same methods of analysis, and that, after all, was what was wanted in the foundry and blast-furnace plants more than any rigidly scientific method which was going to differentiate between pigs the silicon contents of which varied within very narrow limits. Consistency was the thing that mattered in pig-iron, and if standard methods of sampling and analysis could be arrived at it would ease the situation. Some people, for instance, would drill a hole straight into the face of the pig, some included the skin even in the drillings for analysis, and so on, and that sort of thing caused friction between the blast furnace and the foundry.

With regard to gases in pig-irons, he said that from the blast furnace point of view he could not offer much enlightenment on the point. The whole subject of gases in metals was very vague, and it was just one more of those permutations and combinations mentioned by Mr. Fletcher.

In reply to Mr. Logan, on the question of manganese and sulphur, he said it was a well-recognised rule in blast-furnace practice that the higher the manganese which one could run in the burden, the lower the sulphur over the whole series of fractures. If one had trouble with sulphur in the pig, due to the coke used—and blast-furnace coke was not uniform—the trouble could always be cured by high manganese. So far as his experience went, the same factor operated in the cupola.

Mr. **Logan** said the point was whether the difference in the fracture of the white iron and the open iron was due to the difference in the composition of the two pigs used.

Mr. **Yates** replied that it was, but the vital point in the production of all those fractures was the temperature of operation of the furnace, which varied from time to time. He agreed that white iron with 2 per cent. silicon was an anomaly, but such anomalies were produced. In blast furnace work one was dependent upon thermal conditions more than upon anything else, and it was that that one had to watch in getting the fracture required.

On the question of abnormal fractures, he said that fracture was no guide when the pig-iron had been subjected to abnormal cooling conditions. Under ordinary conditions, however, where the same cooling conditions prevailed in the pig bench time after time, there were no alterations in fracture. The conditions in ordinary circumstances did vary slightly, as, for instance, between a wet and a dry day, but on the whole such variations did not produce any alterations in the fracture of the pig, and the properties seemed to persist in the metal when re-cast.

SOME NOTES ON THE CHEMISTRY OF THE CUPOLA.

By F. C. Thompson, D.Met., B.Sc., and M. L. Becker, B.Met. (Associate Member).

The chemistry of the reactions involved in cupola practice is a considerably more complicated matter than would at first sight appear. The following short Paper is, therefore, presented more in the hope of stimulating thought and discussion than in that of adding a very substantial contribution to the subject. The data required before the matter can be really dealt with as a scientific problem is still largely lacking, and as a sequel to this preliminary review it is intended to carry out experimental work to attempt to fill up some, at any rate, of the more obvious gaps. Since the design of any furnace can be nothing but empirical until the fundamental chemical and physical principles involved are understood, the subject is of vital importance to the industry, and any contribution, however imperfect, may hope to add a little to the general store of knowledge. The authors would at the very start impress the fact that they have no wish to appear dogmatic in a field where dogmatism at the present time is irreconcilable with scientific treatment, but have presented a few points in the light in which they appear to them. They feel that it is in the interests of the industry to do this even if their ideas are proved incorrect, as the very fact that such proof is adduced will add to the store of fact available for future workers.

As an example of the indefiniteness of almost everything in this field it may be pointed out that even the details of the combustion of carbon are uncertain. It is generally held that this first burns to carbon dioxide, which later, by interaction with more carbon, is converted into the monoxide. The view is held by some very eminent chemists, however, that carbon monoxide is the first stage of the reaction, and, so far as the cupola itself is concerned, the available data is by no means conclusive. So far as it goes, however, it tends to fall into line mainly with the older view. Rhead and Wheeler (¹) appear to have shown reason to believe that both oxides are formed simultaneously, and this middle course may well prove to be the correct one. The matter is clearly of first-rate importance, and any light thrown on it in the discussion will be of the greatest value.

As an introduction to the subject, it has been thought well to attempt to draw up a thermal balance-sheet for a typical cupola. It is not, of course, the first time that this has been attempted, but in so many cases the attempt has been done with inadequate completeness. Such a balance properly drawn up cannot but indicate the lines on which fuel may be saved and thus afford possible suggestions to designers and others.

The Thermal Balance of the Cupola.

The heat developed by the combustion of the coke can be readily calculated if the calorific power is known together with the composition of the escaping gases.

Let W be the weight of coke burnt per unit time.

Let C.P. be the calorific power of the coke.

Let 1/y be the fraction of the carbon burnt to CO, and 1-1/y or (y-1)/y be the fraction of the carbon burnt to CO_2, then the heat generated per unit time is approximately:—

$$W \times \text{C.P.} \times \frac{y - 0.7}{y} \qquad \text{(I)}$$

Now this heat is divided in many ways. In the first place there is:—

(i) That used in raising the pig-iron to its melting point, melting it, and then raising the molten iron to the tapping temperature.

(ii) The heat required to raise the temperature of the escaping gases to the temperature at which they leave the stack.

(iii) Heat is also expended in forming the slag, melting it and raising its temperature to that at tapping.

(iv) The heat lost by radiation from the walls of the cupola.

In this survey we have considered the conditions during the period after the cupola is running uniformly, and have not considered the heat required initially to raise the temperature of the brickwork, nor have we considered the bed-coke.

Now, there are not available all the data required to work out this theoretical heat balance in detail, and we shall have to be satisfied with approximations in many cases. These can, however, be predicted with an accuracy which is sufficient for the present purpose, namely, the determination of the main sources of wasted fuel.

Let us now take items (i) and (iv) in turn and attempt to determine their magnitude.

(NOTE.—The C.G.S. system will be used for convenience throughout.)

(i) Let M be the weight of iron melted per unit time.

Let s be the mean specific heat in the solid state.

Let l be the latent heat of fusion.

Let s′ be the mean specific heat in the liquid state.

If t is the melting temperature and T that of tapping, then the heat required for this portion of the work of the cupola is:—

$$M[s \times t + l + s'(T - t)]$$

It would appear that the mean specific heats in both the solid and the liquid states are not far from 0.15, while the latent heat of cast iron, though very uncertain, may be taken as of the order of 30.

Thus (i) becomes equal to $M(0.15\,T + 30)$.

(ii.). To burn W gms. of coke per sec. of which the percentage of ash is a, *i.e.* a weight of carbon of $W\frac{(100-a).}{100}$ requires 4/3 this weight of oxygen if the combustion is to CO and 8/3 the weight if to CO_2. If the fraction burnt to CO is $1/y$, then the weight of oxygen needed is $W\frac{(100-a)}{100}\cdot\frac{8y-4}{3y}$

The weight of nitrogen introduced with this oxygen is then $\frac{77}{23}\cdot W\frac{(100-a)}{100}\cdot\frac{8y-4}{3y}$

The weights of CO and CO_2 formed are respectively, $\frac{(100-a)}{100}\frac{W}{y}\cdot\frac{7}{3}$ and $W\cdot\frac{y-1}{y}\cdot\frac{11}{3}\cdot\frac{(100-a)}{100}$

The specific heats at constant volume of these gases are very nearly the same, and from room temperature to, say, 400 deg. C. may, nearly enough, be taken as 0.25. Further, they vary comparatively little with temperature. It may be worth pointing out that water vapour has a specific heat about double this value.

If now t′ be the temperature of the gases as they leave the stack, the heat represented by (ii) becomes nearly:—

$$\frac{W\,(100-a)\,t'}{400}\cdot\left[12.6-\frac{5.8}{y}\right]$$

(iii) So far as the slag is concerned, there are no very reliable figures for the heat of formation and the latent heat of fusion. It is probably sufficient to assume that, taking the heat of formation and the latent heat together, there will be an evolution of about 50 calories per gram of slag formed. This figure may be arrived at in two ways. Akerman (2) obtained for the total heat of fusion of slags of the nature of cupola slags the value of approximately 370 cals. There is not much doubt that the specific heat is of the order of 0.3. At a temperature of around 1,400 deg. C. there will be some 420 cals. needed, and the difference of this figure and the 370 represents the net heat evolution due to the combined formation and fusion. A calculation made by Mr. E. O. Jones, A.R.S.M., has also yielded an almost identical figure.

If burnt lime be used we shall not then be far from the truth in putting item (iii) at:—

$m(0.3T - 50)$, where m is the weight of slag formed.

The production of burnt lime from the limestone charged involves a certain absorption of heat. The value of this is:—

$m' \times 451$ cals. per gram, where m′ is the weight of limestone charged.

The total value of (iii) thus becomes:—

$$m(0.3T-50)+m'\times 451$$

The radiation loss and certain other small items must now be considered. The latter involve such matters as the dehydration of the charge, the water-gas reaction from the steam so generated and that in the blast, the cooling due to the expansion of the blast as it enters through the tuyeres and loss of pressure.

Both theoretically and experimentally it may be shown that in a well-lagged cupola the radiation loss is negligible, being certainly less than 1 per cent. of the heat generated by the coke, and probably very much less. The theoretical treatment need hardly be given here, but as an experimental verification of the fact, the figures may be cited of Piwowarsky and Broglio. (3) For their standard cupola the radiation and conduction loss was 10.4 lbs. of coke per hour compared with a total consumption of 2,150 lbs. per hour, *i.e.*, about one half per cent. It is clear that this source of loss is practically negligible. The water present is difficult to deal with, and in all probability is not important, though there can be little doubt that the dryer and hotter the air the better. Even slight increases in blast temperature may be expected to result in appreciable economies. The cooling of the blast on entry into the furnace for the pressures used in cupola practice can be neglected.

We have thus evaluated the various factors of a physical nature which operate in the cupola, but there is one source of heat which we have neglected, namely, that due to the oxidation of iron and of the constituents in the pig. For each gram of silicon oxidised there is a heat evolution of 6,400 cals., of iron (to FeO) 1,170, and of manganese 1,650 cals.

Let p, q and r be the percentages of these elements respectively which are oxidised, then the heat evolved will be:—

$$\frac{M(6{,}400p + 1{,}650r + 1{,}170q)}{100}$$

Suppose p to be 0.25, r 0.1, and q 1, then this becomes $M(16 + 1.65 + 11.7)$, *i.e.*, nearly 30 M.

We are therefore left with the relationship:—

$$W.\,C.P.\,\frac{y - 0.7}{y} = M\,(0.15T + 30) + \frac{W(100 - a)\,.\,t'}{400}\,.$$

$$\left[12.6 - \frac{5.8}{y}\right] + m(0.3T - 50) + 451\,m' - 30\,M \qquad (A)$$

Now m′ will be about 0.9 m.
And m normally about 0.04 M.

The C.P. of a typical coke may be taken as 7,000 cals., and a as around $12\frac{1}{2}$ per cent.

As a check, and thus to determine whether the values for the various thermal constants chosen are reliable, the result may be used to determine the melting ratio for a typical case. That chosen is for a composition of escaping gases containing equal volumes of the two oxides of carbon and a temperature of about 425 deg. C. With otherwise the same meanings and values for the factors as before, the ratio of the weight of metal tapped at 1,425 C. to that of the coke with $12\frac{1}{2}$ per cent. of ash used is 15.4. This is clearly a reasonable figure, and indicates that the constants adopted are near to the truth, sufficiently so at any rate for the qualitive use of the equation for determining the relative effect of each part of the process. Incidentally equation A is also useful as giving the theoretical limit to which coke economy could be pushed in the ideal case where the escaping gases were at the same temperature as the foundry and contained no carbon monoxide at all. In this limiting case, which, of course, can never be expected in practice, it would be possible to melt a ton of iron and tap it at 1,425 deg. C. with a coke consumption of only just over two-thirds of a cwt.

To illustrate the effects of the completeness of the combustion of the carbon, the temperature of the escaping gases and the tapping temperature, Figs. I, II and III have been plotted. They are self-explanatory and need no elaboration.

It is now possible, making the same assumption as before—*i.e.*, tapping temperature of 1,425 deg. C., temperature of the gases 425 deg. C., and CO/CO_2 ratio=1—to get an idea of the relative amounts of heat used for the different purposes, as shown in the following table:—

For heating and melting the metal	52.6 per cent.
For heating and melting the slag	6.8 per cent.
Lost in gases	47.1 per cent.
Lost by radiation, etc.	0.3 per cent.
Gain by oxidation of iron, etc. ...	6.8 per cent.

Of the heat required for the slag about one-half is used to burn the limestone.

The real efficiency of the cupola as an iron melting apparatus may be measured by the ratio of the heat in the molten iron to that absorbed as a whole. The figures just given show that the efficiency on the basis of the heat from the coke burnt is 52.6 per cent. On that of all the heat provided, however, both from the coke and from the exothermic reactions this is reduced to about 49.1 per cent.

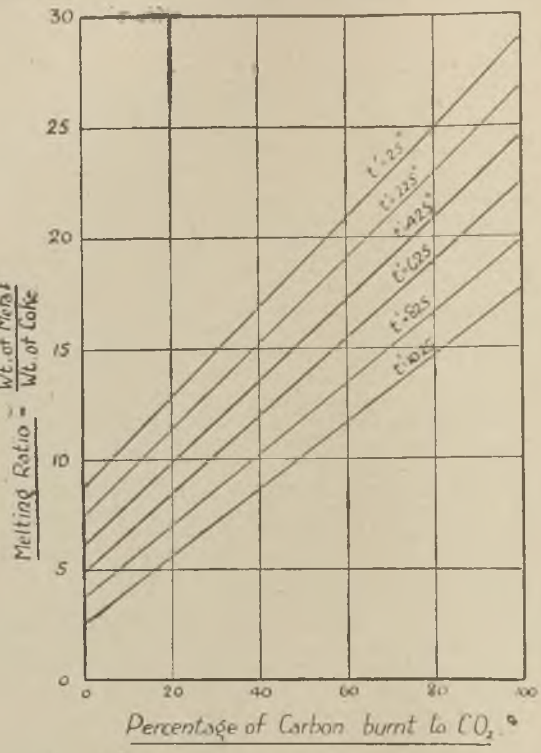

Fig. 1.

Theoretical efficiency of cupola plotted against the percentage of carbon burnt to CO_2 for various temperatures (t') of escaping gases and for a constant tapping temperature of 1,425 deg. C.

Now clearly the only possible sources of economy lie in the heat actual or potential lost in the gases, about one-half of all the heat which could be generated by the coke, and the slight gain by the use of burnt lime. We may now proceed to discuss what appears to be possible in these directions.

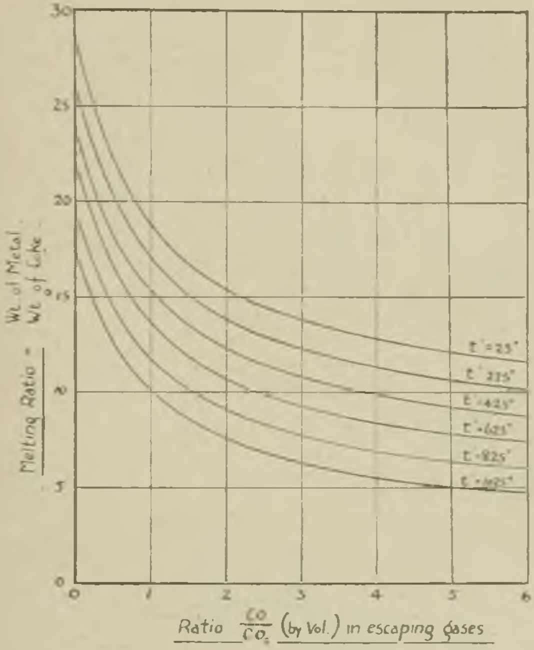

FIG. 2.

Thermal efficiency of cupola plotted against the ratio $\frac{CO}{CO_2}$ (by vol.) in the escaping gases for various temperatures (t') of the latter and for a constant tapping temperature of 1,425 deg. C.

Reactions with Carbon.

It has already been pointed out that the course of the reaction between carbon and oxygen at high temperatures is far from certain, and the most probable effect is that both oxides of carbon are formed. That CO_2 is the main product at first is generally supposed and is in agreement, for instance, with the analysis of the gases recorded by Piwowarsky and Broglio taken at the tuyere level. These gases consisted of:—

CO_2	CO	O_2
15%	0.5%	7%

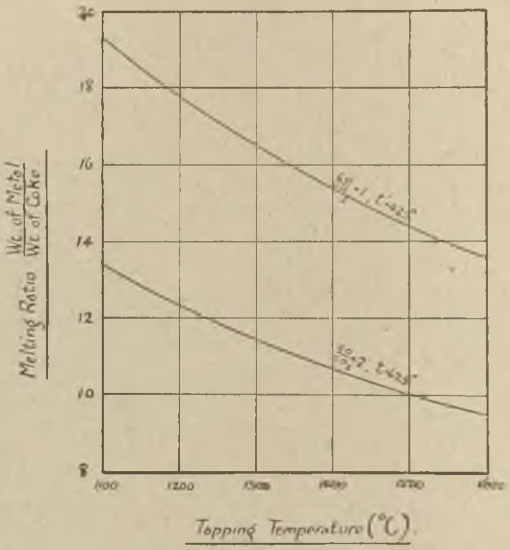

FIG. 3.

Effect of tapping temperature on melting ratio.

This reaction is highly exothermic, and is followed by a further reaction between the carbon dioxide and the hot coke, in which carbon monoxide is the product. This absorbs a great deal of heat and tends to set a limit to the hottest zone of combustion. There is evidence, however, that the reversion to carbon monoxide may not be so complete as is often imagined.

The gases as they leave the zone of combustion pass into the cooler portions of the furnace and in contact with the relatively cool charge give up a portion of their heat. Now, when in equilibrium, a mixture of carbon monoxide and dioxide tends, as the temperature falls, to change its composition so that a definite amount of each gas is present at a definite temperature. This would tend to cause in the stack a gradual disappearance of carbon monoxide and its conversion into the dioxide. It is true that under the conditions which obtain in the cupola where the ascending gas stream is moving with a high velocity, equilibrium cannot be attained, but there will be the tendency for this to happen. The result will be that if AB of Fig. 4 represents the equilibrium content of carbon dioxide at the various temperature zones of the cupola, taking into consideration the nitrogen present, the actual amount of this gas AD will lag behind, or, in other words, the composition of the gases will be that characteristic of a temperature higher than that which actually obtains at the particular level.

Now, two things may cause the gas mixture to approach more nearly to the equilibrium condition. In the first place catalytic agents may be present, and it is known that iron itself has a definite effect in this direction. Secondly, as the time for which the gases are enabled to react is increased the tendency to approach the equilibrium composition will also be increased. This is effected by reducing the speed of the gas stream, *i.e.*, the blast pressure. This conclusion may be checked, and is valuable as affording a confirmation of this reaction in the stack. It appears to be quite generally agreed that rapid melting is incompatible with fuel economy. Osann ([4]), for instance, and Korevaar ([5]) both accept this position. It is, of course, true that the slower gas stream will have more time to transmit its heat to the charge by radiation and hence to leave the cupola at a lower temperature, but the chemical effect is also present. It may be thought that the various published analyses of gases from various positions in the cupola would avail to establish the truth or otherwise of these ideas, but the authors feel that there is no evidence of any set of analyses being available which impress them as being completely reliable. The depth of immersion of the sampling tube into the furnace, changes of composition of the gases with time, and so many other factors come into the experiment that considerable precautions, not generally taken, are required before satisfactory results would be obtained.

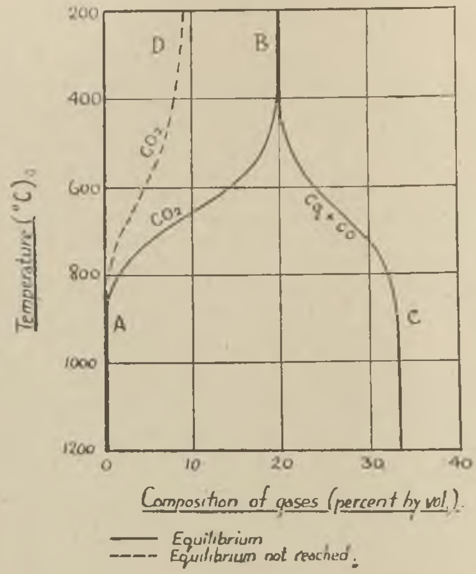

FIG. 4.

Effect of temperature on the equilibrium between carbon and a mixture of CO_2, CO and N_2, resulting from the combustion of carbon in air (calculated for the atmospheric pressure).

To revert to the question of the rate of ascension of the gases, not too high a blast velocity is obviously required, while as an additional assistance the area of the stack may be enlarged above the combustion zone. Some cupolas have been designed on these lines, and although practical points may arise which render them unsatisfactory, and with such we have no intention of dealing, yet the shape is one in accord with the demands of physico-chemical theory. The more slowly, then, the gases rise through the stack, the more complete will be the heat transference to the charge and the lower will be the loss due to the escape of carbon monoxide.

Related with this is the question of the height of the stack. Clearly a cupola so short that the gases were still very hot at the charging door would be bad both from the point of view of the direct heat thus lost and also from the fact that the conversion of carbon monoxide into the dioxide and carbon does not occur to any marked extent until a temperature of about 700 deg. C. is reached. The reaction ceases around 400 deg. C., and from this point of view the cupola should be so designed that with normal working the gases, as they leave the charge, should not be at a higher temperature than this. The economy which can be obtained by reducing the temperature still further is less than that brought about by the previous reduction, since from now onwards the economy can be only that resulting from a more perfect transference of sensible heat to the charge, and no further saving can be effected by a reduction of the carbon monoxide. If the conclusion be accepted, and working from the fundamental assumption that in the stack carbon monoxide is gradually converted into the dioxide, there is little chance of escaping it, one very definite practical fact emerges. For a given output of iron per hour the fuel consumption will be less in a large cupola with a low-velocity blast than it will be in a smaller one in which the blast pressure is higher. It would be of great assistance to know whether or not this can be substantiated.

Porter (⁶) agrees with these results and states that, from the point of view of economy, "increased height of cupola has been shown to rest upon a sound theoretical basis, while the results of practice indicate that it accomplishes the results desired." We wish to stress the fact that such economy is not merely the result of more perfect transference of heat to the charge, but is also that of a more perfect combustion of the coke to CO_2. During the final stages of a blow after charging has ceased and the effective height of the furnace is diminished, there is not only an increase of temperature of the escaping gases, but also an increase in the percentage of carbon monoxide in these gases.

Lime or Limestone.

It has already been seen that the limestone added will, at a certain temperature, be converted into lime and carbon dioxide, and that this reaction absorbs an amount of heat which is more or less equal to the whole of the heat otherwise required for the formation and heating of the slag. The substitution of lime for the unburnt limestone would remove the necessity for the provision of this heat, and lime having a lower specific heat than the carbonate, less heat would be required for its heating to the temperature of decomposition. The heat absorption, in the atmosphere which obtains in the cupola, takes place about 800 deg. C. and thus produces a cooling effect around the very temperature at which the reaction by which carbon monoxide passes over into the dioxide with the deposition of carbon tends to take place. Further, the evolution of a relatively large volume of carbon dioxide can only have a deleterious effect on the extent to which this latter reaction can occur The monoxide is at a temperature at which it is tending to be changed in part into the dioxide, and the further the CO content of the gases is from the equilibrium content at the temperature, the more rapid would the change be expected to be. The dilution of the gases with CO_2 must reduce the rate at which the latter gas is formed, and as a result cause the escaping gases to be richer in the monoxide. It thus follows that although a direct economy of the order of rather more than 2 per cent. of the total coke charged would be effected by the substitution of lime for limestone, there is also an indirect effect, the degree of which it is difficult to gauge, but which may well be far more appreciable, in the better combustion of the fuel to the dioxide. It is in the latter direction particularly that real economy is to be looked for. In any case it appears to be uneconomical to use expensive foundry coke to burn lime, which is essentially what is at the present time being done.

Since it is difficult to store quicklime for any length of time without it becoming slacked, it becomes necessary to consider the effect on the fuel economy of the cupola of the addition of the latter form. In the first place, the heat required to convert this into quicklime is, for the same weight of lime, only a little more than half that required for the decomposition of the limestone. Against this, however, must be put the fact that the specific heat of slacked lime is about 1.8 times that of the carbonate. Neither of these facts, however, appears to be of much importance, since the temperature at which the dehydration of slacked lime takes place is about 450 deg. C. This is a temperature around which the reaction

$$2CO \rightarrow CO_2 + C$$

essentially ceases, with the result that heat taken from the stack at this point is more or less immaterial from the point of view of efficient combustion of the fuel. Even slacked lime, then, has two advantages over limestone. In the first place, as a result of its relatively low temperature of decomposition, it absorbs its heat outside the important temperature range, and secondly, it does not throw into the gases a gas which retards the formation of carbon dioxide from the monoxide. Both facts will tend to accelerate the rate of formation of carbon dioxide. We do not know any full statement of the effects of substituting lime for limestone in the cupola, and if the experiment has not been carefully tried it would appear to be well worth investigation. There are many cases on record where in the blast furnace, generally of small dimensions, economy has followed the substitution, and these confirm from the chemical point of view the suggestions made. There is also one point in connection with design which would follow from the use of lime. Since the cooling effect well up in the stack would be eliminated, the height of the furnace would, for equal efficiency in so far as the temperature of the escaping gases was concerned, require to be raised.

Reactivity of the Coke.

In blast furnace circles particularly, much has lately been written concerning the effect of the "reactivity" of the coke on the fuel consumption. It is not, perhaps, out of place to examine very briefly the problem from the point of view of cupola practice. The authors, however, tread with diffidence, since the question is one of more than usual difficulty and uncertainty.

The reactivity of coke is measured, as a rule, by the extent to which at any temperature it has the power of reducing carbon dioxide to the monoxide. This is largely determined by the size and porosity, the smaller and more porous materials doing this to a greater extent than the larger and denser ones. At the same time there is some other factor, since size and porosity alone do not completely determine the result. As the temperature rises this reactivity also increases, and at the temperature of the melting zone of a cupola there can be very little difference in this respect between the cokes which may be used as a result of their other physical and mechanical properties. If then there is to be anything in the question of reactivity, it must lie chiefly in the behaviour of the coke at the lower temperatures.

Much of what has been written in connection with this subject appears to suffer from serious inconsistencies. Arend and Wagner, (7) for instance, say that for a given temperature the stability of carbon dioxide in the presence of coke will be diminished as the reactivity rises. This being true at all temperatures it should follow that the escaping gases must be richer and richer in carbon monoxide as the reactivity of the coke is raised. This, however, is a rather one-sided way of looking at the matter, since although what has been said is true so far as it goes, it holds when, and only when, the concentration of carbon dioxide exceeds the equilibrium content at that temperature. The effect of the reactivity of the coke is more or less catalytic, and merely accelerates the rate of approach to, but not the value of, the equilibrium composition. It must not be forgotten that as a result of the high speed of the ascending gases and the relatively low velocity of the reaction—$2CO \rightarrow CO_2 + C$—the composition of the gas inside the cupola at any level does not correspond with the equilibrium at the temperature but to one at a much higher temperature. All this is leading up to the point that in the stack of the cupola itself the gases are always richer in carbon monoxide than corresponds with the equilibrium value, and are thus on the opposite side of this equilibrium from that thought of in connection with the usual measurement of reactivity. In a catalytic change the catalyst alters the rate of approach to equilibrium only, and it would thus appear that a reactive coke, just as it accelerates the rate of conversion of carbon dioxide to carbon monoxide, should equally increase that from the latter oxide to the former when the conditions are reversed. If then reactivity means anything at all in cupola practice, and that is a matter which can be determined by experiment only, a reactive coke should be chosen. Indeed, if such a fuel does bring about economy in the blast furnace, and there is general agreement on this point, there is no reason which the authors can see why it should not be equally beneficial in the cupola. The conclusion of Porter that the combustion in the cupola differs from that in the melting zone of the blast furnace appears to us to be based on unsound fundamentals.

The Addition of Further Air Through Auxiliary Tuyeres.

Above the zone of combustion there is undoubtedly a considerable amount of carbon monoxide in the gases. It is but natural, therefore, that the suggestion should have been made and repeatedly tried experimentally that this CO might be utilised by blowing in at a level appreciably above that of the tuyeres a further supply of air. If, however, this is done the obvious result is merely to reproduce more or less the conditions which obtain at the tuyere zone. Much heat is generated at a relatively high level in the furnace, and cannot be transferred to the charge, with the result that the escaping gases will be raised in temperature correspondingly. This will also tend to reduce the lower temperature transformation of carbon monoxide to the dioxide. Even if on the whole the gases do contain a little more carbon dioxide, and even on this point the evidence is not clear, any gain by this rather more perfect combustion may be more than lost by the greater loss of "sensible" heat in the gases. The conclusion can hardly be escaped that what air is required for combustion should be blown in at the tuyeres to keep the zone of combustion as low as possible.

Recalling what has already been said concerning the equilibrium between carbon mon- and di-oxide at high temperatures, it will be realised that the whole argument for auxiliary tuyeres rests on a fallacious basis. At tuyere temperatures the equilibrium is one in which almost the whole of the gas tends to become CO. The addition of more air may temporarily convert some of this into the dioxide, but this, by interaction with more carbon, will pass again into the monoxide stage. The net result will be the same as if the air had burnt not the carbon monoxide, but more coke. This clearly, when taking place high up in the stack, can only lead to wasted energy.

It may incidentally be worth pointing out that in the absence of excess carbon and at, say, 1,650 deg. C. (a temperature which may very well be reached by the hottest gases), there is not complete combustion of carbon monoxide in oxygen, about 1 per cent. of the dioxide formed remaining as carbon monoxide and oxygen. As the temperature falls, however, the latter will rapidly decrease to immeasurably small quantities.

After the above was written the authors' attention was drawn to the Paper by Porter already mentioned. His ideas and ours, though, reached independently, are in such perfect agreement on this point that we venture to quote them. "A second row of tuyeres," he says, "is supposed to effect the more complete combustion of the carbon by the addition of oxygen at a point where it can burn the CO. Theoretically this appears to be an excellent idea, but actually it usually fails to accomplish the result desired, *i.e.*, to materially decrease the proportion of CO, though it may produce other desirable effects."

"Since CO is not formed directly at the tuyeres but only at some distance above or in front of them, it is evident that the second row of tuyeres must be located a considerable distance above the lower ones in order to reach the CO. Now if this is done the result is to produce another zone of combustion and a practical duplication of the conditions at the lower tuyeres. Where the addition of a second row of tuyeres has proved advantageous the benefit can usually be traced to the enlargement of the total tuyere area and the consequent greater volume of air admitted to the cupola."

J. E. Hurst (8) has also recorded his conclusion, drawn from actual test, that auxiliary tuyeres are not, in a properly designed cupola, of advantage.

With regard to the amount of air which may reasonably be injected, it would appear safe to believe that, from the point of view of fuel economy, that amount is needed which will, under the working conditions, just fail to show free oxygen in the escaping gases. So far as the authors can see, this should lead to the most perfect combustion which can be produced under the conditions obtaining in any given cupola.

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(4) Osann, Stahl u. Eisen, 1925, p. 2147.

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(8) Hurst, THE FOUNDRY TRADE JOURNAL, March 4, 1926.

DISCUSSION.

MR. HORACE J. YOUNG, F.I.C. (London), asked the authors how to sample the gases from the cupola so as to obtain figures sufficiently accurate to conform with the intricate calculations in the Paper. He suggested that the Paper was entirely theoretical, and, although it ended with a statement which had been made by many people before, namely, that there was no need for two rows of tuyeres. The paper, in his view, was inconclusive, and he would be glad if the authors, when replying to the discussion, would state the conclusions to which they had come as the result of their work.

Mr. B. Hird considered that researches such as these into the gases given off by the cupola and their relation to the gases that were absorbed by the iron would bring a great deal of light and help to those who had to work cupolas and get results from them. During the last year he had carried out some experiments in connection with the gases contained in cast iron, wrought iron and steel, and they had left him very much fogged. He had been led to experiment because, when trying to cast a wrought-iron bar in a casting he had obtained serious blowholes. He had carried the experiment further by casting chills in moulds and attaching a tube to them, in order to see if he could get any gases therefrom; he was astonished to find that he obtained gases from every chill he used, and there were big variations, although the chills were cast out of the same ladle. Therefore, he very much appreciated the authors' attempts to deal with the matter. Gases formed in the cupola, in his view, were absorbed in the iron, and he asked the authors to carry on their work on the formation and absorption of gases.

Mr. J. E. Fletcher said he could not exactly subscribe to the view expressed by Mr. Young, but considered that the work done by the authors would prove to be of value. One point to be remembered—although he did not think the authors had entirely lost sight of it—was the fact that the speed of the gases through the cupola had something to do with the equilibrium factor in the gas analysis. It was assumed in too many of these cases, he was afraid, in connection with both the blast furnace and the cupola, that theoretical equilibrium was attained in the time in which the gases passed through either the blast furnace or the cupola, and that was where the difficulty arose in a purely scientific investigation, unless comparison was made with the actual facts of the case as recorded from properly-taken analyses at various points of the cupola. He had had considerable experience in trying to get these, and the results were not at all in accordance, in many cases, with the expectations of the authors. With regard to limestone, the amount of heat taken off by the expulsion of the CO_2 from limestone, of course, was very considerable. One question which had been scarcely touched upon was that of the ash in the coke. It had been proved that a percentage of ash in coke had a much greater effect on the thermal value of that coke than could be deduced theoretically, and points of that sort made one extremely cautious in accepting conclusions of a purely theoretical character. He had tried to use a slacked lime through the tuyeres of the cupola instead of introducing it as limestone with the charge. Dr. Stead and himself had had a conversation on the point some years ago, and it had been tried both in Middlesbrough and in the Midlands, but things did not happen as was expected. The attempt was made to introduce the lime as lime with the air blown into the blast furnace as well as the cupola, but slag was formed all round the cupola and next to the lining of the blast furnace, instead of the lime penetrating to the centre of the charge column. Those experimenting with cupolas must bear in mind that they must get the air distributed as perfectly as possible. Finally, he congratulated the authors upon their attempt to help practically by conclusions which at first sight were purely theoretical.

Mr. E. Longden said that while theoretically the single row of tuyeres in a cupola was ideal, it was not so in practice. There was much more slagging up of tuyeres than with two rows.

AUTHOR'S REPLY.

Mr. M. L. Becker, replying to Mr. Young, said it was difficult to convey the whole of the contents of the Paper in the course of the short time allotted to him for introducing it, and it was also extremely difficult for others to discuss the Paper without having read it, but he would be pleased to reply to any further criticisms which might be made in writing. With regard to the sampling of gases, he said it was pointed out in the Paper that the conclusions arrived at were entirely theoretical, and the authors had not as yet taken samples of gases from cupolas, but hoped to do so. They considered it advisable, however, to set down the lines on which they proposed to make the experiments, and later, if time permitted, the experiments would be made and the results probably reported. It was a very difficult matter to sample gases from a cupola, but the method they had in view was to drop a pipe down the centre of the cupola and put it in with the charge. So far as could be ascertained, the method of sampling gases at the edge of the cupola was quite unsatisfactory, because the gases rising at the centre of the charge were of different composition from those at the edge of the charge, next to the lining. Also, the temperature varied very much as between the centre and the edges. The authors had not been able to go into the question raised by Mr. Hird, namely, of determining how far the gases affected the properties of the iron cast, but had simply taken the cupola as a heat generator, with the idea of finding out how much heat was required to get the iron out at a certain temperature. Nevertheless, the ratio of carbon monoxide to carbon dioxide in the melting zone must be of profound importance when considering the quality of the iron tapped from the cupola. If the ratio of carbon monoxide to carbon dioxide was not very great, the immediate result would be the oxidation of the iron. He considered that if that went on to any great extent that the metal itself might contain oxide, either in solution or otherwise, and give an unsuitable casting. Dealing with Mr. Fletcher's point as to the rate at which the gases passed through the charge, he said the authors wanted to know if anybody had practical information on the subject; if anybody could give any direct evidence that they were wrong they would be only too pleased, because their object in giving the paper was to find out where they were. The effect of ash in the coke was not dealt with, but was simply taken as 12½ per cent. The fusibility of the ash and the formation of slags, of course, must enter into the question, but, at the same time, the calorific value of coke of a given ash content, he believed, was more or less constant. With regard to the introduction of lime at the tuyere zone, he had heard of others who had done that without success, and that seemed to bear out the conclusion which the authors had arrived at, namely, that the effect of the limestone was very slight indeed so far as the heat balance was concerned. The authors had not expressed an opinion in the paper as to whether a single or a double row of tuyeres was advisable, but they did wish to make the point that extra air introduced at a considerable distance up the cupola stack, in order to burn the carbon monoxide originating in the stack, had not been found to be satisfactory.

CAST IRON FOR ELECTRICAL MACHINES.

By J. H. Partridge, B.Sc. (Hons.),
(University of Birmingham).

The paper is divided into five sections:—(1) Introduction; (2) explanation of terms; (3) industrial requirements; (4) experimental—(*a*) the effect of silicon; (*b*) the effect of manganese; (*c*) the effect of aluminium; (*d*) the effect of chromium; (*e*) non-magnetic alloys; (*f*) malleable cast iron; and (*g*) the relationship between the structure of cast iron and its magnetic properties—and (5) summary and conclusions.

In the experimental section, sub-sections (*a*) and (c), reference is made to a fifteen minutes' anneal at 900 deg. C. before machining. This annealing appears to be an erratic procedure, and is due to the author being influenced by the customary procedure in testing ferro-magnetic materials and also by the work of Dr. Nathusius, who annealed all his specimens for 24 hours at 900 deg. C. before testing. The author realises, of course, that cast iron, having certain desirable properties when in the cast state, is far more valuable and useful than cast iron having similar properties when in the annealed condition.

Introduction.

Twenty years ago the frames and housings of electric motors and generators were constructed of cast iron. It was found that cast steel was magnetically superior to cast iron; cast steel housings were readily adopted by designers, and in a few years it had almost entirely replaced cast iron for electric machinery. There was very little information on the magnetic properties of cast iron. Designers condemned it without investigating its properties, without giving it a chance to defend itself.

This investigation, carried out at the instigation and under the direction of Professor T. Turner, is not intended to be a treatise on this subject, but serves to show the effect of some of the common elements on the magnetic properties of cast iron and to show that this material has a promising future in the electrical industry. It definitely disproves the old idea that cast iron does not have any useful magnetic properties.

Explanation of the Terms.

As this subject is rather more physical than metallurgical, it is necessary to explain a few of the terms used in magnetism. The entire space round a magnet in any part of which it is possible to detect magnetic force due to the magnet is called the magnetic field of that magnet. The intensity of such a magnetic field at any particular point is determined by the force exerted on a unit pole placed at that point. If the unit pole moves so that the direction it takes is, at every instant, the direction in which the magnetic force acts, the course it takes through space is called a line of magnetic force. In general these lines are curved, for the direction of the magnetic force varies, as the unit pole passes from point to point through the field. The well-known curves in which iron filings group themselves when scattered round a bar magnet represent approximately the forms taken by the lines of force. For a bar-magnet the lines of force start from the positive pole, bend round in curves, and converge on the negative pole. Now if the magnet is broken across, each piece becomes a magnet, and there are lines of force across the gap. Consequently, the lines of force must be regarded as being continuous closed curves, part being in the metal itself and part being in the air. That part of the line of force in the metal is known as a *line of magnetisation*, or a maxwell. In a uniform field —that is to say, a field in which the magnetic force has the same direction and the same intensity at all points—the lines of force are straight, parallel and equally spaced, and the strength of the field is equal to the number of lines of force crossing one sq. cm. perpendicular to the direction of the force, and is generally denoted by the letter H. If a piece of brass be placed in this field the field does not change; the same number of lines force pass through the brass as through an equal area of surrounding air. If, however, a piece of iron is placed in the field the latter is distorted and more lines of force pass through the iron than through an equal area of surrounding air. In other words, the lines of force prefer the path through the iron, which may be said to be a better magnetic inductor than the surrounding air. The very fact that there are extra lines of force passing through the iron causes it to become a magnet, and indeed the strength of this magnet is proportional to the number of these extra lines of magnetisation which traverse it. The total number of lines of magnetisation traversing the iron, divided by its area, is known as the *magnetic induction*, generally denoted by B: *i.e., B is the magnetic induction per sq. cm.* Since there are no extra lines of force induced in brass, it does not become magnetised; the number of lines of magnetisation per sq. cm. within the brass specimen is always equal to the number of lines per sq. cm. in the field, i.e., $B = H$. For iron, however, B is very much greater than H. This may be expressed by saying that iron is more *permeable* with respect to lines of magnetisation than the surrounding air The lines of magnetic induction may be visualised as crowding into the iron, finding an easier path through it than through the air. The quality by virtue of which the iron of the specimen conducts the lines of induction better than the air is called its *magnetic permeability*. Thus the permeability of the iron is the ratio of the number of lines of induction per sq. cm. in the specimen (*i.e.*, B) to the number of lines of force per sq. cm. in the air surrounding the rod (*i.e.*, H); thus the permeability $= \frac{B}{H}$ and is generally denoted by μ. Suppose a specimen of iron is subjected to a magnetic force H, and that the magnetic induction produced by this force is B. If the force H is altered in any way the magnetic induction B will also change, and these changes may be represented graphically, as shown in Fig. 1. At first there is little increase in the magnetic induction, as represented by the line OA. Then there is a sharp and rapid increase in the induction, as shown by the curve AB, which becomes exceedingly steep; this is the region of maximum permeability shown by the peak on the dotted curve, for obviously if B becomes very large, whilst H only increases a small amount, the ratio $\frac{B}{H}$ must become very large. Lastly, the curve rounds off until the rate of ascent again becomes small and hence the permeability diminishes.

Fig. 2 illustrates that if, when the point C is reached the magnetic force is diminished, the induction does not fall along the curve CBAO, but

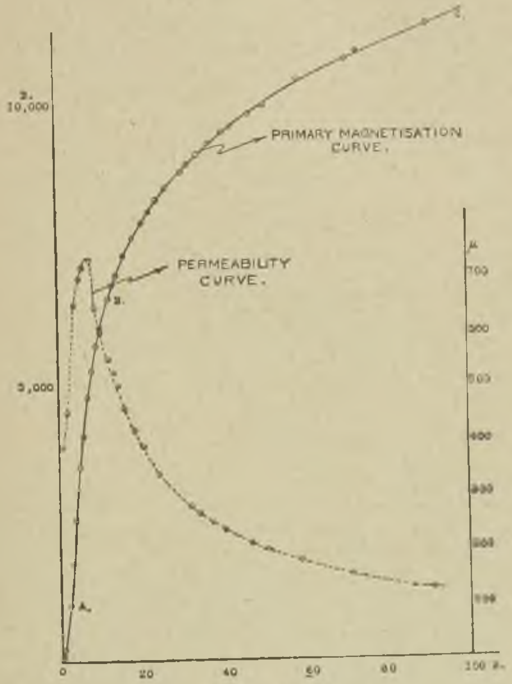


Fig. 1.

takes the curve CD instead. Thus when the magnetic force has been reduced to zero, magnetism equal to OD remains in the specimen, and is hence called the *residual* or *remanent magnetism*. If the magnetising force is now reversed a negative force equal to OE is required to reduce the remanent magnetism to zero. Hence OE is a measure of the degree of stability with which the remanent magnetism is held and is known as the *coercive force.* The greater the coercive force the more strongly is the remanent magnetism held, and *vice versa.* On decreasing the force still further, the curve EF is obtained, and if this force is again reduced to zero the induction follows the curve FG. The remanent magnetism OG is equal to the remanence OD, the magnetism simply being in the opposite direction. If now the force is increased to the original positive maximum, the curve GHC is obtained.

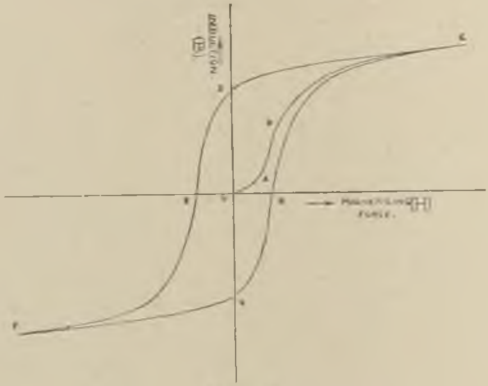


FIG. 2.

Thus it will be seen that on decreasing the magnetic force from a positive value to an equal negative value, and then again increasing it to the original positive value, the induction follows the curve CDEFGHC, and an amount of energy proportional to the area of this curve, or the so-called "*Hysteresis loop,*" is dissipated during the process. This energy takes the form of heat, and, consequently, the specimen becomes warm when the magnetism is successively reversed or varied in any way. The cores of transformers and dynamo armatures are familiar instances of point.

This heating, which occurs as a consequence of hysteresis, has, of course, nothing to do with the additional heating which Foucault or eddy currents may cause when quick changes of magnetism take place. Now the area of the loop gives the energy dissipated in ergs per cubic centimetre of the specimen per cycle of magnetisation. Now, ergs per cc. per cycle is rather an inconvenient unit, so that the hysteresis loss has been expressed in watts per lb., assuming the specimen to be subjected to 100 cyclic changes per second. This magnetic hysteresis of iron is very important, as two illustrations will show:—Take the case of a large dynamo with an armature of soft iron weighing 1 ton with a hysteresis loss of, say, 10,000 ergs. per cc. per cycle. If this armature rotates at such a speed that the iron undergoes 100 cyclic changes of magnetisation per second, then 17.7 h.p. is required to overcome the magnetic hysteresis of the iron. Nearly 4,000 cyclic changes of magnetisation would produce a rise in temperature of 1 deg. C. Suppose that the dynamo is a 4-pole machine rotating at 1,000 r.p.m., there are 2,000 cyclic changes per minute—hence the temperature of that armature would rise ½ deg. C. per minute, assuming that there is no radiation or conduction.

Industrial Requirements.

The magnetic properties of any material must suit its industrial requirements. Thus the armatures of D.C. and the stators of A.C. motors and generators must not only possess high permeability but must also have the lowest possible hysteresis loss, since these parts are subjected to an alternating magnetic field. The frames of such D.C. machines and the rotors of A.C. generators must have the greatest possible magnetic permeability, the hysteresis loss being immaterial, since such parts are not subjected to an alternating magnetic field.

The required permeability is especially high in the pole pieces of D.C. machines in order to reduce as far as possible the weight of copper required in the field coils. The pole pieces are sometimes made of wrought iron forgings cast into the C.I. magnet frame and fitted with pole shoes of laminated wrought iron, as shown in Fig. 3.

Sometimes the pole piece and shoe are built up in one piece from wrought-iron laminations and bolted to the cast-iron magnet frame. This form gives a pole of rectangular section, whereas the wrought-iron pole piece is almost always of circular section.

Cast iron is never used for pole pieces owing to its low permeability, but occasionally pole pieces and magnet frame are cast together in cast steel and fitted with shoes.

For permanent magnets, however, not only is the greatest remanent magnetism required, but the coercive force must also be as large as possible Soft iron, for example, retains 92 per cent. of its magnetism after the magnetising force has been withdrawn. But since the coercive force of soft iron is only about 2 c.g.s. units, this residual magnetism is held so feebly that even the lightest touch of the fingers suffices to destroy most of it. Consequently, soft iron would not be suitable for a permanent magnet. The best magnets have a coercive force of about 150 c.g.s. units, but such high coercive force is only obtained by sacrificing the remanent magnetism to a certain extent, and an approximation of the value of a material for magnets is obtained from the product of the coercive force and the remanent magnetism. Such a product should be in the neighbourhood of 1,000,000.

Fig. 3.

For bed plates, end plates for generators and motors, cable bones, shields for motor, etc., a non-magnetic material is desirable in order to minimise the losses due to stray flux.

Cast iron, occasionally qualified by the adjectives "soft" and "hard," is sometimes mentioned in tables of magnetic properties, and from such tables one is led to suppose that it is useless, when viewed from the standpoint of its magnetic properties.

It has always been stated that cast iron possesses low induction and low permeability and high hysteresis loss. Values such as 8,000 for the maximum induction at a field strength of 150 c.g.s., 250 c.g.s. for the maximum permeability, 12 c.g.s. for the coercive force, and 35,000 to 40,000 ergs for the hysteresis loss are quoted. However, cast iron offers great possibilities as regards its magnetic properties. Examples are given in this Paper of cast iron with twice this induction, from four to ten times the permeability, and nearly one-tenth the hysteresis loss.

Experimental.

American washed iron of the following analysis was used for the present investigation.

	First supply.	Second supply.
	Per cent.	Per cent.
Total carbon ..	3.16	3.84
Graphite carbon ..	nil	nil
Manganese	Trace	Trace
Silicon	0.046	0.03
Sulphur	0.016	0.02
Phosphorus ..	Trace	Trace

The iron was melted in a 30-lb. salamander crucible, elements were added either in the metallic form or as ferro-alloys, and bars 12 in. by 1 in. diameter were cast in sand-moulds. The bars were machined down to 1.128 centimetre diameter. The primary magnetisation curves were determined by using an Iliovici permeameter, and the hysteresis loops by the bar-and-yoke method.

The Effect of Silicon.

In order to determine the effect of silicon on the magnetic properties of cast iron, bars containing various percentages of this element were cast. The analysis of these bars is given in Table I.

It will be noticed that the silicon increases from 0.6 to 4.0 per cent. With the exception of those bars marked,* all bars were tested in the cast state, without even being annealed to remove machining strains. The bars marked* in this and

TABLE I.—*Composition of Alloys of the Silicon Series.*

Specimen	T.C.	G.C.	G.C.	Si.	Mn.
1	2.77	1.88	0.89	0.6	0.015
2	2.79	2.14	0.65	0.807	Trace
*3	3.11	0.24	2.87	1.43	0.024
*4	2.95	0.35	2.6	1.97	0.025
*5	2.74	0.46	2.28	2.26	0.02
*6	2.675	0.28	2.42	2.46	Trace
8	2.70	1.46	1.24	2.41	0.04
9	2.58	1.1	1.48	2.745	0.035
10	2.54	1.35	1.19	4.165	0.035

subsequent tables were annealed at 900 deg. C. for fifteen minutes, and were then turned down to size. Specimen 7 was accidentally broken and was not available for testing magnetically. The magnetisation and permeability curves for all the specimens are given in Fig. 4, and the magnetic properties are shown in Table II.

TABLE II.—*Magnetic Properties of the Silicon Series of Alloys.*

Specimen	B max. (Max. magnetic induction.)	H max. (Max. magnetic field strength)	μ max. (Max. permeability.)	H for μmax.	Remanent magnetism.
1.	9,977	99.58	264.0	15.1	5025
2	9,678	99.78	237.0	16.2	4733
*3	11,480	98.9	481.5	8.0	5124
*4	11,644	100.13	497.0	8.0	5523
*5	11,747	100.53	549.0	6.9	4578
*6	11,900	100.3	737.0	7.8	4724
8	11,090	101.43	271.6	16.0	4667
9	10,833	101.43	253.0	16.0	4431
10	10,540	98.36	254.0	14.0	4060

The most prominent feature is the magnetic superiority of the annealed specimens compared with the unannealed ones. The effect of annealing may be seen by comparing specimens 6 and 8 which have almost identical silicon contents. Specimen 6 has been heat treated before turning, but specimen 8 is in the cast condition. The

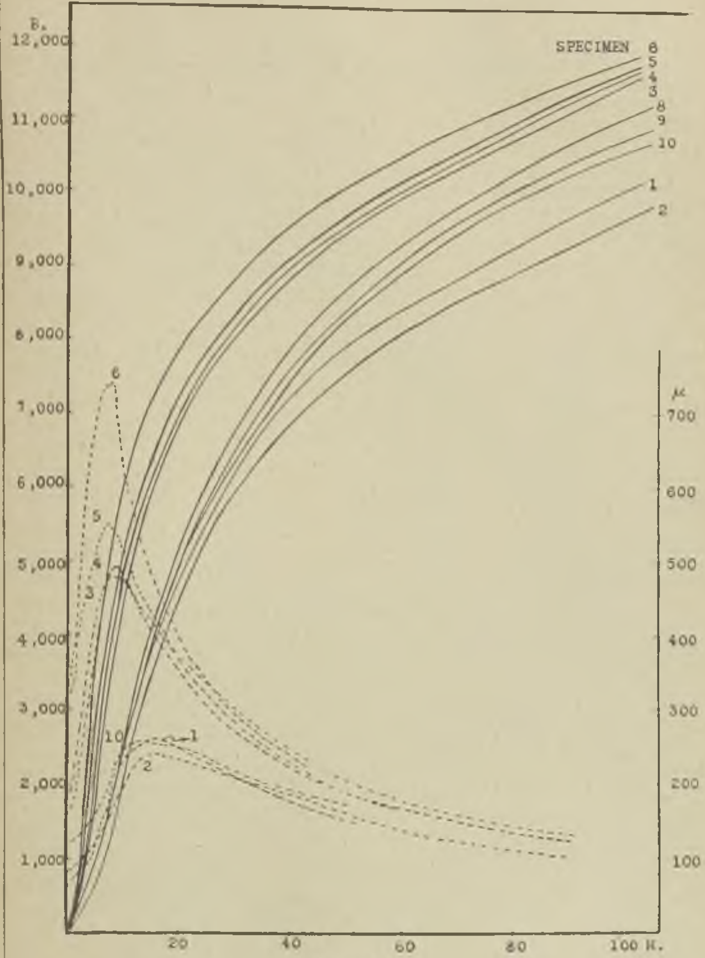

B.
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
SPECIMEN
6
5
4
3
8
9
10
1
2
6
5
4
3
10
1
2
μ
700
600
500
400
300
200
100
20
40
60
80
100 H.

FIG. 4.

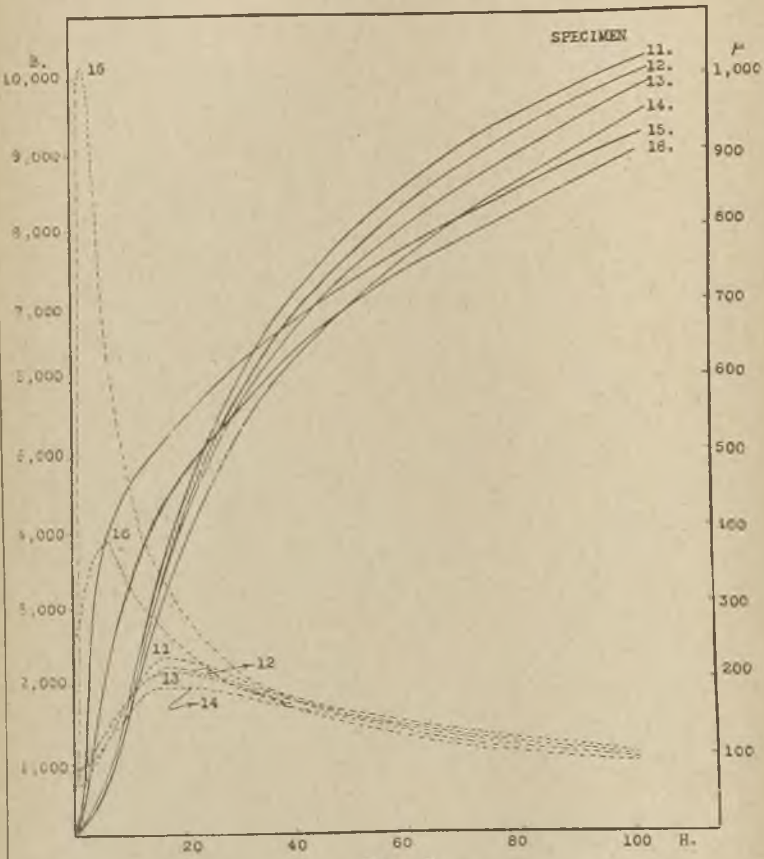

SPECIMEN
11.
12.
13.
14.
15.
16.
B.
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
μ
1,000
900
800
700
600
500
400
300
200
100
16
16
11
12
13
14
20
40
60
80
100
H.

Fig. 5.

maximum induction of the former is 11,900 c.g.s. whilst that of the latter is 11,090 c.g.s.

The dotted curves in Fig. 4 represent the change of permeability with respect to the field, and it will be noticed that the maximum permeability increases with increasing silicon content, and that the maximum permeability of the annealed specimens is more than twice that of the unannealed ones. The low induction of specimen 2 is due to the high percentage of combined carbon. The magnetic properties of the cast specimens appear to deteriorate with the higher the content of silicon. Thus, specimen 10 is not as good magnetically as specimen 9, which in its turn is not as good as specimen 8. These specimens were not prepared in one heat and they are rather an imperfect series of alloys. Moreover, the casting conditions may have a considerable influence on the magnetic properties of the material. As the author was chiefly concerned at this time with obtaining high permeability and low hysteresis loss, and since it is evident that annealing raises the induction and permeability of cast iron, all the specimens were embedded in their own turnings in a sealed iron box. They were then heated to 875 deg. C. and allowed to cool at the slow rate of 30 deg. C. per hour to 675 deg. C., from which point they were allowed to cool with the muffle. In this way most of the carbon was precipitated as finely divided graphite, the strains due to turning were removed, whilst oxidation was prevented by annealing the specimens in their own turnings. Primary magnetisation curves and

TABLE III.—*Primary Magnetic Results on the Silicon Series.*

Specimen.	B max.	H max.
1	10,170	99.45
2	9,810	100.0
*3	11,060	98.35
*4	11,320	101.4
*5	11,480	99.1
*6	11,430	99.2
8	11,690	100.5
9	11,570	103.8
10	11,960	99.8

hysteresis loops were taken, the results being shown in Tables III and IV. The maximum induction increases with increasing silicon content.

With the exception of specimen 9, the addition of silicon reduces both the hysteresis loss and the coercive force. Moreover, with high silicon content, as in specimen 10, the hysteresis loss is exceptionally low, being nearly as low as that of wrought iron. The last column in the table gives the energy dissipated per lb. of iron, assuming the specimen to be subjected to 100 magnetic cycles per second at a flux density of 10,000 maxwells per sq. cm.

TABLE IV.—*Other Magnetic Properties of the Silicon Series.*

Specimen.	Coercive force.	Hysteresis loss in ergs/cc. per cycle, for B = 10,000.	Watts loss per lb. of metal.	Density.
2	12.7	34,080	20.997	7.363
*3	9.8	27,680	16.750	7.231
*4	8.5	26,120	16.440	7.213
*5	7.0	23,860	14.898	7.180
*6	6.5	18,850	12.049	7.164
9	7.6	20,120	12.748	7.163
10	3.5	8,700	5.634	7.038

TABLE V.—*Composition of High Silicon Series.*

Specimen	Si.	T.C.	C.C.	G.C.	Mn.
11	2.54	3.06	1.35	1.71	0.02
12	2.87	2.97	1.25	1.72	0.03
13	3.41	2.97	1.17	1.80	0.032
14	4.76	2.76	0.88	1.88	0.053
15	6.04	2.61	0.09	2.52	0.085
16	7.38	2.4	0.1	2.3	0.095

Alloys containing up to about 8 per cent. of silicon were then prepared in one heat and these were tested in the cast state, after turning to a diameter of about 1.170 centimetre and then grinding to a diameter of 1.128 centimetre. The analysis of these specimens is given in Table V.

Primary magnetisation and permeability curves were taken by using the permeameter and are shown in Fig. 5. A summary of the magnetic properties is given in Table VI.

Thus silicon decreases the magnetic induction and the remanence, and, when present in amounts not exceeding 5 per cent., it also decreases the maximum permeability of cast iron in the cast state. On referring to Fig. 5, it will be noticed that specimens 15 and 16 are much more magnetic than the other specimens in comparatively weak fields. This property is reflected in the permeability curves, the permeability of specimen 15 being 1,021 c.g.s. at a force of only 2.25 c.g.s.

TABLE VI.—*The Magnetic Properties of Second Silicon Series.*

Specimen.	B max.	H max.	μ max.	H for μ max.	Remanence.
11	10,190	99.75	230	16.4	4300
12	10,100	100.13	218	16.4	4290
13	9,845	100.2	213	15.2	3800
14	9,455	100.13	193	20.48	2900
15	9,200	99.71	1,021	2.25	2900
16	8,935	97.3	383	5.88	1650

TABLE VII.—*Hysteresis Loss on Second Silicon Series.*

Specimen.	Limits of induction.	Coercive force.	Hysteresis loss ergs/c.c. per cycle.	Watts loss per lb.	Density.
11	10,000	12.7	32,435	9.984	7.225
12	10,000	13.1	32,900	20.19	7.238
13	10,000	12.0	28,700	18.02	7.221
14	10,000	9.8	22,840	14.50	7.143
15	8,000	2.2	4,075	2.652	6.951
16	4,500	1.7	2,390	1.551	6.949

This is a property common to alloys possessing very low hysteresis loss, namely, they are very permeable in weak fields, but they are not any more permeable than ordinary alloys in strong fields.

Hysteresis loops were next determined, and the magnetic properties are given in Table VII. Owing to the magnetic hardness of some of the specimens, the hysteresis loops could not be determined between the limits of B=10,000 maxwells. The limits of induction between which the loops were determined are given in the first column of Table VII. However, it must not be supposed that the hysteresis loss is directly proportional to the limits of induction between which the loop is determined, since the loop becomes very narrow at its extremities.

TABLE VIII.—*Composition of the Manganese Series.*

Specimen	Mn.	Si.	T.C.	C.C.	G.C.
M1 ..	0.235	1.724	2.64	1.35	1.29
M2 ..	0.63	1.736	2.82	1.38	1.44
M3 ..	1.07	1.727	2.69	1.49	1.2
M4 ..	1.49	1.705	2.73	1.41	1.32
M5 ..	2.66	1.466	2.65	2.65	nil

TABLE IX.—*Magnetic Properties of Manganese Series.*

Specimen	B max.	H max.	μ max.	H for μ max.	Remanence.
M1	10,900	100.13	264	15	4950
M2	11,225	99.96	260	17.2	4960
M3	11,016	99.59	241.2	20.2	5420
M4	10,240	93.9	234	16.6	5090
M5	8,420	100.0	160	30	4600

Thus, with the exception of specimen 11, silicon reduces the coercive force and the hysteresis loss. The hysteresis loss of specimen 15 is exceptionally low, and it is remarkable since it occurs in an alloy which is in the cast state.

The Effect of Manganese.

In order to investigate the effect of manganese on the magnetic properties of cast iron, the manganese was varied whilst the silicon was kept constant. The silicon was added to give soundness and to make the specimens soft and machinable.

The chemical composition of the specimens is given in Table VIII.

The magnetisation and permeability curves are given in Fig. 5, and the magnetic properties in Table IX.

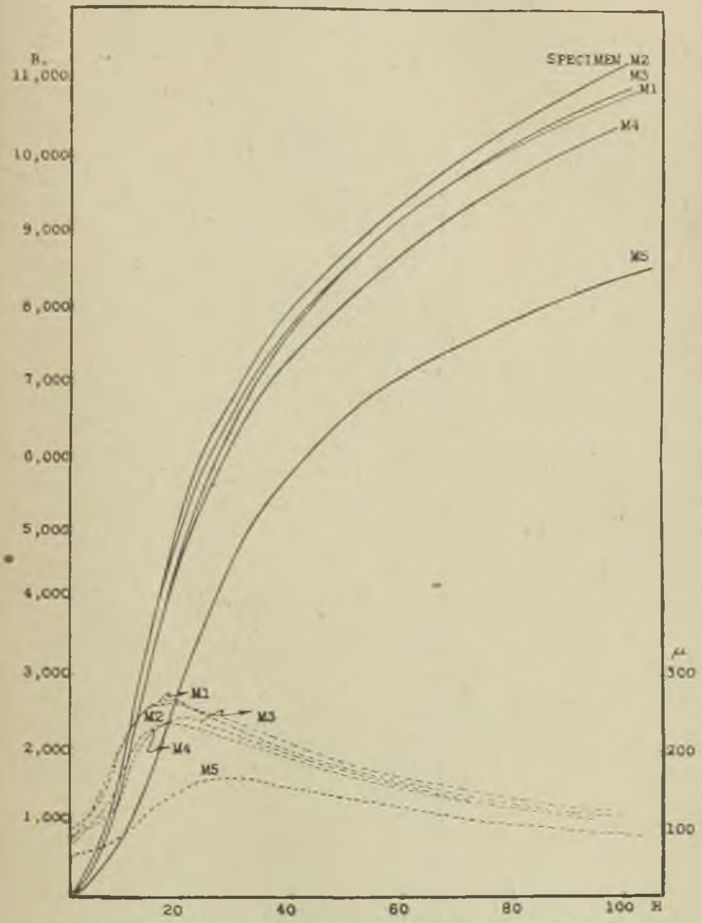


FIG. 6.—MAGNETIC PROPERTIES OF MANGANESE SERIES.

H

TABLE X.—*Magnetic Properties of Heat-Treated Manganese Series.*

Specimen.	Maximum induction.	Remanent magnetism.	Coercive Force.	Hysteresis loss in ergs/ c.c. cycle for B=10,000	Hysteresis loss in Watts per lb.	Density.
M1	11,160	5550	9.5	Accidently	broken	7.337
M2	11,400	5930	9.5	28.200	17.403	7.315
M3	11,180	5800	11.0	29.550	18.551	7.397
M4	10,560	5440	12.0	31.600	19.350	7.405
M5	8,520	4760	20.0	35.000	21.061	7.538

It is seen from the curves that manganese is prejudicial to good magnetic properties and should be as low as possible when high induction and high permeability are required. The decrease in the induction with increasing manganese content is shown in Fig. 7. The specimens were then annealed in a similar manner to the previous specimens, namely, they were surrounded by their own turnings in a closed iron box, heated to 875 deg. C. and allowed to cool very slowly. The magnetic properties of the annealed specimens are given in Table X, from which it is seen that annealing slightly raises the induction, the slight increase being probably due to removal of strain.

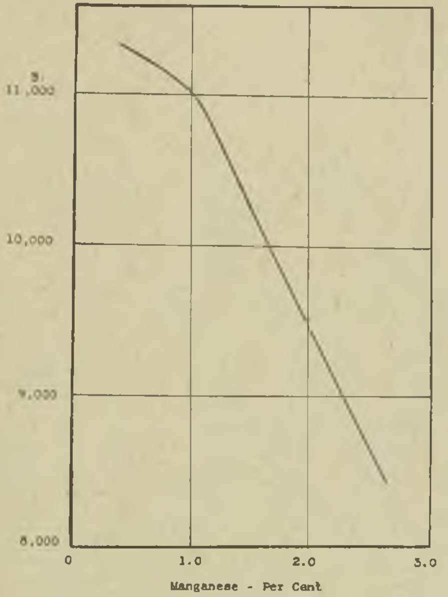


Fig. 7.—Effect of Manganese on the Induction.

Manganese increases the hysteresis loss and the coercive force, but decreases the magnetic induction and remanent magnetism. Thus manganese should be kept as low as possible, when cast iron having high permeability, high maximum induction and low hysteresis loss is required.

Influence of Aluminium.

Aluminium was added to American washed iron to ascertain its effect on the magnetic properties of cast iron. Aluminium behaves like silicon in that it renders the iron sound and precipitates graphite. Thus silicon is not necessary. The analyses of the first series of specimens is given in Table XI.

TABLE XI.—*Composition of the Aluminium Series.*

Specimen.	Al.	Mn.	Si.	T.C.	C.C.	G.C.
A1	0.31	trace	0.047	3.09	3.06	0.0
A2	0.62	,,	0.047	3.05	2.96	0.03
A3	1.03	,,	0.046	2.84	1.34	1.59
A5	1.23	,,	0.045	2.56	1.91	0.650
A6	3.00	,,	0.046	2.60	1.42	1.18

TABLE XII.—*Magnetic Properties of the Aluminium Series.*

Specimen.	B max.	H max.	μ max.	H for μ max.	Remanent magnetism.
A1	10,530	100.13	319	13.2	5900
A2	10,510	99.15	289	15.0	5660
A3	9,980	99.59	245	18.0	4940
A5	8,780	99.25	125.5	42.75	3970
A6	7,950	101.03	105.2	38.5	4170

Specimens A1, A2 and A3 were annealed at 900 deg. C. for fifteen minutes before machining. The magnetisation and permeability curves are given in Fig. 8, and a summary of the magnetic properties is given in Table XII.

Thus there is a steady decrease in the maximum induction and remanent magnetism as the aluminium content is increased. The effect of annealing is very pronounced, the curves for specimens A5 and A6 being very much lower than those of the annealed specimens.

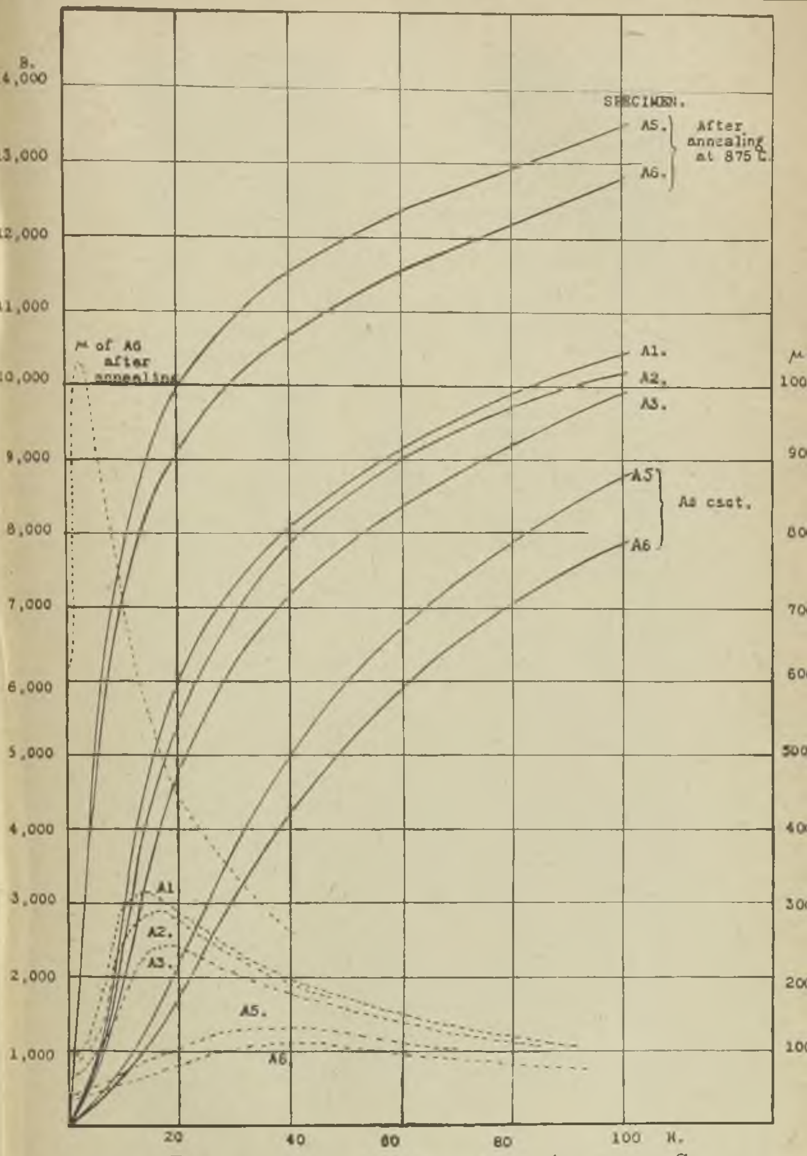


Fig. 8.—The Magnetic Properties of the Aluminium Series.

Before taking hysteresis loops, the specimens were annealed in their own turnings at 875 deg. C. and allowed to cool very slowly. Primary magnetisation curves and hysteresis loops were then determined. A summary of magnetic properties is given in Table XIII.

There is an increase in the maximum induction, maximum permeability and remanence of specimens A1, A2 and A3 on annealing. This is due to further graphisation of these alloys. Up to 1 per cent. aluminium causes a slight decrease in the induction, but the most noticeable feature is the extremely high induction of specimens A5 and A6. In the cast condition the inductions of these specimens were 8,776 and 7,950 c.g.s. respectively, whereas in the annealed condition they are 13,470 and 12,850 c.g.s. respectively. Moreover, the permeability of these specimens has been increased tenfold by annealing, as shown in Table XIV, which also gives the graphite analysis of the specimens before and after annealing.

TABLE XIII.—*Magnetic Properties of Heat-Treated Aluminium Series.*

Specimen.	B max.	H max.	Remanence.	μ max.
A1	10,700	102.7	6210	360
A2	10,540	101.1	5990	321
A3	10,370	100.13	5760	312
A5	13,470	99.4	4800	1045
A6	12,850	100.7	4600	1030

TABLE XIV.—*Graphite Content and Magnetic Properties of two Aluminium Alloys before and after Heat-Treatment.*

Specimen.	Cast condition.			Annealed.		
	μ max.	H for μ max.	Graphite.	μ max.	H for μ max.	Graphite.
A5	125.5	42.75	0.65	1045	2.5	2.1
A6	105.2	38.5	1.18	1030	3.0	2.45

The magnetisation and permeability curves for specimens A5 and A6 in the annealed condition are shown in Fig. 8. The extremely high induction of these specimens is largely due to the small amount of combined carbon, and to the distribution of the graphite. Table XV gives a summary of the properties of these specimens.

Aluminium, up to 1 per cent., apparently increases both the coercive force and the hysteresis loss, but further addition causes a considerable decrease. The coercive force and hysteresis loss of specimens A5 and A6 are very little greater than those of soft iron. Alloys containing from 1 to 4 per cent. of aluminium were then prepared and tested in the cast condition. The analysis of these specimens is given in Table XVI.

TABLE XV.—*Hysteresis Losses of the Aluminium Series.*

Specimen.	Coercive force.	Hysteresis loss in ergs/c.c. per cycle for B = 10,000	Loss in Watts per lb. of metal.	Density.
A1	9.9	28,000	16.778	7.572
A2	13.0	36,210	21.590	7.611
A3	12.4	36,100	22.090	7.375
A5	3.4	9,000	5.908	6.908
A6	2.7	7,100	4.716	6.809

TABLE XVI.—*Composition of Second Series of Aluminium Alloys.*

Specimen.	Al.	T.C.	C.C.	G.C.	Si.	Mn.
A7	0.865	3.61	1.35	2.26	0.03	Trace
A9	1.52	3.63	1.48	2.15	0.03	,,
A10	2.23	3.52	1.63	1.89	0.02	,,
A11	2.50	3.64	1.34	2.30	0.023	,,
A12	2.83	3.50	1.59	1.91	0.025	,,
A13	3.60	3.61	1.36	2.25	0.018	,,
A14	4.09	3.42	1.57	1.85	0.02	,,

The primary magnetisation and permeability curves are given in Fig. 9, and a summary of the magnetic properties is given in Table XVII.

Thus aluminium decreases the maximum induction, the maximum permeability, and the remanent magnetism. The magnetic properties obtained from the hysteresis loops are given in Table XVIII.

Except in the case of specimen A7, aluminium increased the coercive force. The hysteresis loss first decreases and then increases.

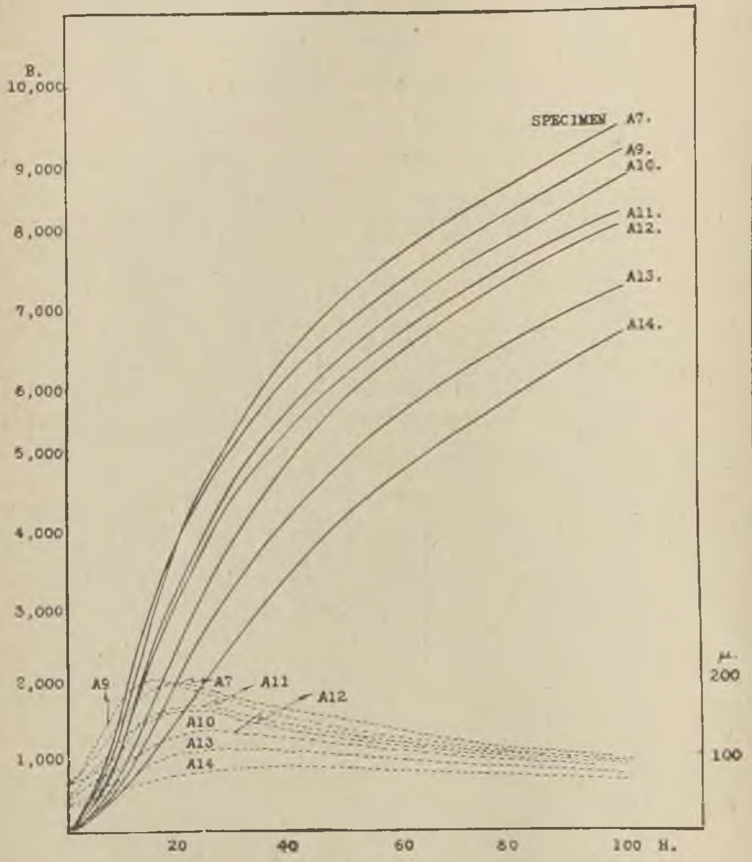


Fig. 9.

Effect of Chromium.

In addition to the chromium, silicon had to be added to the washed iron in order to make the specimens sound and machinable. A great deal of difficulty was experienced in making these specimens, they had to be prepared in two heats, and they contained amounts of silicon varying from 1.7 per cent. to 3.6 per cent. The analysis of the specimens is given in Table XIX. and the magnetisation and permeability curves are shown in Fig. 10.

TABLE XVII.—*Magnetic Properties of the Second Series of Aluminium Alloys.*

Specimen.	B max.	H max.	μ max.	H for μ max.	Remanence.
A7	9450	98.35	196	19.88	3850
A9	9155	100.13	199	16.20	3850
A10	8750	98.35	165	20.56	3580
A11	8440	104.80	158	18.12	3500
A12	8140	93.70	134	26.0	3040
A13	7260	98.31	109	32.36	3410
A14	6660	98.33	87	41.30	3210

TABLE XVIII.—*Hysteresis Losses of Second Series of Aluminium Alloys.*

Specimen.	Limits of induction between which the loop was determined	Coercive force.	Hysteresis loss in ergs/c.c./cycle.	Loss in Watts per lb. of metal.	Density.
A7	9600	13.4	31,750	20.213	7.123
A9	9100	12.7	30,335	20.083	6.851
A10	8800	14.4	30,810	19.453	7.184
A11	8500	14.8	31,880	20.448	7.075
A12	8100	18.4	39,790	25.460	7.090
A13	Could not be fitted into the yoke.				6.753
A14	6700	24.6	41,540	28.433	6.627

TABLE XIX.—*Composition of Chromium Series.*

Specimen.	Si.	Cr.	Mn.	T.C.	C.C.	G.C.
C1	2.632	0.63	0.02	2.59	1.21	1.38
C2	3.627	1.06	Trace	2.42	0.94	1.48
C3	3.116	1.79	0.015	2.45	1.06	1.39
C6	1.71	7.51	0.01	2.10	2.10	nil

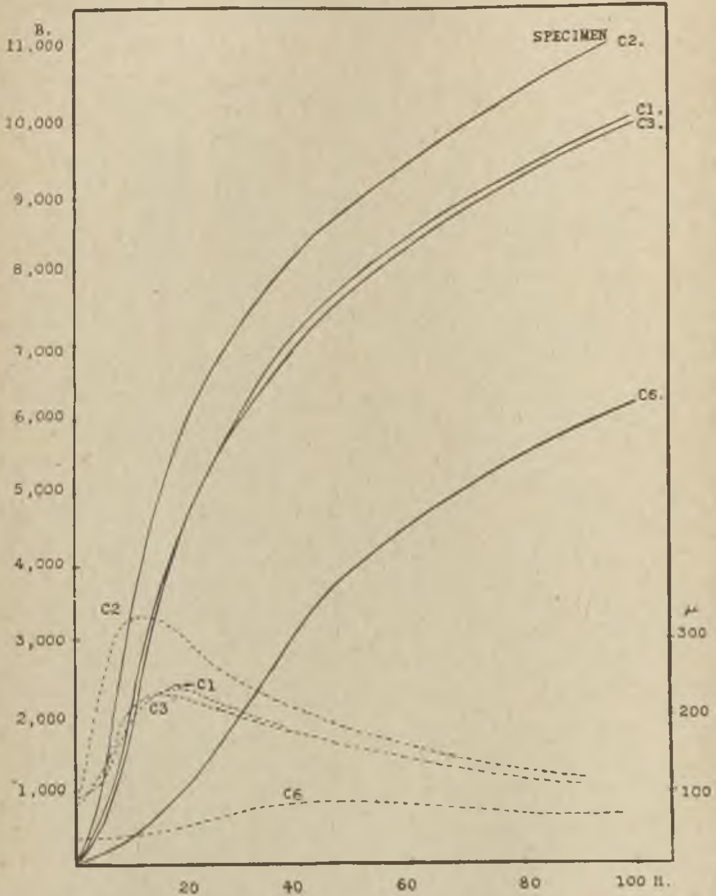

B.
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
SPECIMEN C2.
C1.
C3.
C6.
C2
C1
C3
C6
μ
300
200
100
20
40
60
80
100 H.

FIG. 10.

A summary of the chief magnetic properties is given in Table XX, from which it is seen that chromium is prejudicial to good magnetic properties.

It is difficult to draw accurate conclusions from specimens C1, C2, and C3, owing to the varying amounts of silicon. The induction of specimen C2 is high owing to the large percentage of silicon, whilst the induction of specimen C3 is not very much less than that of specimen C1, because the former contains 0.5 per cent. more silicon than the latter. The addition of chromium decreases the maximum permeability of the remanent magnetism, and increases the force at which this maximum permeability occurs.

TABLE XX.—*Magnetic Properties of the Chromium Series.*

Specimen.	B max.	H max.	μmax.	H for μ max.	Remanent magnetism.
C1	9,925	97.43	231	15.1	4460
C2	10,970	96.58	330	13.1	5150
C3	9,920	99.07	229.7	17.4	4160
C6	6,120	99.6	80	45	3310

TABLE XXI.—*Hysteresis Losses of the Chromium Series.*

Specimen.	Remanent magnetism.	Coercive force.	Hysteresis loss in ergs/c.c. per cycle for B = 10,000.	Hysteresis loss in Watts per lb. of metal.	Density.
C1	5550	11.8	31,130	19.802	7.271
C2	5290	10.0	29,000	18.72	7.082
C3	4960	8.7	21,000	14.988	7.270
C6	3350	33.0	45,350	27.642	7.537

In the hysteresis tests, chromium appears to increase the coercive force and hysteresis loss, as shown in Table XXI.

Non-Magnetic Alloys.

Several bars containing various percentages of nickel were cast in order to determine the effect of this element on the magnetic properties of cast iron. However, only one of these bars could be

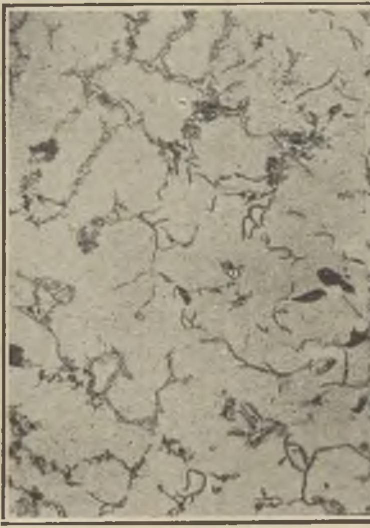


FIG. 11.
SPECIMEN N3,
ETCHED × 100.

FIG. 12.
SPECIMEN F,
ETCHED × 100.

FIG. 15.
SPECIMEN N3
(ANNEALED),
ETCHED × 100.

machined. It is well known that nickel lowers the thermal transformation points of steel. Consequently a series of alloys containing progressively increasing amounts of nickel will be martensitic

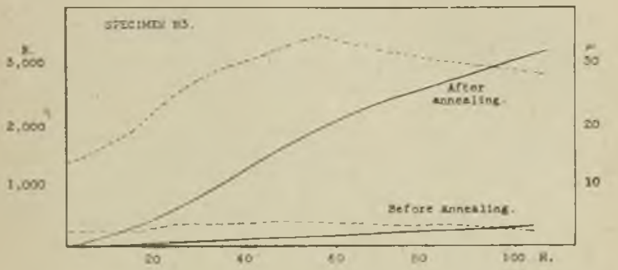


FIG. 13.

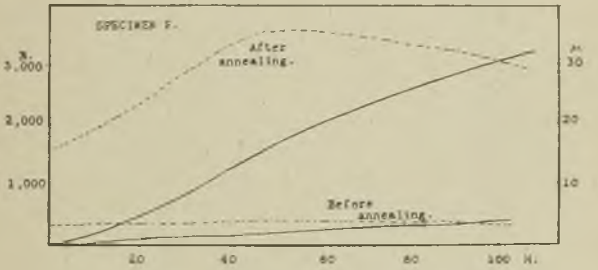


FIG. 14.

over a considerable range of composition. The bars in this martensitic range cannot be turned in a lathe. The bar which was machined consists mainly of austenite. The analysis (Specimen N3) is as follows:—

Specimen.	Ni.	Si.	Mn.	T.C.	C.C.	G.C.	P.
N3	12.35	1.30	0.025	2.56	1.16	1.4	—
F	10.00	2.57	2.04	2.20	0.59	1.61	1.96

Specimen F was made after seeing a short paragraph in the technical Press on "No-Mag," which is a patented non-magnetic cast iron made by Messrs. Ferranti. The paragraph stated that "No-mag" consisted of 80 per cent. of cast iron, the additions being nickel and manganese, and that it was cast into very thin sections. The micro-structure of Specimen N3 is shown in Fig. 11, from which it will be noticed that the ground mass is austenite, and that there is a small amount of carbide present. Thus nickel causes the iron to remain in the austenitic condition and consequently the iron is non-magnetic. The micro-structure of Specimen F, shown in Fig. 12, consists of austenite containing a little martensite, an inter-granular constituent consisting of a mixture of cementite and phosphide eutectic, and graphite. The presence of this martensite made the iron extremely hard and difficult to machine.

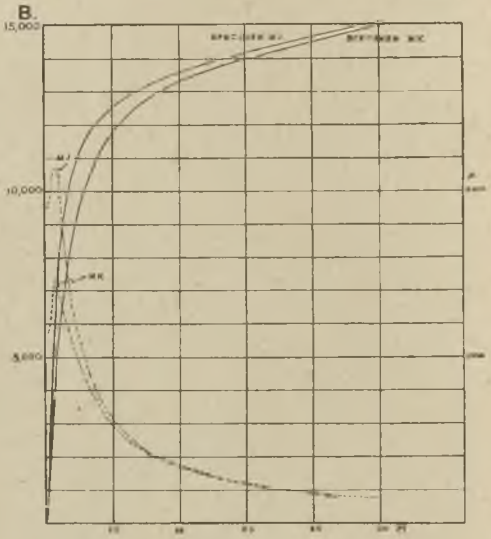


FIG. 16.

The magnetic properties of "N3" and "F"

are shown in Figs. 13 and 14 respectively, from which it will be seen that the specimens are feebly magnetic. Table XXII gives the chief magnetic properties of the specimens. It should be noted that the permeability scale in Figs. 13 and 14 is ten times the scale used in previous figures.

TABLE XXII.—*Magnetic Properties of Two Nickel Alloys of Cast Iron.*

Specimen	B max.	H max.	μ max.	H for μmax.	Remanent magnetism.
N3 (as cast)	419	99.15	4.6	60	6
F ..	377	99.61	3.8	60	nil
N3 annealed	3140	103.2	35.0	57	1330
F at 875°C.	3280	105.5	33.7	46	1630

TABLE XXIII.—*Magnetic Properties of Black Heart Malleable Iron.*

Specimen.	B max. (H = 100)	μ max.	H for μ max.
M.J.	15,150	2,140	3.0
M.K.	14,950	1,490	3.24

These specimens become magnetic on annealing, due to the austenitic breaking up and producing martensite. The structure of Specimen N3, after annealing is shown in Fig. 15.

TABLE XXIV.—*Hysteresis Losses of Malleable Iron.*

Specimen.	Limits of induction between which loss was determined.	Coercive force.	Hysteresis loss in ergs per c.c. per cycle.	Hysteresis loss in Watts per lb.	Density
M.J.	10,500	2.17	6,799	4.235	7.281
M.K.	10,000	2.36	7,010	4.380	7.259

Malleable Cast Iron.

Two specimens of black heart malleable cast iron, kindly supplied by Messrs. Leys Malleable Castings Company, Limited, of Derby, were tested.

The analysis is given in the table below, whilst the primary magnetisation and permeability curves are shown in Fig. 16.

FIG. 17.—SPECIMEN 5, ETCHED × 100.

Specimen.	T.C.	G.C.	C.C.	Si.	Mn.	S.	P.
M.J.	2.24	2.16	0.08	0.89	0.29	0.036	0.123
M.K.	2.29	2.24	0.05	0.97	0.30	0.036	0.123

A summary of the magnetic properties obtained from these curves is given in Table XXIII.

Hysteresis losses were determined, the results of the tests being given in Table XXIV.

Thus black heart malleable cast iron has a very high induction and permeability combined with low hysteresis-loss, and low coercive force.

Fig. 18.—Specimen 6, Etched × 100.

The Relationship Between the Structure of Cast Iron and its Magnetic Properties.

The magnetic properties of cast iron depend to a very great extent upon its structure. Consideration of both structure and chemical composition is necessary if results are to be interpreted correctly, otherwise magnetism would appear to be a very capricious property. A few photo-micrographs are given to illustrate the principles underlying the relationship between structure and magnetism.

Figs. 17, 18 and 19 show the micro-structures of Specimens 5, 6 and 10. Specimen 10 is in the cast state, and has a pearlitic ground mass, while Specimens 5 and 6 have been annealed, and consist mainly of ferrite. The micro-structures of Specimens M3, M5, A5 and C6 are illustrated by Figs. 20, 21, 22 and 23 respectively. All these specimens have a pearlitic ground mass, and free cementite is also noticed.

Fig. 19.—Specimen 10, Unetched × 100.

Thus for the highest magnetic-induction and permeability a ferrite ground mass is essential. The amount of pearlite should be as low as possible. The presence of free cementite is a sure indication of low magnetic induction, and should be avoided at all costs when high permeability is required. The presence of free carbide also indicates high coercive force, high hysteresis loss, and low remanent magnetism.

The structural change in Specimens A5 and A6 on annealing is illustrated by Figs. 24 and 25. (Compare Figs. 22 and 24). The carbide has decomposed, leaving the graphite as small nodules in a ground mass of alumino-ferrite. The permeability of these specimens was increased tenfold by this change, the induction was doubled, and the hysteresis loss was decreased to less than 10,000 ergs. The hysteresis loss of these specimens in the cast condition would probably have been well over 30,000 ergs. The high induction, high permeability and low hysteresis loss of these specimens is due to the large amount of ferrite and the presence of all the carbon in the nodular form as temper carbon. The micro-structure of Specimen M.J. is shown in Fig. 26, from which it is seen that this specimen consists of ferrite grains and temper carbon. The structure readily explains the high induction, high permeability and the low hysteresis loss of this specimen.

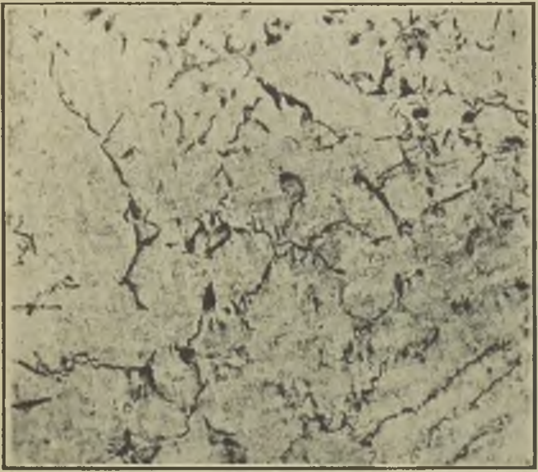


FIG. 20.—SPECIMEN M3, ETCHED × 100.

Summary and Conclusions.

1. The highest magnetic induction and permeability are obtained with cast iron which has been annealed. In the extreme case the magnetic induction was increased 70 per cent. and the

maximum permeability was increased tenfold on annealing.

2. When high permeability is required, the graphite should be in the form of temper carbon, as little combined carbon as possible should be present, and free cementite must be absent.

3. In the cast state, silicon decreases the magnetic induction, but its presence may be advantageous in alloys which have to work at low flux densities (*e.g.*, transformer cores). Specimen 15 is an example of an alloy which is very magnetic in comparatively weak fields, having a permeability of over 1,000 c.g.s. at a field strength of 2.0 gauss.

Fig. 21.—Specimen M5, Etched × 100.

4. Both in the cast and annealed conditions silicon reduces the coercive force and the hysteresis loss. In the case of Specimens 10 and 15, the hysteresis losses are remarkably low, being equal to that of very soft iron. In the case of Specimen 15,

the low hysteresis loss is remarkable, since it occurs in a cast alloy.

5. Both in the cast and annealed conditions manganese, nickel and chromium are prejudicial to high magnetic induction.

6. In the annealed condition manganese and chromium increase the coercive force and hysteresis loss and decrease the remanent magnetism.

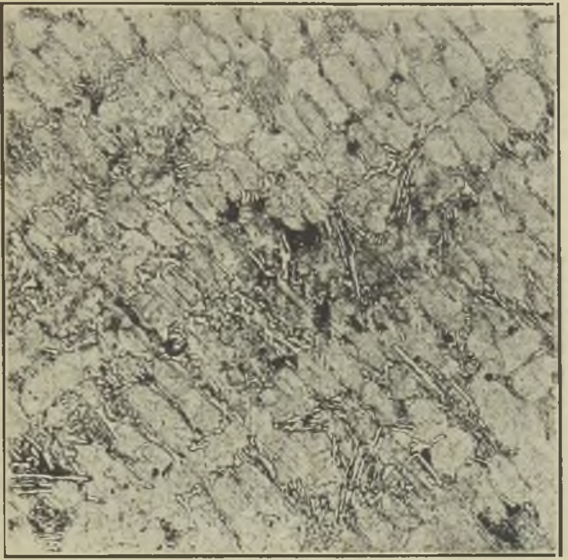


Fig. 22.—Specimen A5, Etched × 100.

7. In the cast state aluminium decreases the magnetic induction, permeability and remanent magnetism, and increases the coercive force and the hysteresis loss.

8. In the annealed condition aluminium, in amounts up to 1 per cent., decreases the magnetic induction and the maximum permeability, but increases the coercive force and hysteresis loss. When present in amounts from 1 to 3 per cent.,

however, aluminium causes a huge increase in the induction and permeability, Specimens A5 and A6 having inductions of over 13,000 c.g.s. and permeabilities of over 1,000 c.g.s. It also causes a heavy decrease in the coercive force and hysteresis loss. The coercive force and hysteresis loss of Specimens A5 and A6 are very little greater than those of soft iron.

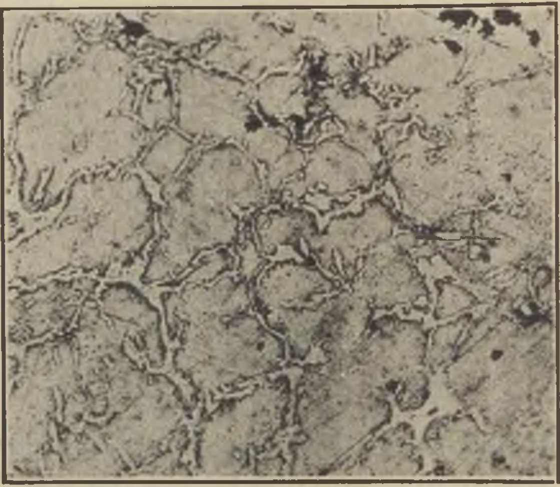


FIG. 23.—SPECIMEN C6, ETCHED × 100.

9. The presence of sufficient nickel, or nickel and manganese, makes cast iron non-magnetic. Sufficient of these elements must be added to render the iron entirely austenitic, the presence of martensite making the iron feebly magnetic, hard and difficult to machine. An easily machinable non-magnetic cast iron could be made by having nickel and manganese present in such proportions that the combined effect of these two elements on the carbon is negligible. Sufficient silicon would then be added to precipitate just sufficient graphite to give the required strength, machining properties, surface, etc.

10. Malleable cast iron possesses high induction and permeability and low hysteresis loss and coercive force.

11. The presence of graphite does not prevent the attainment of low hysteresis losses, but when high permeability and induction are required, the amount of graphite should be as small as possible.

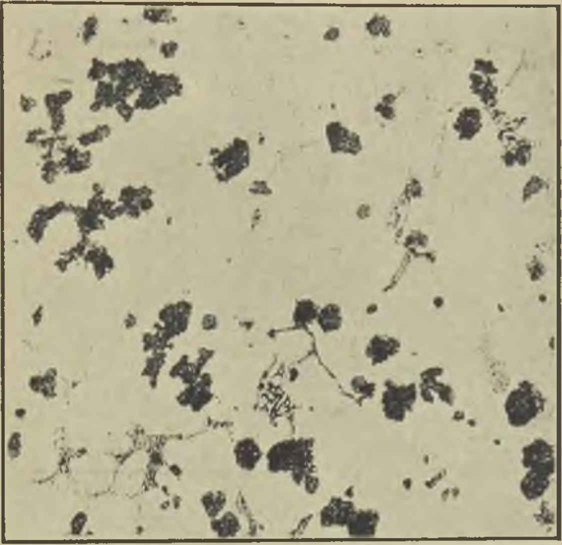


FIG. 24.—SPECIMEN A5, ETCHED × 100.

Thus the high permeability (2,500 c.g.s.) of black heart malleable cast iron is due to the small percentage of graphite, and pearlite.

In an article in the "Electrician" of August 7, 1925, Mr. O'Neill deplored the lack of information on the magnetic properties of cast iron, and urged that this material ought to be studied from the standpoint of its magnetic properties. He stated that "most grey irons have a hysteresis loss of from 30,000-40,000 ergs per c.c. per cycle, although Hopkinson reports tests on a bar of this material (analysis not given) showing an energy loss of only 13,000 ergs. The coercive force of his sample was only 3.8, so that its behaviour was surprisingly similar to that of cast pure iron." This statement is typical of the general opinion, formed 25 years ago, of the magnetic properties of cast iron. The author has endeavoured to prove that the above statement by no means applies to all cast irons, and that it is possible to produce cast iron with a hysteresis loss equal to that of soft iron, certainly less than that of wrought iron or mild steel. This class of cast iron should enable cast-iron frames to be used in the electrical industry. Poles could then be cast with the frame, thus avoiding joints, which are very undesirable. Cast iron has the advantage of high electrical resistance. The resistance of Specimen 15 is about eighteen times the resistance of a similar bar of soft iron. This high resistance would reduce the eddy currents in the case of alternating current

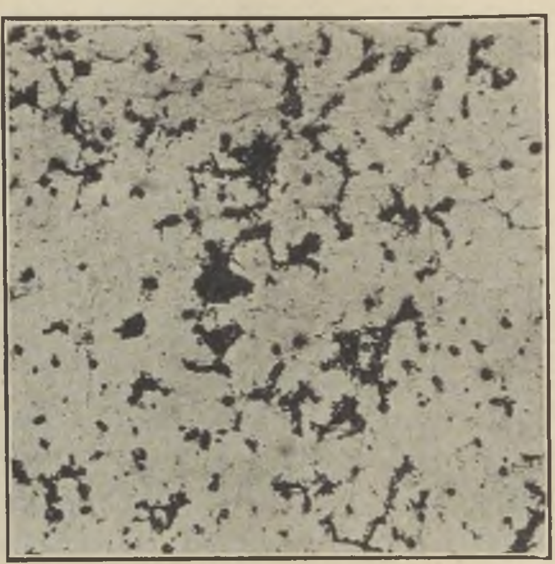


FIG. 25.—SPECIMEN A6, ETCHED × 100.

generators, thus resulting in considerable saving. Cast iron also has the advantage of cheapness, convenient casting properties and low melting point. A great disadvantage of cast iron in the cast state is the relatively low induction and permeability compared with black heart malleable iron. However, when cast iron is malleabilised in order to produce high induction and high permeability, the electrical resistance is greatly reduced, being only some three times the resistance of soft iron. However, the author doubts whether it would be economical to produce a malleable cast-iron frame for an electric alternator.

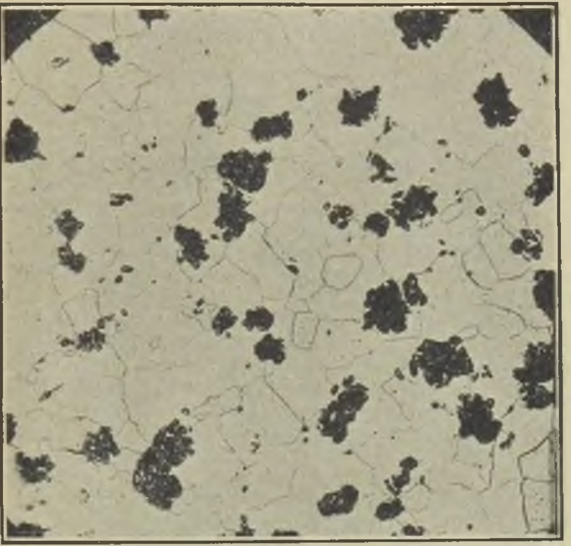


FIG. 26.—SPECIMEN M.J., ETCHED × 100.

In conclusion, the author wishes to thank Professor Turner not only for indicating such an interesting subject, but also for his kind interest in the work and for his many valuable suggestions. He also desires to thank Professor S. W. J. Smith for giving every facility for carrying out the magnetic determinations, and for his kind interest in

the work, which has been carried out in the Metallurgical and Physical Laboratories of the University of Birmingham, with the assistance of a grant from the Department of Scientific and Industrial Research. The author is indebted to the staffs of the Laboratories and to his fellow research workers for help and encouragement. His thanks are also due to the British Cast Iron Research Association, and particularly to Mr. S. E. Dawson, Member of Council of that Association.

DISCUSSION.

The **President** raised objection to the use of the word "annealed" throughout the Paper, and suggested that the expression "heat treated" should have been used, because in practice annealing was associated with a much longer process than that described in the Paper.

Mr. S. E. Dawson (Messrs. Ferranti, Ltd.), in expressing agreement with the President as to the use of the word "annealing," said that in connection with non-magnetic cast irons the use of the word, in its ordinarily accepted sense, was quite wrong, as they could not be annealed by long heat treatment; as a matter of fact, one did just the reverse, and quenched. With ordinary cast iron the metal was heated up and allowed to cool very slowly over a long period, but since non-magnetic cast iron consisted mainly of austenite which was converted by heat into martensite, the effect of this operation would be to thereby produce some small amount of martensite which would render the material slightly magnetic and hard, and it could only be re-converted into austenite and the soft condition by re-heating and quenching. He also pointed out that heat was not the only factor in bringing about this change, since excessive mechanical work has the same effect, probably due to the formation of strains in the austenite. This was to be seen on the small turnings which were rendered slightly magnetic when non-magnetic cast iron was rough machined, the turnings being slightly converted into martensite so that the permeability might be as high as 10 although the casting itself was not affected. Such a degree of change was, of course, only slight compared with the usual cast iron permeability of 300 or more. These turnings returned to their unity permeability on heating and quenching as described.

Referring to Specimen F in the Paper (page 8) and the author's statement that it was made after seeing a notice in the technical Press regarding "Nomag," it was clear from the analyses shown that this specimen was not in accordance with that material, which was 10 per cent. nickel and 5 per cent. manganese, whereas the specimen made by Mr. Partridge contained only 2.04 per cent. manganese. This specimen would not be entirely non-magnetic, because it was necessary to have a minimum content of about 10 per cent. manganese effect made up either in the form of manganese itself or the equivalent of nickel which was half as strong as manganese in this respect. For example, 10 per cent. nickel and 5 per cent. manganese gave a total manganese effect of 10 per cent. (5 per cent. due to the nickel and 5 per cent. due to the manganese). The Specimen F indicated by Mr. Partridge contained a total of only 7.04 per cent. (5 per cent. due to the nickel and 2.04 per cent. due to the manganese itself).

A non-magnetic iron made wholly of manganese would, of course, be extremely hard and unusable, but 10 per cent. nickel and 5 per cent. manganese gives both a non-magnetic and a machinable iron.

WRITTEN CONTRIBUTION.

Mr. H. Field (Willenhall) wrote that he thanked the author for a very notable contribution to the literature on this subject. Many of the facts which he has noted already find application in the industry, but other parts, and especially the section on aluminium, are of the greatest interest.

It was to be regretted that some of the bars in Table I did not represent irons which were commercially practicable. Once again the use of the crucible for melting has led to the carrying out of long experiments on irons with total carbon content lower than can be obtained in commercial melting practice. This leads to a further factor in the very high combined carbon which is associated with low total carbon, for instance, in samples S 8, S 9 and S 10, there is a combined carbon more than twice as high as is obtained in practice in one-inch diameter bars with over 2.5 per cent. silicon. By this means the author is led to suggest annealing where none should be required, as the combined carbons of S 3, S 4, S 5 and S 6 can be obtained in ordinary cast metal of these silicon contents and dimensions.

In Table V, the earlier bars contain more normal total carbon, but here again the combined carbon is abnormally high, as in commercial metal with 3.4 per cent. silicon the combined carbon in practice would not exceed 0.25 per cent. If the author obtains 1.17 per cent. combined carbon in a one-inch diameter bar how would he produce machinable castings $\frac{1}{8}$-in. thick?

It is unfortunate that such metals are chosen for a research of this kind, as they largely discount the practical value of the results obtained.

In a later paragraph of the paper the author refers to " Nomag," a patented non-magnetic cast iron, and reports that a somewhat similar alloy which he made was "hard and difficult to machine." In fairness to Messrs. Ferranti, it should be pointed out that " Nomag " is as soft as ordinary cast iron.

Under the heading, " Malleable Cast Iron," the author speciafically deals with blackheart malleable, but makes no mention of European malleable. This is rather hard on our English product, which is already having an uphill fight for existence. Actually the curve given in Fig. 16 is no better than that regularly obtained on well-annealed whiteheart malleable cast iron, which can be made almost equal in permeability to mild steel.

Mr. J. G. Pearce (Director, B.C.I.R.A.), wrote that doubtless some criticism will have been raised on account of the fact that the author of this paper has not dealt with cast irons, but with synthetic mixtures of a pure iron carbon alloy and the various elements, the influence of which he desired to determine. From this point of view the title of the paper will appear misleading.

In dealing, however, with such an alloy as cast iron, it is necessary to make such preliminary tests, but it is equally important that they should be produced and treated in a commercial way, particularly when dealing with the influence of the addition of special elements. It is at this stage in a piece of work of this character at which the Cast Iron Research Association should consider completing the work, and this matter is under consideration.

London Branch.

ELECTRICALLY-PRODUCED BLACKHEART MALLEABLE.

By F. A. Melmoth (Mappin Medallist) (Member).

Malleable iron, particularly in this country, has been, and still is, looked upon by engineers and designers as a material possessing very definite shortcomings. Its use is therefore strictly limited, and its scope of applicability, rather than increasing, is decreasing, mainly owing to the extended use of steel castings and stampings. The most common complaint registered against it is that of irregularity, and one is afraid the justice of the impeachment has very often to be admitted.

In spite of the work by Dr. Hatfield and others, the fundamentals of malleable cast iron do not appear yet to be fully elucidated, with the inevitable result that difficulty and irregularity in its production are still experienced.

Turning to the blackheart variety of this product, research, more particularly in America, has succeeded in solving many of the fundamentals associated with the material, and the product being more regular, its field of application has correspondingly enlarged, blackheart malleable having become one of America's most important ferrous products.

Some time ago, largely owing to troubles experienced with malleable iron, it became necessary for the writer's firm to consider seriously the production of its own requirements in this material.

Obviously, a decision had first of all to be arrived at as to which type of malleable offered the most promising field for development, always bearing in mind materials and equipment available, together with probable production costs. It was desired, if practicable, to bring existing electric melting equipment into action on this product.

After prolonged investigation into the rival claims of blackheart *versus* whiteheart, it was decided to proceed with blackheart material, and endeavour to try out thoroughly the possibilities of its manufacture in the electric furnace.

The decision was based on the following assumptions:—(1) Under given conditions the production of blackheart malleable is more certain than is the case with whiteheart; (2) the test results available in correct material of either type are of a higher standard in blackheart; (3) the regularity of the product with varying thicknesses of section is more marked in the case of blackheart; (4) the temperature of annealing is lower, and time required less, which spells economy; and (5) the very heavy consumption of annealing pans in the whiteheart process is considerably mitigated by the facts in No. 4 above.

Metal Production.

The manufacture of the necessary metal can be approached from either of two angles, the electric furnace being utilised:—(*a*) Synthetically, by carburising steel scrap, and (*b*) by the direct melting of pig-iron, and its adjustment to the necessary composition.

The cost of pig-iron of the correct type, and the influence of transport charges, rendered method (*b*) one of considerable doubt from an economic point of view. Investigations were therefore primarily confined to method (*a*).

The details of the production of a white cast iron synthetically in the electric furnace are so well known that space need not be occupied in entering closely into them, and the writer proposes to deal only with the control which becomes necessary when such material has to be of a type which can be afterwards malleablised to the blackheart condition.

The fundamental condition is that the iron must be so correctly balanced in its carbon and silicon contents that the after-application of the necessary temperature for the required time will result in the precipitation of practically the whole of the combined carbon as temper carbon, by the catalytic action of the silicon. The material after annealing will then consist of a matrix of silicoferrite, with scattered, finely-divided and nodular-shaped particles of temper carbon. It should be noted that whilst in the whiteheart variety the malleablising process is directly through the abstraction of carbon by oxidation, no oxidising action is relied upon in the blackheart process. Although a slight surface oxidation of carbon is inevitable during annealing, basically the process depends upon a change of condition of the carbon content, induced by the effect of temperature and time and the silicon content.

This change being a very delicately balanced action, and susceptible in the extreme to variations in conditions, control of carbon and silicon becomes of the utmost importance.

Analysis Sought.

The analysis range found to be most suitable in the hard state is as follows:—Carbon, 2.35 to 2.6; silicon, 0.80 to 1.00; manganese, under 0.3; sulphur, as low as possible, say 0.03; and phosphorus, 0.15 to 0.25 per cent.

The carbon and silicon are of course somewhat variable in their requirement, and depend largely upon the average sectional area of the class of work being made. Bearing in mind the essential of a definitely white non-graphitic fracture in the casting before annealing, it is possible, on very light work, somewhat to increase the upper limits of the range given above for these elements.

Influence of Composition.

Carbon.—The tensile strength of blackheart malleable is to a large extent inversely proportional to its total carbon content. This is due to the fact of the continuity of the tough ferrite matrix being interrupted to a greater or less degree by the particles of temper carbon. It follows, therefore, that to obtain the highest degree of strength the carbon content must be as low as is possible to produce—with the silicon present—a material, after annealing, in which the combined carbon has been almost entirely dissociated from the Fe_3C iron carbide form to free carbon and free ferrite.

To obtain this result it is possible, within reasonable limits, inversely to balance carbon and silicon contents. Thus, with a low carbon content and a high silicon, or inversely with a higher carbon and lower silicon, the ultimate end would be, within limits, similar.

The point of paramount importance is that no free carbon must exist in the unannealed state of the material, or the resultant product after annealing is quite accurately described technically as "rotten."

Silicon.—The function of silicon is only that of a catalyser. Its presence in definite amounts, somewhat inversely proportional to the carbon, is essential to the decomposition of the iron carbide into free iron and free carbon during the annealing process.

If present in too large a quantity the liability to the precipitation of graphite during cooling from the molten condition is markedly increased. The percentage allowable is also controlled to a considerable extent by the average cross-sectional area of the castings being made, and its amount should vary in inverse direction to the section.

Manganese.—The *simple* carbide of iron Fe_3C is more easily dissociated into its components by the action of heat, when unaccompanied by a double carbide, such as the double carbide of iron and manganese. The presence of manganese in quantities sufficient to produce appreciable amounts of the double carbide certainly appears to retard annealing, and tends towards the formation of pearlite, the eutectic mixture of iron carbide and iron. This produces a marked inclination in the material towards "banding." The presence of a greater amount of sulphur than is normally present in the electric-furnace product would probably, by accounting for part of the manganese as manganese sulphide, permit of a somewhat higher upper-limit figure. With the very low sulphur existing in electric-furnace white iron, the author has been unable to detect any real advantage in the use of manganese. If, as is sometimes claimed, it contributes additional strength, it may be because it tends towards the formation of pearlite, a constituent pre-eminently of value in whiteheart, but of dubious benefit to blackheart material.

Sulphur.—This, if present in appreciable quantities, is decidedly harmful to blackheart malleable. This is on account of its action in tending to stabilise the iron carbide content, which makes its transition to free carbon and free iron difficult by normal methods of annealing.

The percentage of manganese present would doubtless have a modifying action in this direction, but the objections to the latter element previously stated make it advisable not to rely on this action, but rather to keep sulphur content as low initially as is possible and commercial.

Phosphorus.—Up to 0.25 to 0.30 per cent. no detrimental effect has been directly attributable to this element. The reverse appears rather to be the case, as it has been noticed at times that a low phosphorus content has resulted in annealing being more difficult. It can be assumed, therefore, that up to the limits mentioned, the action of phosphorus is in favour of the easy decomposition of iron carbide into its component elements.

Above these limits the known action of phosphorus on the ferrite becomes noticeable, and the material to some extent loses in tensile strength. The author would also expect that the capability of the material to resist shock impact would be lessened, but has no figures to offer to confirm this.

Chromium.—This element can be dealt with as an accidental impurity. Its action on iron carbide is well known, and it would therefore never be intentionally added to blackheart malleable iron. If present in appreciable quantities it results in the almost complete retention of the carbon in the combined condition, and annealing in an impossibility. In small quantities its action is to produce in the material a strong tendency to "banding."

The influence of the various elements being approximately as stated above, it becomes necessary to decide whether or not the electric furnace is a suitable medium for the production of the material. More definitely, could the electric furnace be relied upon to give the necessary control of composition in order that the elements mentioned would be consistently kept within the essential limits?

The author states with confidence that the range of analysis given can be easily conformed to in the electric furnace. No serious trouble was encountered, and given some experience of electric melting, no fear of serious variations likely to affect annealing need be entertained.

Silicon content being vital calls for special caution. Under the basic slags used there is a tendency for a partial absorption by the slag, which, however, can be counteracted by the usual means of keeping the slags reducing, and controlling the time for which the silicon content is exposed to such action.

Practical Results Obtained.

The metal was found to be fluid, and very sound. No abnormal difficulties of casting arose, and no intricate special precautions in moulding were found to be necessary. The author is of opinion that the metal does not demand the amount of feeding to produce a sound casting usually found with cupola-produced metal. It appears to be entirely free from gases likely to produce unsoundness in the casting, and the amount of superheat obtainable in the electric furnace makes the production of light sections a comparatively easy matter. It possesses no undue tendency to crack either during or after solidification, and compared with the cupola product appears very much stronger in the hard cast condition. This latter is quite an important commercial factor, as it reduces appreciably possibilities of fracture in handling before annealing.

Potentialities of Electrically-made Malleable.

Is the material affected in any way by the electric furnace atmosphere, or any possible arc action, which would cause it to resist annealing under ordinary commercial conditions? After making some hundreds of tons of the material, the author suggests that no trouble need be experienced if the following fundamentals are adhered to:—

(1) The iron as cast must be entirely free from free carbon; (2) the carbon and silicon must be so balanced in their *relative* proportions as to produce, when annealed, the almost complete dissociation of the iron carbide; (3) manganese should be kept low; and (4) sulphur as low as possible. These points refer only to the metal as such, and further contributory points bearing on the question will be dealt with later.

The author having satisfied himself under laboratory conditions that the material would produce correctly-constituted blackheart malleable, large enough quantities were produced to bring into action an annealing furnace more nearly of commercial size. The effects of mass action, packing conditions, and so on were then capable of being observed.

It is quite normal to find that conclusions arrived at by laboratory or other small-scale investigations are completely upset when the hard facts of bulk production and workshop conditions and appliances come into the equation. Numerous points arose for settlement, principally connected with the following causes:—(*a*) Packing material; (*b*) time required for heat conduction through large boxes; and (*c*) local variations in temperature in the annealing furnace.

Packing Material.—To make sound blackheart malleable the packing material must be (1) of practically a non-oxidising character; (2) of a degree of fineness sufficient to promote close packing and the elimination of as much as possible of included air spaces, and (3) to be not too refractory, which would result in a very slow heat conduction through the packed box of castings.

Several materials were used, sand, millscale, and spent annealing ore being the principal ones. The first material, sand, whilst conforming quite well to conditions (1) and (2), failed very badly in condition (3). To produce satisfactory annealing throughout, the time period had to be considerably increased.

The second material, millscale, conforms to requirements (2) and (3), but as received is far too oxidising for use. A defect is produced which is dealt with under defects due to annealing.

The third material, spent annealing ore, gave fairly good results, but in addition to being somewhat too coarse, its condition as received varies from being almost non-oxidising to a state in which it is strongly oxidising, and more suitable for whiteheart practice.

The defects of millscale and spent ore, being due to excessive oxidising capacity, are able to be corrected. Their action upon the carbon of the castings is productive of a continuous reduction of the amounts of active oxide of iron they contain. When this active oxide is reduced to small proportions, their action from a decarbonising point of view is almost negligible, and so long as additions of fresh material are very small, no further trouble is experienced. The addition of crushed acid slag considerably reduced the activity of the initial packing material, without seriously lowering its conductivity for heat. The packing the author is now using, therefore, is a mixture of spent ore, millscale, and crushed slag, to which additions are made as required, in the smallest possible quantities.

Heat Conduction through Boxes.—This question is of considerable importance. With thermocouples so adapted as to show temperatures of top and bottom of the annealing furnace, the author was surprised to find how long a period elapses before the bottom temperature comes within reasonable distance of the top. This is undoubtedly controlled to some extent by the nature of the packing, and caused the rejection of sand as a packing material.

In a furnace holding 7 to 10 tons of castings packed in boxes 18 in. sq. a period of 18 to 24 hrs. was often required to approach equilibrium of temperature. It has to be remembered that blackheart malleable is very susceptible to high annealing temperatures, and loses materially in quality by such treatment. It is therefore impossible to force the temperature at the top of the furnace in order to aid the bottom.

Furnace Design.

Although good furnaces are obtainable, the difficulty of evenly heating the large mass involved does not appear to have been solved. In the general type most of the heat is admitted at or near the top, at one end, or on two sides. To produce a material showing to the full the real capabilities of blackheart malleable, a very close control of annealing temperature is necessary. The range within which the best material is obtained is not by any means wide, and therefore variations of a local character in the annealing furnace become serious. It is therefore necessary to insist upon a type of furnace which suffers to the least extent from unequal heating.

The formation of temper carbon, upon which fact the whole nature of blackheart malleable is based, takes place slowly and progressively as the temperature falls during the cooling period. Unless the speed of cooling is coincident with the rate of progression of this change, varying amounts of carbon in the combined form will be carried down to the recalescence point, at which point they become pearlite. Such material will not possess the true characteristics of blackheart, being much harder, and less easily machinable. It will break with a steely fracture scattered over with dots of temper carbon. It is essential therefore that the annealing furnace shall be so constructed as to allow of absolute control of the speed of cooling, in all parts. This speed should approximate to 7 to 10 deg. C. per hr. in the upper ranges, falling to a speed of 3 to 5 deg. per hr. as the temperature approaches 760 deg. C., from which figure down to 690 deg. C. no speed of fall greater than 3 to 5 deg. per hr. is permissible. Such figures call for careful insulation of the furnace particularly in the vicinity of the doors.

The Annealing Process.

The process of annealing is, shortly, as follows: The carbon content, entirely in the form of Fe_3C, or cementite, is taken into solid solution in the iron by retaining at the desired temperature for a sufficient length of time. The period of soaking at the full temperature causes the graphitisation of this solid solution, assisted by the action of the silicon content. This graphitic carbon is then precipitated from solution in the form of temper carbon, as the temperature is slowly and progressively reduced. Temper carbon and graphitic carbon are essentially the same, the difference being one of form. The degree of fineness of the temper carbon is largely a matter controlled by the maximum temperature reached during annealing. The higher the temperature, the more the temper carbon particles take the form of graphitic carbon, and as a consequence, the weaker the material. This, of course, is in addition to any weakness contributed by the action of long-sustained high temperature on the ferrite, which becomes more coarsely crystalline, and therefore weaker, the higher the temperature of annealing.

The solution of the iron carbide, or cementite, and the graphitisation of the resulting solid solution take place at a speed which is controlled by the temperature attained during annealing. In order to shorten the annealing process, it might therefore be thought advisable to work at higher temperatures. A consideration of the above points will show, however, that this cannot be done without a corresponding loss in the quality of the material produced.

The common defects normally due to the annealing operation are as follow:—(1) Banding, or the production of pearlite in the outer skin of the casting; (2) a coarse crystalline arrangement of the ferrite with consequent loss of strength and ductility; (3) a structure composed largely of pearlite with scattered particles of temper carbon, which is brittle; (4) an angular coarse formation of the temper carbon, with loss of strength and ductility; and (5) a mixed structure of temper carbon and pearlite containing scattered particles of cementite. This structure is hard, brittle, and practically unmachinable. Taken in the order named, the author is of the opinion that the reasons for these are as follow:—

Banding.—There are several reasons for this defect, but the main one appears to be an excessive removal of carbon from the outside skin of the casting during annealing. It has been previously stated in this Paper that the fundamental principle in blackheart malleable is the balancing of the carbon and silicon content in such a manner as to be able to dissociate the iron carbide into free carbon and free iron by the action of heat. If, with a given silicon content, too low a carbon content were used, normal annealing and cooling would produce, not blackheart malleable, but a brittle steely material, having a structure largely pearlite, with only part of the carbon deposited as temper carbon. It follows, therefore, that a local removal of carbon, from any cause, is liable to be followed by the production, in greater or less degree, of this state of affairs in the part affected.

An oxidising packing material, say containing an excessive amount of active ferrous oxide, would remove carbon from the outer portions of the castings, and bring about this result. A coarse packing, with excessive air spaces, tends in the same direction. The author would add that this oxidising action is aggravated by a high annealing temperature, and pearlite bands are frequently due to this error. Another reason, somewhat connected with the one dealt with, but perhaps open to argument, is believed by the author to be the following:—

It has been previously stated that in order to produce material as high in tensile and ductility as possible, the carbon content must be kept on the low side, that is, so far as is permissible to produce normal behaviour during annealing. As the result of many experiments, the author is convinced that some absorption of surface carbon takes place always in commercial annealing, no matter what precautions are taken. He suggests, however, that a compensating action is proceeding during the annealing period. Oxidation can only continue until such time as the gaseous atmosphere of the box of castings becomes largely carbon monoxide, when it ceases entirely.

The cementite being in solid solution at this time, is tending to diffuse, causing a movement towards equilibrium of carbon content between centre and outer portions of the castings. If the total carbon was originally on the low side, this diffusion may be of an amount insufficient to raise the outer portions to a percentage of carbon capable of being precipitated as temper carbon during cooling. Pearlite formation naturally follows, and the casting possesses a hard outer skin, of varying depths and very difficult to machine. *Per contra*, the original carbon content being on the high side, diffusion is sufficient in quantity to build up the carbon content of the outer skin affected by oxidation, and sufficient is present for temper carbon precipitation to proceed normally.

The steps necessary, therefore, to combat this defect are the use of a packing as little oxidising as possible and fine enough to prevent the inclusion of excessive air in its interstices, a temperature of annealing not too high in an ambition to speed up matters, and a carbon content not forced too low in a laudable but perhaps over-enthusiastic effort to obtain abnormal tensile and elongation results.

Coarse Ferrite.—This formation is almost entirely due to the use of too high an annealing temperature, although it is possible it may be accentuated by an excessive phosphorus content.

Pearlite and Scattered Temper Carbon.—This structure may be caused by too short a time at full temperature. Graphitisation may not be completed, and part of the carbon exists in the combined form, although the original cast form of the iron carbide may be completely removed. Too rapid a cooling rate also tends towards the same condition, the temper carbon not having a sufficient period during which to form.

Angular Formation of Temper Carbon.—The form taken up by the particles of temper carbon is a function of temperature. Low temperature and sufficient time produce a nodular, more or less innocuous shape, whilst this form becomes progressively more angular and deleterious in its influence as the temperature increases. This constitutes a further argument against undue haste and the use of high temperatures.

Temper Carbon, Pearlite and Cementite Structure.—This mixed structure is obtained when either temperature or time, or both, have been insufficient. The original iron carbide existing as cementite must be completely taken into solution. In this case all the reactions involved have only proceeded partially, and the material is worthless as it stands. It can, however, in this case be salvaged by a careful second annealing at a reasonable temperature, thus allowing the partial changes to complete themselves.

Physical Test Results.

In correct conditions, where precautions are taken to obviate the various annealing defects above dealt with, a material is produced possessing a remarkably high standard of performance under test. Many hundreds of charges from 30 to 40 cwts. each have been run into castings, and the results obtained from standard test bars, annealed with the castings, carefully logged for comparison purposes. Average results appear to run about 25 tons maximum stress with 14 to 15 per cent. elongation on 2 in., but a considerable number of charges have given results well over 26 tons and 20 per cent. elongation. The maximum figures obtained up to now are 26.9 tons with 28.0 per cent. elongation on 2 in. The general strength of the castings made from the charge represented was abnormal for malleable, and was almost comparable with castings made from mild steel.

It is not claimed that such results can at present be obtained in all instances, even with the most extreme degree of care, but careful investigation as to the causes of these occasional remarkable results should lead to a more complete understanding of their character, and the consequent raising of the average standard.

In all cases where material giving over 20 per cent. elongation has been obtained the total carbon was on the low side, in the neighbourhood of 2.35 per cent., and it has not been found possible to produce results of this nature from material in the higher ranges of carbon, no matter how careful the annealing control. Unfortunately, however, low-carbon material is much more susceptible to the production of pearlite bands, from any of the causes previously dealt with, than is the higher-carbon material. The solution appears therefore to be the complete elimination of the band-producing condition, so as to enable the general product to be run at the lowest practicable carbon content consistent with a satisfactory behaviour of the material from a casting point of view.

Tensile and elongation properties in blackheart malleable, unlike other metallic alloys, increase or decrease together. In correctly constituted material a high tensile is associated with a high degree of elongation, and a low tensile with a low elongation. This remark refers only to material which can accurately be described as blackheart malleable—that is, an iron carbon alloy in which the whole of the carbon has been precipitated as temper carbon, with a general structure of correctly proportioned ferrite.

Some of the intermediate products due to incorrect annealing, and containing considerable percentages of carbon as pearlite, will, as might be expected, sometimes show unusually high tensile figures, but in such cases elongation is always low.

The anticipated difficulties regarding the constitution of packing materials, and even heating of annealing furnaces, having been overcome, the regularity of the product became very good.

Unusual cases of abnormally high elongation figures, whilst being interesting and offering useful opportunities for research as to their cause, are not the best criterion of the value of a product such as malleable iron. The author feels sure that the fact of the last 52 charges of metal of 35 cwts. to 2 tons per charge, having given results after annealing which average 25.7 tons per sq. inch with 17 per cent. elongation, will more easily demonstrate that the product has decided possibilities.

DISCUSSION.

Commercial Success Queried.

The Branch-President (Mr. G. C. Pierce), after congratulating Mr. Melmoth, said that it was pleasing to note that there were some firms who were prepared to attempt to establish good, commercial blackheart malleable iron. He believed he was right in saying that formerly blackheart malleable iron castings were considered to be a type which could be produced successfully only in America, and one or two British firms, and all credit was due to Mr. Melmoth, and to Messrs. Lake & Elliot, for their efforts to establish a new commercial method of production in this country. Mr. Melmoth had expressed himself as satisfied that the castings could be produced commercially. He (the Branch President), however, without asking for any particular figures, would like to know whether Mr. Melmoth could give an assurance that these castings could be produced commercially, in competition with America.

Mr. Melmoth replied that, naturally, he based his statement on the ordinary purchase prices of malleable cast iron in this country. The issue raised by the Branch President, however, was altogether outside the scope of the Paper; it was far too large to be brought into the equation. The American schemes of production for malleable cast iron were not even approached in this country, from the point of view of magnitude, capital invested, and so on, all of which had a considerable influence on production costs, but he could say that it was possible, using a cheap base material, to produce malleable cast iron in this country which could find a market. That, he felt, was as far as he need go. If the costs of production were so high that the product could not find a market, then it was dead in any case, but if it were being sold every week to the extent that his firm were able to sell it at the present time, then it was obvious that it was being produced here commercially.

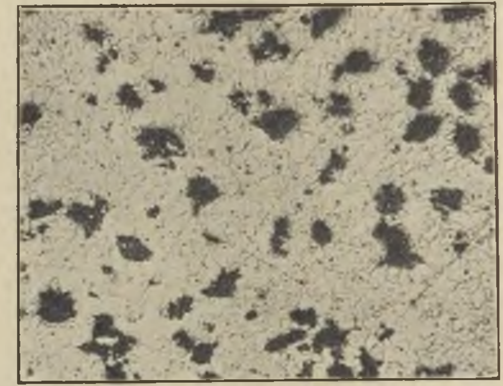


FIG. 1.

This section (x 50 dias) is of material of normal analysis and annealed in ordinary works conditions. Note shape of temper carbon is roughly nodular, and fairly evenly distributed. The test result was: Max. stress, 24.9 tons per sq. inch; elongation per cent. on 2 in., 20 per cent.; and cold bend, 1 in. x 5-16 in., 170 deg. unbroken.

High Temperature and Graphite Precipitation.

Mr. V. C. Faulkner said it was stated by the author in his excellent Paper that the details of the production of a white cast iron for the manufacture of malleable iron synthetically in the electric furnace were so well known that space need not be occupied in entering closely into them. He would like the author to give him the references for this "well-known" process, because he could not at the moment recollect a Paper on that particular phase of metallurgy, but he imagined, however, that the process would have, for its raw materials, steel scrap, anthracite and ferro-silicon. About a fortnight previously, in the German paper, "Stahl und Eisen," Professor Piwowarsky had published an admirable Paper showing that if iron, no matter whether it was white or grey iron, were

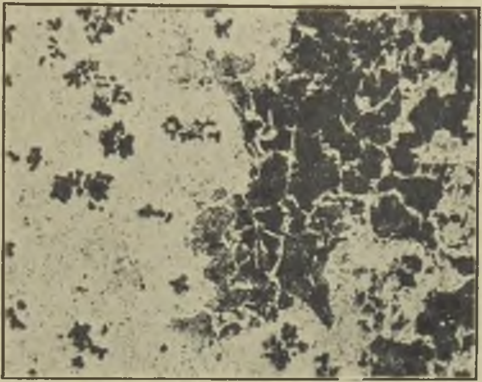


Fig. 2.

This section (x 50 dias) is of similar analysis to Fig. 1, and annealed under the same conditions. The packing material, however, was too oxidizing, and the defect of "banding" has been developed. The normal temper carbon and ferrite structure, shown on left hand portion of print, can be seen merging into a pearlite formation on right hand side. This was decidedly hard in machining. The test result was: Max. stress, 24.2 tons per sq. inch; elongation per cent. on 2 in., 8.5 per cent.; and cold bend, 80 deg. unbroken.

teemed at a very high temperature—above 1,500 deg.—it became more grey; the writer had made special reference to this particular method of producing malleable, and said it had been found that, owing to the action of the electric arc, locally overheating the metal iron was liable to be produced which showed a certain amount of graphite, which, of course, was detrimental to the production of good castings. Continuing, Mr. Faulkner asked whether difficulty had been experienced as the result of the presence of chromium in the raw materials, *i.e.*, in the steel scrap, because an examination of the average scrap heap in Great Britain would reveal that there was a considerable quantity of chromium scrap amongst it.

The Process of Manufacture.

Mr. Melmoth said that when he had stated that the details of the production of a white cast iron synthetically in the electric furnace were well known he was certainly taking it for granted that, amongst the people engaged in the electric furnace trade this particular process was well known, Mr. Faulkner being included in that number. During the war a quantity of white iron was made here for replacing Swedish white iron. It was made entirely from wrought iron or steel scrap, carburised with anthracite coal, exactly as Mr. Faulkner had stated. Really there was very little in it. A base material somewhat suitable in composition—because one did not want to have to do much adjustment afterwards, although the composition might be corrected even if varied slightly—was melted down with an excess of carbonaceous material, such as anthracite; then a bath sample was taken in order to show the percentage of carbon, the silicon was adjusted by means of ferro-silicon, the slag put into condition, and the material tapped. It became difficult when, say, manganese was high in the initial scrap. Then one had to take advantage of the affinity, or increased affinity, for oxygen of manganese over carbon, and slightly oxidise the bath, in which case one put the manganese into the slag and brought it down in the bath to the required amount, afterwards pulling off the slag. There was no serious difficulty about the manufacture of the white iron itself. The effect of high temperature of casting, as stated by Mr. Faulkner, seemed to be a logical sort of statement. One of the things that had come to the front very much was the question of pre-heating moulds for the production of pearlitic cast iron. If the electric furnace were permitted to utilise its full capability for heat—it was limited only by the refractories—the iron might become very much too hot. If that were the case, then that superheat, to his mind, would be used to pre-heat the mould during the period before solidification. A given composition, under those conditions, would produce graphite. In other words, a composition which, when cast into a cold mould, would give a white metal, and when cast into a hot mould would give a grey metal. He was satisfied, assuming the temperature were reasonable, that perfectly white castings could be made. The test results alone should be sufficient to prove that; had primary graphite existed in those cases, it would have been a physical impossibility to have produced tests showing over 20 per cent. elongation.

Chromium in the Scrap.

With regard to the presence of chromium in the scrap, he had experienced that difficulty, and so would anybody who chose his scrap indiscriminately. A certain amount of care had to be shown in that connection, but it was possible to get scrap without chromium. That was one of the ordinary precautions which anyone who indulged in this particular method would have to take.

Blackheart versus Whiteheart.

Mr. J. W. Gardom, after thanking Mr. Melmoth for his lecture, said that during the previous lecture an engineer had said that the foundryman did not know anything about his job, and now Mr. Melmoth stated that, owing to the irregularity of the material he had bought, he had had to make his own malleable. But when one had decided to make malleable, one had to decide whether to make blackheart or whiteheart. Mr. Melmoth had given a number of reasons why blackheart had been chosen. The first was that, under given conditions, the production of blackheart malleable was more certain than was the case with whiteheart. He (Mr. Gardom), however, did not think so. Actually, he was rather of the opinion that the production of blackheart was more difficult than the production of whiteheart. Quite a number of people did not share that view, for the reason, he believed, that blackheart was being made mostly in America, where they had spent much time and money on making it properly, and it was essentially a high-output product. That meant that a percentage of the production costs were given over to control, and that percentage was sufficiently high to allow of one or more skilled workers being employed on nothing but control. Unfortunately, most of the whiteheart malleable makers in this country were not able to afford that luxury. Again. he was afraid that most or many of the whiteheart makers were tempted, by the keenness of the engineer-buyer, to

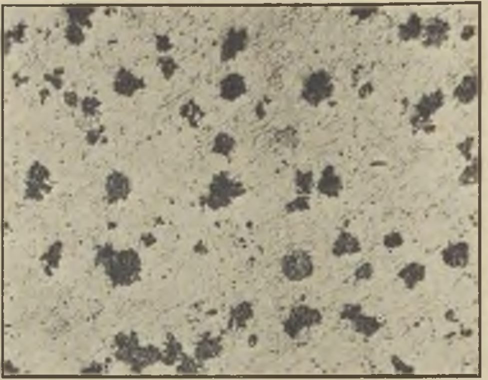


Fig. 3.

This section (x 50 dias.) has a normal analysis, and was annealed in same conditions as Fig. 1. The shape of temper carbon and its distribution are both very good. This is typical of the structures giving the very highest test results. The test result on bar was: Max. stress, 28.3 tons per sq. inch; elongation per cent. on 2 in., 26 per cent.; and cold bend, 180 deg. unbroken.

cut down their costs too much. They tried to cut their costs to meet competition, or the supposed competition, of other people, and in order to do that they cut out essential operations. That meant that they were lowering the quality of the product, and one could not blame the difficulties of manufacture, for instance, in that case.

Where Whiteheart Succeeds.

Another reason why Mr. Melmoth had decided to make blackheart malleable was that "the best results available in correct material of either type were of a higher standard in blackheart." Of course, test results could be made anything. One obtained higher tensile, elongation and bending figures with blackheart, but they were not everything. There was also, for instance, the question of rigidity. One did not get that property in blackheart to the extent that one did in whiteheart, and it was an essential property in many machines. Then there was the yield point, and a figure could be obtained with whiteheart which was from 2 to 4 tons higher than that obtained with blackheart. Also, the average of three Izod tests he had carried out was 7 ft.-lbs. for the blackheart and 8 ft.-lbs. for the whiteheart. The tests were made in the laboratory. Again, his firm (Messrs. Bagshawe, of Dunstable) had devised fatigue tests on malleable which was to be used particularly for axles. Part of an axle was mounted and rotated at a speed of 1,000 r.p.m., and a load was applied at the end.

It was practically the Wohler test, but not quite the same thing. The application of the load at that speed meant that there was an alternating load applied 2,000 times per minute—compression and tension. The tests were commenced with a given load, which was increased after a certain number of hours. The blackheart gave 14 kg. per sq. mm., and the whiteheart gave 15 kg. per sq. mm., and, for the purpose of comparison, it might be interesting to note that 0.30 carbon steel gave 17 kgs. per sq. mm.

He considered that the whiteheart made by his firm, at any rate, had a better machinability than other people's blackheart. It was, of course, a very difficult thing to evolve a test which would not produce argument, but, for a given feed and traverse, that whiteheart could be worked at about 120 ft. per minute, whereas blackheart which he had tested could only be worked at 100 ft. per minute. Also, for certain parts of electrical apparatus whiteheart was again better. Its resistance to corrosion was greater, and, for such things as electro-plating, and probably for galvanising

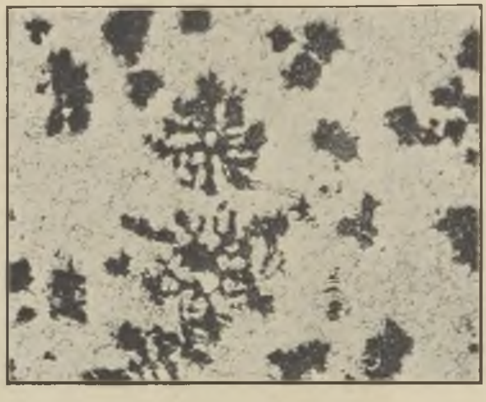


FIG. 4.

This section (x 50 dias.) was cut from a bar of rather abnormally high carbon content, namely, 2.66 per cent. Castings were white in fracture before annealing, so far as could be seen. The large, badly shaped temper carbon particles are characteristic of high carbon content, and are invariably associated with low tensile and elongation properties. Tensile result on bar: Max. stress, 22.2 tons per sq. inch; elongation per cent. on 2 in., 11 per cent.

as well, it was better than blackheart, and would certainly give a much higher polish if necessary.

It had been stated that the scope of applicability of malleable was decreasing rather than increasing, mainly owing to the extended use of steel castings, but later it was stated that the amount of superheat obtainable with the electric furnace made the production of light sections a comparatively easy matter. That meant that Mr. Melmoth was superheating the charge and so approaching the melting point of steel. What was the use, therefore, of making malleable? Why had he not made steel?

Consumption of Annealing Pans.

Continuing, Mr. Gardom asked at what temperature Mr. Melmoth opened up his annealing furnaces. As to the lecturer's reference to the very heavy consumption of annealing pans in whiteheart, he had his own ideas about that, and was not saying that the consumption was not heavy, but he would like to know the number of tons of annealing pans used in producing a ton of blackheart malleable. As to the statement that the temper carbon was produced as the temperature was lowered, he supposed Mr. Melmoth would agree that temper carbon was produced as soon as the A.C.1 point was passed, and, if that were so, he would also agree that temper carbon was produced very rapidly over the first period of the annealing operation, and that the rate slowed down more and more as equilibrium was approached. He believed he was right in saying that 75 per cent. of the temper carbon was produced in 25 per cent. of the time the material was held at annealing temperature. If that were so—and some people seemed to think it was—would it not be permissible, after the majority of the temper carbon had been produced in the form in which it was required, to raise the temperature so that the temper carbon was precipitated more quickly, and so cut down the annealing time, because in the remaining time the temper carbon produced could not destroy the initial formation?

As to the composition of the metal, as given in the paper, he was rather doubtful about the phosphorus content, and would rather have seen a little less phosphorus and a little more sulphur; but, for the composition given, what did Mr. Melmoth consider the best annealing temperature? Some notes had been given as to the mixing of the materials for annealing, and he asked Mr. Melmoth if he would give also the proportions they were mixed in.

Blackheart versus Whiteheart.

Mr. Melmoth, dealing first with his statement that, under given conditions, the production of blackheart malleable was more certain than was the case with whiteheart, said he was afraid he had judged whiteheart very largely by the published accounts of its behaviour, coupled with its behaviour in the machine shops of his firm. So far as the published accounts were concerned, one would imagine that people representing malleable firms would hardly write accounts in which they appealed for help, more or less, and state that they had questions which they could not solve, and, he believed, called upon the British Cast Iron Research Association to help them, if the production of whiteheart were quite so plain as Mr. Gardom would have them believe. So far as blackheart was concerned, America, undoubtedly, had already carried out a considerable amount of that investigation which was being asked for in connection with whiteheart. There might be, and probably were, quite a number of whiteheart foundries producing satisfactory malleable continuous, but apparently his firm were not buying their material from those foundries. The research carried out by the Americans had solved a number of questions, and one could almost predicate what was going to happen with a given temperature of annealing and a given analysis in a blackheart malleable casting, though not quite.

With regard to unreliability, he had mentioned that also; as the result of his own experience his firm were buying very large quantities of malleable iron and could get definite satisfaction for a time, but later something happened to the material, and, although probably many thousands of castings came through satisfactorily, maybe another batch gave very serious trouble. Matters would then be straightened out again, because, when anything went wrong, most of the makers knew what was the trouble and put it right, but after a time the unreliability factor again arose. That was honestly his experience.

As to the effect of the keenness of the engineer buyer, that applied equally to both blackheart and whiteheart, and one could hardly give favour to whiteheart in that connection.

Coming to the test results, he said Mr. Gardom's figures were very illuminating, but he did not know whether he had had a number of test results on blackheart to compare with those on whiteheart, or whether he was covering a very limited area. If the latter, his investigations were rather small, to say the least. The test results he himself had given were produced out of the ordinary oven, and not in the laboratory. The test bars were packed in the boxes with the castings and cast at the same time, and no special attention was given to them.

Rigidity or Brittleness ?

With regard to rigidity, Mr. Gardom had said that whiteheart was superior to blackheart in that connection. Exactly. "Rigidity" meant, *in proportion*, "brittleness." It must necessarily mean that. The more rigid a thing became, the less ductile it became. It was granted, therefore, that whiteheart had the greater rigidity. As to the test for fibre stress, which was an adaptation of the Wohler test, he did not quite understand the way in which the figures were given, because they were usually given as revs. under a given fibre stress load, so that he was not in a position to reply to that point.

Machinability.

As to machinability, here, again, Mr. Gardom's results were probably obtained on a few samples, and he was not prepared to question the figures. But, on the other hand, he saw no reason why the machinability of blackheart should not be quite equal to that of whiteheart castings. Mr. Gardom had referred to surface speeds, but he had not referred to the drilling of bosses. One of the troubles was that, although one could get a soft surface almost invariably in whiteheart, as soon as the sections thickened, the trouble began.

Galvanising.

Where galvanising was concerned, he agreed that whiteheart won every time. The temperatures at which it was carried out were not by any means good for blackheart, although it could be done under reasonable conditions, with special reference to temperature.

Replying to the question as to why he had not made steel instead of malleable, he said that he *was* making steel. But malleable was called for, and, with the base material which was being used, and various other factors, he believed malleable could be produced cheaper than steel. The temperature at which the annealing furnaces were opened up was about 650 deg. C.

Annealing Pan Consumption.

With regard to annealing pans, he could not give accurate figures of weights of pans per ton of castings. His remarks had been based largely on comparisons of the appearance of annealing pans, and of whiteheart furnaces against blackheart furnaces after being drawn. He believed that Mr. Hurren had given a figure of 12 cwts. for every ton of castings he had produced in the Rover Company's foundry, but the figure was nothing like so big in blackheart work.

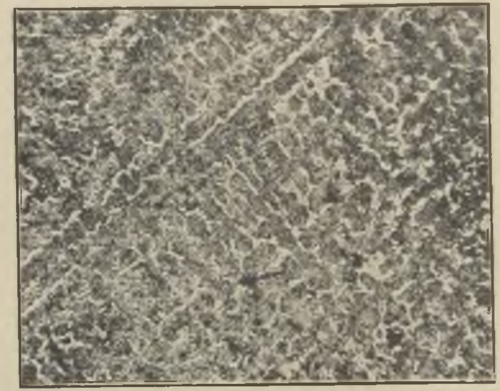


Fig. 5.

The bar (x 50 dias.) from which this section was cut was specially prepared in the laboratory to show the effect of shortened period of annealing. It is of normal analysis, and was taken quickly to 850 deg. C. and held 30 hours, afterwards cooling fairly rapidly. The original white iron structure has largely persisted. Cementite has been only partially taken into solution, and odd small areas of temper carbon produced. Fracture was quite steely, with small dots of temper carbon, and the material not commercially machinable.

As to whether it was permissible to raise the temperature when the bulk of the temper carbon was precipitated, he said it was permissible, but he had run these furnaces up, holding them, on heating, at about 750 deg. C., and afterwards rising to full temperature, in order to allow a certain amount of temper carbon to precipitate itself at the lowest temperature, and to get the greatest amount of fine grain. But it was not only temper carbon that entered into the problem. When the higher temperature was reached, the ferrite structure would be affected, which would mitigate against high elongation.

Influence of Sulphur.

As to sulphur, the action of that on iron carbide was fairly well known. Sulphur tended to retain carbon in the combined condition. It was just as easy to take it out as to leave it in, and he had taken it out. In the whiteheart process he fully appreciated the significance of it, but in the case of blackheart its significance was altogether the opposite, and, consequently, the more he could get out the better.

Annealing Temperature.

The highest temperature was in the neighbourhood of 850 deg. C. It could be raised to 900 deg. C. fairly safely, but—and he ought to have mentioned this in the Paper—it was proportional somewhat to the total carbon content of the material. If that content were on the high side, a lower annealing temperature could be used, and *vice versa*.

Packing Material.

The proportions of annealing material were not by any means fixed. Assuming that the packing material showed signs of being on the oxidising side, he would more or less dilute its oxidising capabilities by adding material of a non-oxidising character, so as to keep it at all times as near a non-oxidising material as could be obtained—it never could be absolutely non-oxidising.

Mr. H. O. Slater, though he claimed to be one of the first in London to interest himself in the production of malleable, said he had not produced it for ten years, during which time, no doubt, a great deal of progress had been made. He had always held the view that the electric furnace would be far superior to any other melting medium for malleable iron. The malleable iron business was one in which he was convinced science must march hand in hand with practice. There had been things which had absolutely puzzled the practical man in connection with annealing and with melting. The test figure given by Mr. Melmoth had surprised and pleased him. Ten years ago he had prided himself upon producing a test piece with a tensile strength of 24 tons, and, he believed, with an elongation of 4.7. Metallurgists would no doubt say that the material was on the hard side. It was, but it was perfectly machinable. As to the construction of the oven used by Mr. Melmoth, he asked where the oven was fired from, and where the dampers were situated.

Mr. Melmoth said, with regard to the ovens, there were two types, both fired from the end, with longitudinal flues and side ports. In both cases the ports were about 1 ft. above the level of the ground, and each port was dampered. The ovens had a firebox only.

Cost of Blackheart.

Mr. G. Bagshawe asked if the cost of melting of malleable iron by the blackheart process in an electric furnace compared favourably with other forms of melting, and, if so, how many melts Mr. Melmoth must get from the same furnace per day, presuming he started from the cold in the morning, in the ordinary way. The pan costs were very high, and the fact that they were high in malleable iron production was frequently not recognised. The annealing temperature for blackheart malleable had been given by Mr. Melmoth as about 90 deg. C.; he himself was under the impression that that was higher than the American annealing temperature, and very nearly approaching the English. If that were so, he could not quite see where the advantage was. American malleable was produced nearly 25 per cent. cheaper than English, and that was the secret of the success of malleable production in America. They were able to sell 4 tons where we were selling 3. A very considerable part of the 25 per cent. was due to the larger quantities produced. Would the electric process of melting, in Mr. Melmoth's opinion, help to bring the English costs down to somewhere near the American costs, and thereby increase the production, in spite of the fact that we had very much smaller quantities to deal with? It was a difficult question, but it presented a possibility, not only to the malleable iron founder, but to everybody in the country who used the product, such as, for instance, motor car manufacturers, who were probably the largest users in America at the present time. He believed that the American motor car manufacturers used more malleable than the railway people. In England, the quantity of malleable used for railway work was negligible.

Mr. Melmoth said that the number of heats taken per day out of a furnace, admittedly, must, practically speaking, control the cost of production of the material, and it had to be admitted from the beginning that enough must be demanded to keep a furnace in satisfactory working trim. His firm were rather preferentially situated. Their electric furnaces were melting steel, and could be turned over to malleable as and when required. Normally, they would perhaps take out three charges in an ordinary working day, and on that basis he failed to see why it should be expensive. His remarks in that connection, however, might be somewhat biassed, in view of the fact that the electric furnaces were used for both steel and malleable. The question as to whether the electric method of making blackheart malleable iron would enable the product to be sold at prices similar to those of the American product was one which would require a good deal of thought before it could be answered. His paper was not written with a view to suggesting that Britain could produce blackheart malleable more economically from the electric furnace than from any other melting medium. He was not saying that it was not commercial, because it was; he was quite sure of that, but to suggest that we were going to knock the bottom out of other people's costs was absurd, and had never been hinted at. Mr. Bagshawe had answered his own question when he had said that the greater part of the difference between the American and English prices was due to the enormous outputs attained in America. Bulk production was the method of producing cheaply, but a significant feature was that the Americans appeared to be developing a process of manufacture of blackheart malleable by what appeared to be an even more complicated and expensive system—he would call it a triplex system. The Americans, who were some of the biggest malleable makers, were developing that process and apparently making ends meet, and yet they used a cupola, a converter, and an electric furnace; so that it appeared that the electric furnace was finding its way into the American blackheart malleable trade. With regard to Mr. Bagshawe's remark that malleable was not used on the English railways at all, but that it was on the American railways, he asked whether that was due to the American malleable being more suitable for use on railways than the whiteheart.

Pearlitic Cast Iron.

Mr. Graves referred to a lecture delivered before the London Branch last session on pearlitic cast iron, in which it was stated definitely—if his recollection was correct—that there was a marked tendency nowadays for pearlitic cast iron to take the place of malleable. The tensile strength of pearlitic cast iron was given as 24 tons per square inch, and, for the purpose of comparison, he asked Mr. Melmoth if he could give the tensile strengths of blackheart malleable castings.

Mr. Melmoth replied that whoever had made that statement had made a very wild one. Undoubtedly, pearlitic cast iron had its own field, but he himself did not feel, although he was open to conviction, that pearlitic cast iron would cause the malleable makers to sleep less soundly. After all said and done, no matter in how many frills it was wrapped, being cast iron, it had a portion of the defects which were inherent in cast iron; *i.e.*, it could not, under any condition of manufacture, possess the proper degree of ductility. It possessed a most unusual tensile strength, but it did not possess the normal toughness or elongation properties of a good malleable iron.

Vote of Thanks.

Major Small, proposing a vote of thanks to Mr. Melmoth for his paper, said it had provoked a most interesting discussion, and he did not think anybody could have replied to criticisms in a more straight-forward a manner. What he had always found rather difficult to understand, however, was why we in this country should admit the fact that America beat us on costs and in many cases the finished product. It seemed to him most extraordinary that this subject of mass production was so constantly raised, and that the whole of Great Britain, including skilled foundrymen, should sit down quietly and accept the position. Could not Britain produce anything in the foundry business and be first in the field in such a sphere of commerce? Finally, Major Small again thanked Mr. Melmoth for his paper and the discussion it had provoked.

Mr. Ashwell, seconding the vote of thanks, also referred to pearlitic cast iron. He said his firm had experimented on a similar type of iron. They had electrically heated a cold mould, had raised its temperature to a certain point, and poured ordinary cast iron into it. The mixture consisted of old gas stoves and other scrap, with 5 per cent. of pig-iron and silicon and phosphorus, and a satisfactory casting was produced. Recently he had been to Germany for six weeks, and had brought back with him a sample of pearlitic cast iron made there. That casting, and the one already referred to as having been made by his own firm, were subjected to certain tests, and the latter broke under the tensile test at a stress which was 75 lbs. higher than that at which the German casting broke. Malleable iron originated in England, and it was thrown back on another country to produce as a commercial product, because our own country would not find the money, and the same thing was happening to-day. We could not find the money to produce articles which originated from British brains, and there might be many present at that meeting whose forefathers had had to give their ideas away to other countries, whilst the latter had sold them back to this country at extravagant prices.

Mr. J. W. Gardom, who supported the resolution, said that, although he had a great respect for Mr. Hurren, as, indeed, had everybody else, he was quite wrong when he had said that malleable was going out. He hoped Mr. Melmoth would go on with his work and would give more information about it later. His criticisms that evening had been made solely for the purpose of creating discussion and obtaining information.

The vote of thanks was carried with enthusiasm.

Mr. Melmoth acknowledged the vote of thanks and expressed his gratitude. He could not allow Major Small's remarks to pass without comment. Major Small had asked repeatedly when English foundries were going to do something, but, with all respect, he would suggest that Major Small might read metallurgical history. He would then find that the steel trade, and no doubt the iron trade also, had been definitely in the forefront in doing things, although it must be admitted that the almighty dollar had been able to develop those things to a greater extent than had the more subdued English pound. That, however, did not alter the fact that the discoveries had been made in English foundries. In many cases the initial credit was due to this country. There was a lot in Mr. Ashwell's statement that we could not get our processes financed. It was very difficult, particularly at the present time, for any firm in this country to finance any big scheme calling for a large outlay, and it was not altogether in their hands. Whilst accepting the vote of thanks with very great gratitude, he thanked Mr. Gardom personally for his energetic contribution to the discussion.

Birmingham Branch.

MOULDING MACHINES.

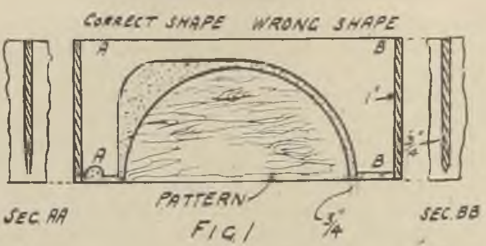
By E. Longden, Member.

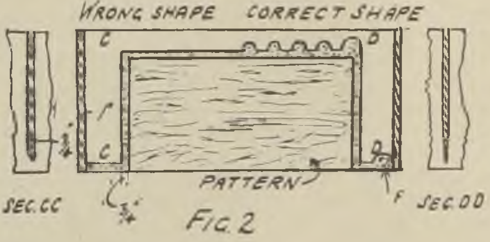
The advantages accruing from mechanical aids in the foundry are very considerable, although application is very much more difficult than in the engineering departments. Considerable developments have taken place over the last fifteen years in the application of moulding and core-making machinery in the production of castings.

It is surprising what a large number of types of moulding machines there are in use in the chief manufacturing countries of the world. Also there are many founders who have built machines specially to deal with certain repetition lines of work and over which no modern machine could excel. Some of these machines are quite unknown to the foundry trade generally.

These keen competitive times compel the founder to keep down his costs of production to the lowest possible level, with the result that in many foundries, in spite of little business, comparatively great strides are being made in the application of moulding machines. The lessons now being learned in lean times will not, most certainly, be lost when the volume of trade reaches a higher and more profitable level. So that when better times arrive still more and more machinery will be introduced; machinery which has been well proved during slack times.

The introduction of moulding machines has been synchronous, in the writer's own experience, with the improved working conditions in the foundry. In spite of the natural aversion of the moulder to mould-making machinery, really good progress has been made. Given an improvement in trade, the foundry business will do more than hold its own in improvements and the world's work, and the extraordinary output and quality of costings which were turned out in pre-war days will be exceeded and excelled in the years to come when the full effect of the introduction of mechanical appliances will have matured. Thus the decidedly better working conditions of the foundry worker, which every right-minded person must welcome, will be maintained and improved by these very machines which he so detests and, in many instances, hinders.





It is stated that the relative cheapness of machinery is due to the fact that the machines can be operated by semi-skilled workmen who can be quickly taught to manipulate them. Also that the skilled workman is opposed to the introduction of machinery because he thinks his skill is less needed and that his earning capacity will be reduced. Also that the semi-skilled man when given a piece price endeavours to run his machine as much as possible and thereby earn more.

This feeling was certainly evident some fifteen years back, but to-day even the conservatism of the moulder is less flagrant, due to better education and association with moulding machines, and nowadays it is possible by a reasonable application of tact to develop the machinery with his help. If the skilled moulder will operate the machines on which substantial moulds are made, to their fullest extent, helped by one or more labourers, exceedingly good results can be obtained.

Without doubt the smaller repetition type of casting is more likely to be produced to its fullest capacity by the immediate introduction of the semi-skilled worker. (Semi-skilled is used in opposition to the wrongly-used term unskilled.)

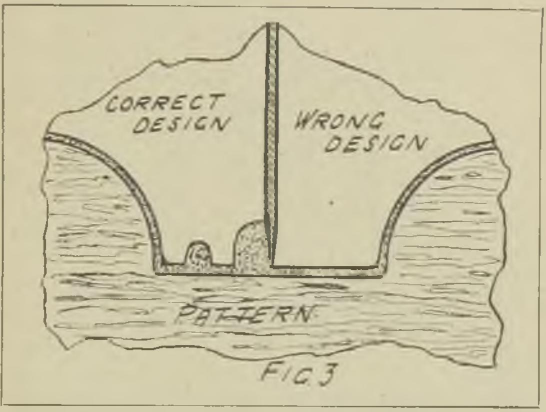


FIG 3

After considerable experience in the control of moulders making very high-class castings, it can be definitely stated that there is now a very serious shortage of the really skilled moulder. With such conditions, if a machine is introduced which reduces the amount of moulder labour by 50 per cent., the need for moulders is reduced by 50 per cent. *in that particular case.* If in every direction where machinery can be applied it is fully exploited, the shortage of moulders, which will be very acute with an improvement in trade, will be materially helped, although machinery has its limitations in the foundry as in no other department because of the peculiar nature of founding which depends so much on the human element.

Mechanically, as in other matters, the foundry was severely neglected in pre-war days. The engineer contented himself by applying his talents to the improvement of the engineering departments, so much so that to-day the need for the all-round mechanic is not very evident. There are very few machines in a modern engineering shop that cannot be quickly mastered in a few months' time by a man of average intelligence. Having made such enormous strides in the machining operations, and consequently greater accuracy in the machined casting, so that the work of the fitter, in a great many instances, has been reduced to a mere assembly of parts, the engineer turns questioningly to the foundry, and let us hope that he may accomplish in this department, even if only in a comparatively small way, improvement spurred by that which he has so splendidly done in the engineering departments. His attention and help is sought after and welcomed by the modern foundry foreman and manager who have, as a rule, quite enough to do to occupy their thoughts on general problems and practice.

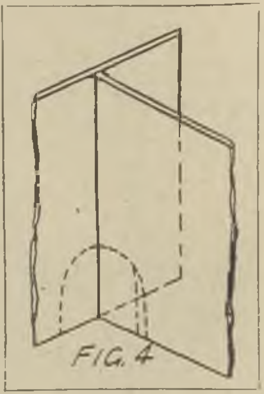


FIG. 4

Many of the moulding machines have been invented by foundrymen, and the others only made practicable by his co-operation.

To-day there is not a foundry, however small, which can afford to run without moulding and core-making machinery of some description.

There are several well-known firms whose efforts are almost wholly employed in producing and improving moulding machinery. Developments are such that there is now no excuse for any founder working without them. The future will experience improvement not so much in design of moulding machine as in the general application of those machines as now developed.

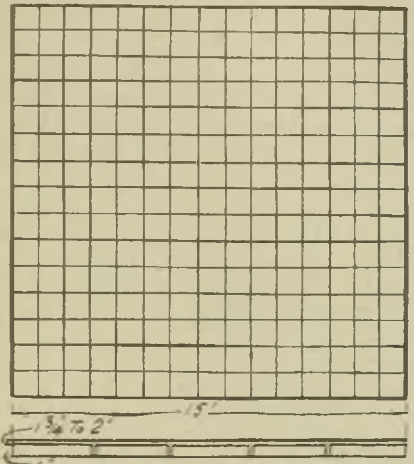


FIG. 5

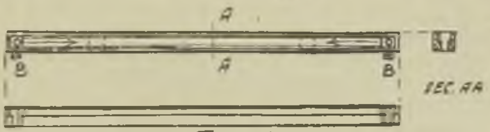


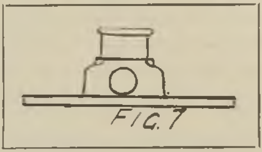
FIG. 6

Moulding machines were at one time only employed when producing large quantities of small repetition castings, but machines are now in regular use on which quite a variety of shapes can be made within the capacity of the machine, and with numbers off each piece which are not very large. Really there is now no casting which is made, however large, which cannot be helped at some stage of moulding by a certain type of machine.

Early Work on Mechanical Moulding.

The origin of the moulding machine dates back to somewhere about 1826, when an invention was brought out in the Harz district of Germany whereby castings could be quickly made by the use of a pattern plate. Two plates were made, one forming the top and the other the bottom impression of the casting, so that when the two half-moulds were brought together, complete castings were produced.

By 1851 the pattern plate assumed its present form. Fairburn and Hertherington were responsible for producing single plates which combined the top and bottom halves of the pattern and were chiefly made of cast iron, but bronze and other metals were used.



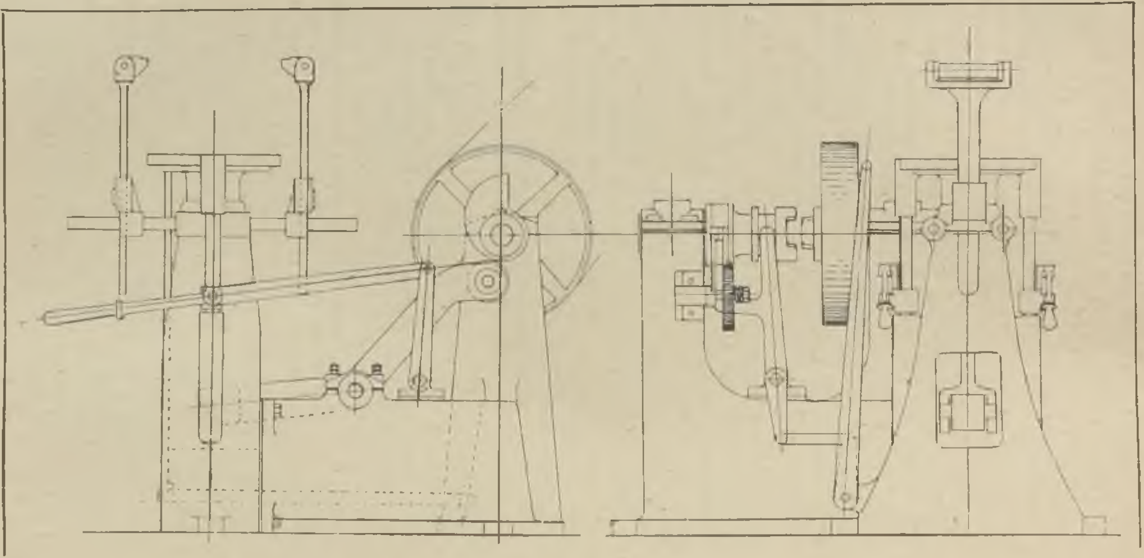
The improvement in production due to the introduction of the pattern plates can be ascribed to the elimination of the following operations, etc.:—Locating of pattern or patterns in the moulding box each time a mould is rammed up, and in arranging the patterns care is taken that all space in the moulding box is usefully filled; the making of odd sides and joints; cutting of runner, and sometimes riser gates because they are moulded into the pattern plate once and for all (and here much waste can be avoided, often due to the careless and irregular way in which gits are cut and located); the pattern draw is more accurate, as correct guides are necessary, consequently much repairing of damaged moulds is avoided; better looking castings are secured which are truer to form and weight, enabling machining by the aid of special jigs to be more frequently practised. Hand-moulded castings vary in weight from 5 to 15 per cent.

Oddsides, or ramming blocks as Jobson used to term them, and matchplates are made from various materials such as:—Hard-rammed-polished-dry-sand, fireclay, oilsand, cement like Portland cement, a mixture of pitch and cement, gypsum cement or sulphate of lime, what is commonly known as plaster-of-paris, and the present metal matchplate which is the logical development.

From the pattern plate, with its improved guide draw, the hand-ram mould machine, with its easily controlled mechanical draw, would suggest itself to some and to others the combination of the revolving pattern plate to save turning over of boxes by hand and waiting for crane. Although this latter combination constitutes one of the earliest types of machines which were invented by such men as Jobson and Woolnough and Dehne (the latter type being constructed and marketed by Samuelson & Company, Limited, Banbury), they constitute practice which is well worthy of note and continuation for making many lines of castings in spite of the advance of power-driven moulding machines of late years.

The early attempts to ram moulds mechanically would possibly be by the aid of pneumatic rammers guided by hand.

Methods of jar-ramming sand moulds dates back probably 40 years, but the machines at that time were very crude indeed, and the principle or reciprocating motion was produced by cam action, belt power drive, clutch, and fast-and-loose pulleys on the cam shaft, main driving shaft running overhead to supply a battery of machines. Patterns were stripped from the moulds on a separate machine with ropes running over sheave pulleys and balance weights to suit the weight of patterns and plates. About the year 1896 a combination of pattern draw was introduced to work with the cam jolter, but still not a part of the jolter. The addition was a pneumatic cylinder fixed against the wall at the rear of the machine, the piston rod being fitted with a yoke and long arms, these arms came in contact with the underside of a stripping plate and the upward movement of the piston in the cylinder raised the stripping



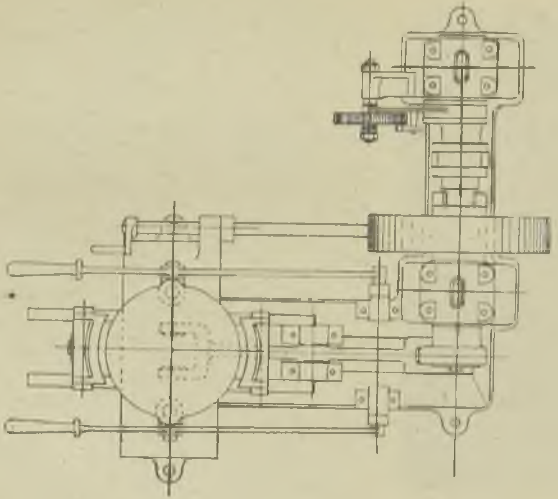


FIG. 8.—PLAN, SIDE AND END ELEVATION OF A MECHANICALLY OPERATED JARRING MOULDING MACHINE.

plate and mould, but the greatest load rarely exceeded 1 cwt. Mr. J. B. Neesham, of Glasgow, was responsible for many of these early developments. He was also responsible for the first railway axle box that was ever made on a jolt-ram machine, making it possible at that time to produce from 40 to 50 axle box castings per day. Such a machine would be of great value, because at that time of day axle boxes were ordered at the rate of 10,000 each order.

FIG. 9.—MAKING A 12-IN. ELBOW CORE.

Mr. Neesham, who is a patternmaker by trade, obtained his first introduction to the jarring machine in April, 1893. (At that time such a machine was unknown in the British Isles.) At the age of 33 Mr. Neesham went out to America and commenced duties with S. Jarvis Adams, of Pittsburg; this firm had purchased an invention for jar-ramming sand moulds. The machine was operated from an overhead shaft, on which were eccentrics and long rods extending to the foundry floor. By this means the table was lifted and bumped on a large block of oak. They next introduced the cam action, but the jarring table was still lifted by two arms fixed in a horizontal position, and worked similar to the old-fashioned elve in a forge. Mr. Neesham resigned from S. Jarvis Adams to take the post vacated by Charles Herman, who was a locksmith by trade, but the real inventor of the pneumatic jar machine. Mr. Neesham describes him as being an extremely ingenious man. The old members of the Pneumatic Engineering Appliance Company bought the English rights of the Herman pneumatic jar machine. The first small machine was then shipped to England, July, 1902. Mr. Neesham came over to England and started up this first small jarring machine which was erected in the machine shop of Sexley and Farmers Signal Works, Chippenham, Wilts. Thus Mr. Neesham, after starting up the machine, made the first moulds made on the first jarring machine in this country. Mr. Neesham then took out a patent in the U.S.A., which was for the first combination of a mechanical jar and pattern draw machine. A sketch of this first machine is shown in Fig. 8. Along with his brother, who helped him with the drawings, they sold the rights to a Pittsburg foundry.

Fig. 10.—Moulds for 12-in. Elbow Cores.

Mr. Neesham joined John Macdonald & Company, of Glasgow, and has developed what is known as the Ajax series of jar-ram moulding machines, which weigh from 8 cwt. up to 10 tons.

Eventually there came along the "Herman" hand-jarring machine, with a drop pattern device and movable impact block to allow the pattern to be lowered from the mould after jarring. Then we learn of the "Herman" pneumatic jolting machine, with a combination of a pattern draw device, the jarring cylinder contained within an outer casing and air pressure on both sides of piston, the jolt was dependent on the air pressure on the top of the piston to force it against the impact block. About 1901 we have again the "Herman" pneumatic jolt ram turnover machine, and finally other makers with their larger and more fully developed machines which has resulted in the fine and large modern machines of the present day.

FIG. 11.—MAKING AN ANCHOR MOULD.

Messrs. J. Macdonald & Son, Limited, of Glasgow, are familiar to most foundrymen as being the principal British manufacturers of such machines. These machines are built to jar up from a delicate name plate to an engine bed. The jarring method is the most applicable device in use to-day for the greatest variety of castings. The very large machines are built to jar a load of ten tons, turn the mould over and draw the pattern, with the very minimum of finishing. There always will be a little finishing by hand on all the large machine-made moulds, but the donkey work is done in a few minutes.

To meet and help the jolt machine great attention must be given to the patterns, they must be well made, of good, sound stability, perfect finish, and no back draft, at least [illegible] in. to the foot should be allowed. Patterns must be frequently varnished with good shellac varnish, preferably made by the patternmaker himself from methylated spirits and not wood alcohol. Half the battle and the greatest assistance to moulding machines of whatever type is good and accurate patterns. Patterns of a medium size can be made in such a manner that they are in themselves in a sense a moulding machine. They can be divided up and shared between two or more moulders, each making his part for the final casting.

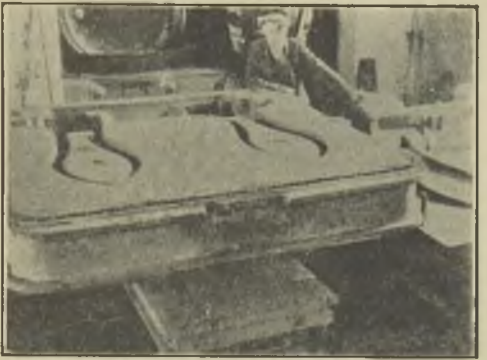


Fig. 12.—A Complete Half Mould for an Anchor.

Hydraulic Machines.

Due to lack of time the author has been unable to trace properly the origin of the hydraulic moulding machine, but they were in use probably 25 years or more ago. The Bonvillain and Ronceray Moulding Machine Company, of Paris, are well-known makers of such machines. With light work quite remarkable results can be obtained.

There are moulding machines driven by electricity, as represented by the Pneulec Machine Company, Limited, Smethwick (Electric Pneumatic), patents, and the Scott's, of Norwich (Electric), patent.

Within the last three or four years there has been a new development of a hand jolt-machine made by the Denbigh Engineering Company, Limited, of Tipton.

Again, there is the sand slinger machine, made by the Foundry Plant & Machinery, Limited, Glasgow. This machine, as the name implies, simply rams the sand. Quite heavy casting moulds can be rammed both in the floor and moulding boxes. There are many more types of moulding machines made by other well-known makers of foundry moulding machines and equipment.

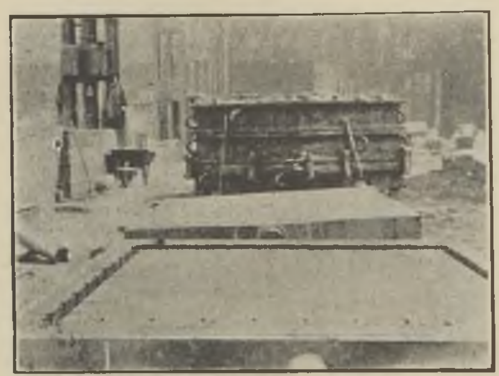


FIG. 13.—MAKING A TANK PLATE.

Centrifugal Casting.

In pipe moulding there are various devices and modifications of moulding machines. Of course, the most modern pipe moulding or casting machine is the centrifugal casting process as practised by the Stanton Ironworks Company, Limited. The Centrifugal Castings Company, Limited, Scotland, also make some wonderful castings centrifugally.

In the hollow-ware foundries very few power moulding machines are used, nor in the textile, stove grate or radiator foundries. In radiator foundries, it is thought, machines are employed for making the cores. During the Glasgow Conference period a visit was paid to a well-known company's works. They produced in their foundries large quantities of stove grate, rain water and general builders' castings. The writer does not remember seeing more than about six power-moulding machines in the whole of their extensive foundries, two being sand slingers, the remainder being large jolt ram machines of German origin. This was very startling, because the foundries were very large and all castings of a purely repetition nature. Castings were actually being made from loose patterns with considerable numbers on. They must be able to produce cheaply, otherwise the question of moulding machines would have been forced on them. The founder must decide which type of machine will suit the particular line of castings to be made.

FIG. 14.—THE FINISHED TANK PLATE.

The withdrawal of the pattern will depend on the depth of pattern above the pattern plate. With fairly shallow patterns and plenty of taper the boxes are either lifted off by hand or the plate lowered away from mould. In this case there is always the danger of breaking the edges of the mould and the sand falling away, and the box must be turned over.

A better method is to turn the pattern over in contact with the sand and box, and then either lift the pattern from the mould or lower the mould from pattern. Any loosened sand can then be easily pressed back into position. Such methods are very advisable with deep moulds.

FIG. 15.—CRANE BASE MOULD.

Stripping Plates.

Turnover plates alone may not be suitable for deep, straight-sided or intricate moulds; in such cases various types of stripping plates are employed to support and lift the sand from around the pattern. A simple stripping plate is sometimes devised so that when the moulding box is turned over and the plate withdrawn the strip plate falls with the box, carrying the sand with it right close to the pattern. In other cases a pattern is drawn through the stripper, and so on.

Stripping plates are very often expensive. Instead of copying exactly the shape of outline of the pattern the plate is sometimes made with an opening somewhat larger than the pattern around which it is placed and a fusible metal poured into the space thus formed. Some wonderful and ingenious combinations of stripping plates are employed in the motor-car trade.

Fig. 16.—Annealing Pan Making. Filling in the Mould.

Core-making machinery follows on very much the same lines as moulding machines. Also, there are machines on which can be made both round and square cores after the fashion of the sausages. The same type of cores can be made in tubes in short lengths rammed by hand, and are then ejected from the core box mechanically.

Jolt Machines.

The plain jar-ram machine eliminates hand ramming, the making of joints, and in many cases the cutting of runner gates, etc. Even with a plain jolt the time saved can be very considerable, as the time to ram sand moulds can exceed 50 per cent. of the total time to make the complete mould. Large moulds can be rammed in about 30 seconds.

Fig. 17.—Annealing Pan Making.
Raising the Mould.

A jarring turnover and pattern drawing machine goes much further and cuts out the labour of turning the box over by hand or crane and the drawing of the pattern, which is done more steadily than by hand, with the consequent saving in repairs.

Jar and stripping machines take a shorter cut to the complete mould. After jarring, the sand and box is stripped upwards from the pattern or the pattern is drawn downwards through the strip plate, whilst the jar squeeze and stripping machine cuts out also the flat ramming of the top of the sand after jolting.

The plain squeezer machine cuts out most of the hand ramming only, always remembering that there is the saving in all types of machines of the making of joints and cutting of gits, and, again, the more perfect pattern draw and lifts which reduces mould repair, as previously stated.

There is an air-operated squeezer machine which is described as the sand straddler. It is mounted on wheels, the body having a wide span to enable the machine to pass over or straddle the sand heap which is piled in long rows. As the moulds are made the machine is pushed forward, thereby avoiding the labour of carrying the completed moulds any distance.

FIG. 18.—ANNEALING PAN MAKING. LOWERING THE MOULD.

It seems hardly necessary to explain what happens when sand is jolted in a container like a moulding box. Each jolt of the machine can be equal to hundreds or even thousands of blows by the ordinary hand rammer. Frames are usually placed above the flask to provide sufficient sand completely to fill the flask when ramming is complete. It is better to err on the side of feeding in too much sand rather than too little. Sometimes when jolting large moulds, especially the bottom part, sand is first fed in to reach a certain part of the pattern after jolting, incidentally allowing the moulder to tuck vital places; then sufficient sand is again piled in the box completely to fill the box after jolting. Only in very rare cases is it necessary to ram the mould in more than three stages. The moulder should help the sink of the sand by spreading the sand outwards from the middle as jolting proceeds. If the contour of the pattern is such that there are no projections the ramming is ideal. But, as will be imagined, the sand during jolting will sink away under projections. To overcome this weakness in the ramming process various devices are adopted. In many cases a simple blocking and coring out under the projection is all that is

FIG. 19.—ANNEALING PAN MAKING.
REMOVING THE MOULD.

needed. In other cases blocks of wood are placed above these projections, and after jolting taken away to allow the soft places to be hand rammed. In certain cases a hole suitably shuttered can be arranged for in the side of the moulding box, so that after jolting difficult and undercut portions of the mould can be rammed by hand. Oil sand cores can be made to form certain parts of a mould and inserted in the moulding box before filling in

FIG. 20.—ANNEALING PAN MAKING.
MACHINE TABLE TILTED.

the sand and jolting. Oil sand cores can also be located in the mould during the ramming up stage to form sturdy seatings or prints for receiving and holding heavy cores. Properly made oil sand cores will stand the jolting very well indeed. There are many other devices, but the above outline will set the candidate for jolt ramming thinking along the right lines.

Care must be exercised when preparing facing sand for jolt ram machines. The sand must posssess sufficient plasticity at the mould joint to retain a perfect outline of the pattern; above the joint and over the remainder of the pattern it can be a little more open. The backing up sand is not so important, but it should have the property of cohesiveness. One advantage in favour of the jolt ram machine is concerned with the facing sand. When once the pattern is covered with facing and the backing sand filled in, the jolting action never disturbs the facing material, therefore there is no possibility of the rough black backing sand getting in contact with the pattern.

FIG. 21.—ANNEALING PAN MAKING. POURING THE MOULDS.

As facing sand entails considerable cost to bring it to the right condition, it can be used sparingly without fear of any part of the pattern becoming exposed to the rougher backing sand.

Hydraulic Moulding Machines.

The systems as practised by the Bonvillain and Ronceray Company for use on their hydraulic moulding machines seem to be developments of the early work of such men as Jobson and certain German and French inventors. It is thought they have either three or four patented systems. They teach the purchaser how to make match and pattern plates almost entirely by the moulder.

The system, termed "The Reversing Pattern Plate," used to be arranged something like the following: The ordinary wooden pattern is made to make a sand mould in the usual way, using a machined and correctly fitting two-part box with special pinning arrangement. After the top part has been taken off the two half boxes are placed together, joints upwards, the machined sides of the boxes securing exact alignment relative to the pattern or patterns in the moulding box. The two parts are bolted together, a frame is placed on the two boxes and filled with plaster-of-paris, the resulting plaster pattern plate holding both halves of the pattern. Two sand impressions taken from such a plate and placed together will make a mould containing two castings, thus allowing production on one machine. It pays to adopt this method for numbers of 100 off each piece.

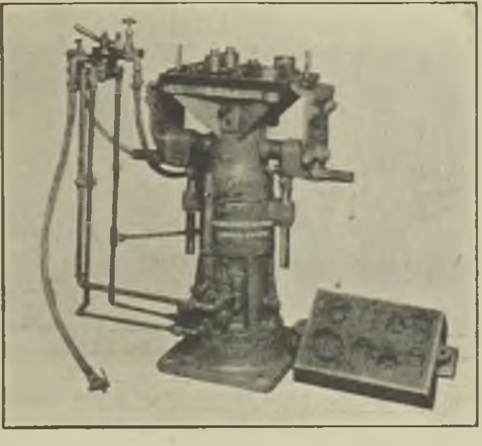


Fig. 22.—No. 1 Ajax Pattern Drawing Machine.

For numbers of more than 100 it pays to make a more substantial pattern, so that a gypsum plate is made faced with a thin layer of white metal. To make such a plate a complete mould is made in the usual way, well smoothed and blackened to give a high polish. Sand moulds are then made from this sand mould, giving a reproduction of the pattern in sand. The face of the sand pattern is then carved all over to a depth of about $\frac{1}{8}$ in. to $\frac{1}{4}$ in. When the two sets of half boxes are placed together a hollow space is formed, into which a white metal is poured, thus giving a layer of about $\frac{1}{8}$ to $\frac{1}{4}$ in. of metal. The hollow metal pattern is placed in an iron frame and backed with Gypsum. Patterns are quickly and easily made.

If the reversing pattern plate is considered cumbersome, two plates can be made, one having the top impression and the other the bottom impression. In such a case it is usual to work on two machines.

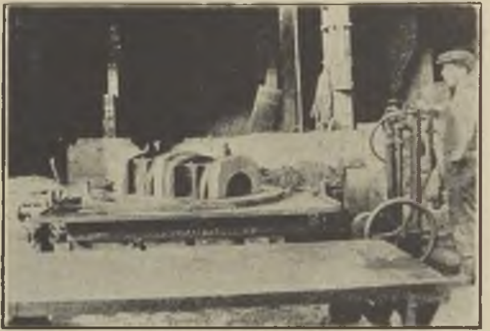


FIG. 23.—MOULDING AUSTRALIAN AXLE BOXES. THE PATTERN MOUNTED.

Many modifications of the above methods have been general in most districts for many years.

Built-up Pattern Plates.

The built-up pattern plate is a term which can be explained in two ways. One could describe a machined plate on which is built one or more patterns with runner gates as a built-up pattern plate, but the term is applied mostly to describe a plate made up of a number of small plates held together in a common frame. One or more of the plates can be taken out of the frame and replaced by others as desired. The small plates are about $\frac{1}{2}$ in. thick and made in the same manner as the reversing plates as explained earlier. The following pictures and remarks will illustrate the making of various substantial castings on the "Ajax" jarring machines.

Figs. 9 and 10 show the patterns and moulds of a 12-in. elbow pipe. Some of the moulds are cored. The half pattern is seen on the turnover table of the machine, a half-mould on the crane chains and a complete casting fronts the machine. The production is 12 castings per day.

Fig. 11 gives a picture of the moulding of a large anchor, the half pattern of which is secured to the turnover table of a No. 20 "Ajax" Jarring Turnover Machine. Fig. 12 shows a complete half mould resting on the mould carriage. The size of the moulding box is 6 ft. 9 in. × 6 ft. 9 in. × 19 in. deep on the one side and tapering down to 12 in. on the other. The output was three steel anchor castings per day.

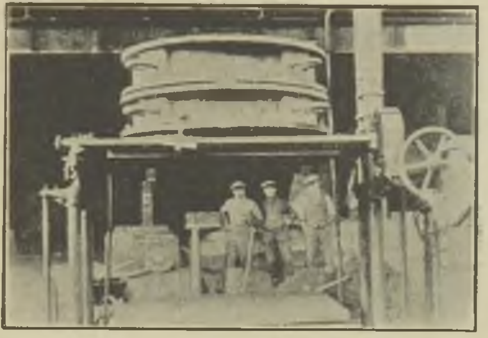


FIG. 24.—AXLE BOX MAKING. MOULD ELEVATED READY FOR TURNING OVER.

Figs. 13 and 14 show a 5 ft. sq. tank plate made on a No. 20 "Ajax" plain jar machine. Fig. 13 depicts the bottom and top moulds. The top mould is proof that flat tops can be jar rammed with complete success. The boxes are 6 ft. 2 in. × 5 ft. 7 in. × 7 in. deep. The important point to consider when jar ramming flat top parts is to have the bars the correct distance from the face of the plate and the bevel edge of the bars at the correct angle. Fig. 14 shows the flange side of the casting.

Fig. 15 describes a large mould for a crane base, the size of box is 9 ft. × 7 ft. 10 in. × 22 in. for the drag and the depth of the core box is 14 in. The machine used for these moulds is a No. 24 turnover machine, the size of the turnover table being 10 ft. × 7 ft. Such a machine is in use in a large foundry in the North of England.

The pictures from Fig. 16 to Fig. 21 give the method of moulding annealing pan castings, these castings being extensively used by the malleable iron founders in the process of annealing castings. Fig. 16 shows the operator filling in the sand. The box is a permanent fixture on the machine table along with the pattern. The moulds are practically boxless in a sense, the complete mould being contained inside a perforated sheet steel slip case without lugs or pins. Fig. 17 depicts the mould elevated, a cast iron bottom plate being temporarily clamped to the top. The handles of the bottom plate are bent to allow hand room for the two men who carry out and lower to the floor. The clamping device is a fixture to the permanent box. In Fig. 18 is seen the mould contained within the sheet steel shell being lowered away from the pattern which is located within the permanent box. Note the perforations through the

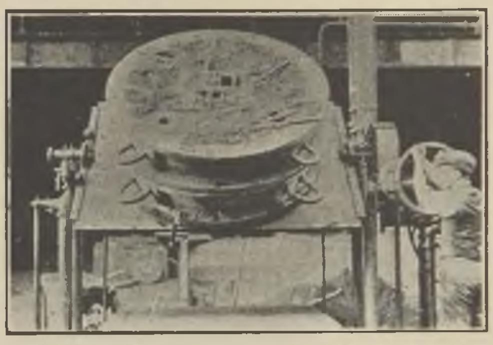


Fig. 25.—Making Axle Boxes. The Mould being Turned Over.

sheet steel shell; they provide for venting the mould. Again, in Fig. 19 is shown two men carrying away a completed mould. Another mould is seen on the floor close to the machine. These moulds leave their own core, and in this picture the green-sand core is visible and a portion of the five-spray gate on the joint at the left of the photograph. Note the permanent box in an inverted position on the machine table. Fig. 20 shows the machine table tilted and the operator blowing out any loose sand. The pattern is located in the centre of the permanent box. In Fig. 21 is shown a row of moulds covered and in the process of being poured. The top parts are very shallow and are rammed by hand, the box resting on a flat plate fixed to two supports at a standard working height for the operator. The machines used are the No. 6 "Ajax" jarring turnover, and the output is 100 12-in. pans per day from each machine. This plant is in operation near Birmingham.

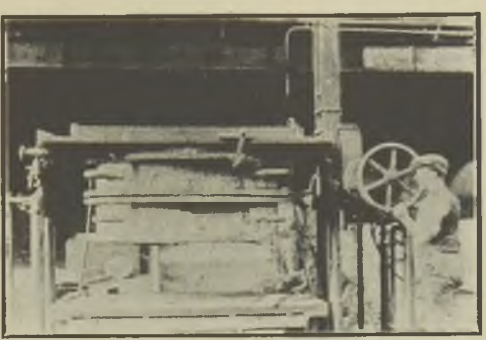


FIG. 26.—MAKING AXLE BOXES. THE MOULD COMPLETELY INVERTED.

A method of moulding the new British standard 12-ton axle box has been previously described.*

This method utilises two No. 6 jarring turnover machines working as one unit. The present actual output for the two machines is 50 complete axle box castings, or 100 half castings. Fig. 22

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* FOUNDRY TRADE JOURNAL, January 31, 1924, page 88.

describes the latest introduction of the "Ajax" jarring machine. This machine is a size No. 1, with pattern drawing device. It is an all-round air and oil controlled machine; the draw is oil controlled and the moulding box adjustments are air controlled, thus dispensing with the use of spanners and so saving time and energy. The machine accommodates about 10 different sizes of boxes.

The views from Figs. 23 to 27 illustrate the operations when moulding two large locomotive axle boxes of the Australian type. The first photograph shows the two patterns on the pattern plate and fixed to the machine table: Fig. 24 shows the turnover table and mould elevated and ready for turning over. Fig. 25 shows the mould being turned over, the picture Fig. 26 with the mould and table completely inverted and Fig. 27 the patterns drawn from the mould. The size of the moulding box is 5 in. to 6 in. dia. × 24 in. deep. Two parts bolted together form the complete box. The castings are steel and made in a large steel foundry in the North of England.

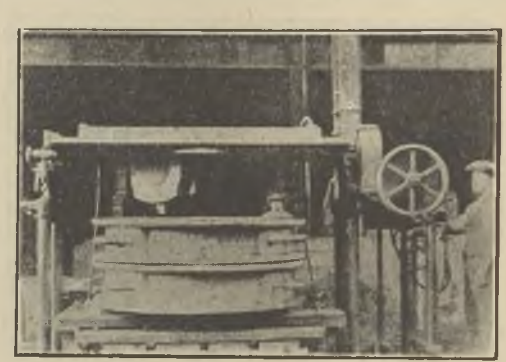

FIG. 27.—MAKING AXLE BOXES. STRIPPING THE PATTERN.

The next picture, Fig. 28, gives a view of a special plain jar machine for ramming long castings; it is size No. 20. Such castings as flanged pipes, lamp-posts, etc., are made on the machine.

This type of machine is operated either by electric power or pneumatic.

Much of the improvement ascribed to moulding machines is due to the excellent provision of tackle. In many foundries, if tackle was made to suit the work made from loose patterns, improvement in quality and output would be noted, although falling far short of the output by modern moulding machines.

When making tackle for use on any type of machine the following sketches and hints are worth considering. They apply more particularly to the jolt ram machine.

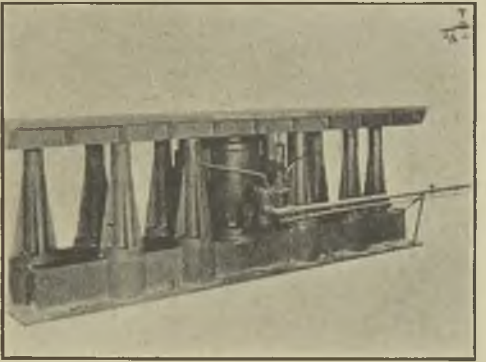

Fig. 28.—A No. 20 Ajax Machine for Lamp Posts, etc.

Fig. 1 shows on the left side the correct way to shape a box bar; the right-hand side of the sketch describes the usual way in which bars are made, but it is the wrong way. By constructing the bars with a gradual taper, as seen in Sec. A, instead of like Sec. B, and the bar cut out instead of following the contour of the pattern, the sand during jolting will settle under the bars more easily, thus avoiding soft places. Fig. 2 gives a rectangular shape, and shows on the right-hand side the correct way to make the bar. By notching the bar in the way described the sand is better accommodated. Again, in Fig. 3 is shown on the left of the sketch the correct design of the bar, and on the right the wrong design, especially when it is desired to lift out cods of sand which have metal on the face of them. Fig. 4 shows by dotted lines the way such a bar should be made. Very often it is inconvenient to have snugs and trunnions on the same box. In certain cases the combination of trunnion with pin hole, as described in Fig. 7, is very useful.

In foundries making heavy castings much labour and time can be saved by making one or more cast-iron plates machined and lined in ft. sqs., as described in Fig. 5. In many instances, as when making large flywheels up to 15 tons, only one-half pattern need be made, which is correctly dowelled on the plate. Quite a variety of heavy castings can be made in this way. When one considers a large moulding box and the labour of lifting sand and other materials to a considerable height, the utility of the plate will become evident. By correctly dowelling on the plate each half mould can be rammed up separately at a convenient height from the floor. Fig. 6 is a sketch of a bar templet for drilling pin and dowel holes in such plates and boxes. The cups B can be adjusted for various sizes of boxes, etc.

West Riding of Yorkshire Branch.

METALLURGICAL COKE.

By A. Jackson, Associate Member.

The first coke manufacturers followed the methods of the old charcoal-burners—that is to say, coal was first carbonised in large open piles or heaps. Air was allowed free access during the early stage of the process, and gradually cut off by blocking up the airholes with breeze as the carbonisation proceeded. These heaps were rectangular in shape, and sometimes attained a length of 200 ft. To build up the heap a line was first stretched in the direction of the axis, and large pieces of coal placed on either side of it. Other large pieces are placed so that, by coming together at the top, they formed a triangular gallerv running the whole length of the heap. The heap would then be built up with smaller coal until it attained a width of about 5 ft. at either side of the central channel. In order to light the heap stakes were placed at regular intervals, running from the top of the heap into the central channel. This left a series of chimneys, into which burning coal was introduced, so that the pile is fired at many points at the same time; ignition becomes general, and coking commences through its whole extent. The man in charge has now to prevent the action from going too far, and as soon as he observes that thick smoke and flames have ceased to be evolved in any part—in other words, as soon as he sees that the volatile matter has been driven off—he prevents the entrance of air at that point by covering it with a coating of breeze. After complete carbonisation, the heap would be allowed to cool for several days, the coke then withdrawn and quenched with water. This method was obviously wasteful; not only were the by-products lost, but some of the coal was burnt to ash, and ultimately the process gave way to beehive coking.

Beehive Coking.

The cavity of the beehive oven, which is about 9 ft. in diameter and 3 ft. 6 in. high, is internally lined with firebricks, well-jointed in refractory clay. The form resembles that of a beehive, hence its name. At the top of the dome is a circular aperture or chimney, which can be closed by means of an iron plate. A slightly arched doorway about 2½ ft. square is also left for the purpose of charging the oven and withdrawing the coke. This opening is strengthened by a heavy cast-iron frame. An oven of this type would take a charge of about 3 tons of coal, which is either introduced through the door as stated, or, in some cases, through a hole in the top of the oven. The oven is charged whilst hot, that is to say, immediately after the withdrawal of the previous charge, so that the coal immediately begins to give off its volatile matter, which escapes through an aperture in the dome. After charging, the door is closed by means of firebricks loosely piled, so that a limited amount of air enters the oven. This ignites the gases, and the temperature of the oven and contents rapidly rise. After about three hours the air supply is gradually cut off. In about forty-eight hours from the time of charging, the coking period will be over, and the oven cooled down sufficiently for drawing. For this purpose, a large iron shovel is used, suspended by a piece of chain from a crane, and this allows the workman to handle large quantities with comparative ease. The coke is thinly distributed on the floor, quenched, and wheeled away in iron barrows. In some cases the coke is quenched inside the oven by means of spraying water under pressure. Care must be taken not to reduce the temperature of the oven so much that it cannot ignite the succeeding charge.

Quenching and Sulphur Content.

This method of quenching is said to reduce the sulphur content of the coke, the decomposition of the water carrying off some of the sulphur as sulphuretted hydrogen. It is also claimed that, as the water is immediately converted into vapour, it has no bad effect upon the open walls.

The quenching of coke in a non-oxidising atmosphere has the effect of producing a brighter coke, more silvery in appearance. In the beehive coking, carbonisation proceeds from the top downwards—the thicker the charge the longer the coking period—so that, by regulating the depth of the charge, the coking period may also be regulated. Coke made on a small charge, known in America as twenty-four-hour coke, contains a higher percentage of ash, by reason of the fact that the carbon at the top will be burnt away. Also, the bottom will be spongy, and will retain some of its volatile matter because of the relative low temperature at the bottom of the oven. The demand, therefore, so far as Beehive coke is concerned, is for a material made on a deeper charge. In such coke the percentage of tops and bottoms is not unduly high, and forty-eight- to seventy-two-hour coke will fetch a higher price for foundry work. From what has been said it will be seen that the fracture of Beehive coke depends on the depth of the charge; the pieces may be as long as the charge is deep. In by-product coke, where carbonisation takes place from the sides, forming a pipe in the centre of the coke mass, the maximum size of coke must be less than half the width of the oven. The Beehive ovens were also wasteful by reason of the loss of the valuable by-products, and, as far as Europe is concerned, have almost become extinct. In America, where the by-product ovens were introduced later than in Europe, the Beehive ovens lingered on for some time, but are now rapidly giving way to the modern method. So that, although the by-product oven was not introduced into America until 1892, during the year 1913 some twelve million tons, or a quarter of the total supply of metallurgical coke for that year, was produced in by-product ovens.

Coking Coal.

Good quality metallurgical coke calls for a special type of coal. Coking coal belongs to the bituminous or semi-bituminous variety. Gruner's classification of coals is based upon their coking properties. The volatile contents of coal is not an infallible guide as to its coking properties. S. Wales coal, with volatile matter as low as 15 per cent., yields a good coke, whilst other coals having a content of 40 per cent. will not coke at all. The position, therefore, so far as the volatile matter of coal is concerned, is qualitative rather than quantitative, and is attendant upon the nature of the volatile matter. Until recently very little was known as to the cause of coking properties in coal. Stokes and Wheeler, in their monograph on the constitution of coal (1918), have collected the available data, and have themselves made original contributions to a solution of this problem, and it would now appear definitely that the coking properties are due to certain resinous constituents of coal. These resinous constituents undergo a period of incipient fusion, or softening, and act as a binding agent, so that the fragments coalesce and yield a compact coke. The presence or absence of these resinous compounds, therefore, determine whether the coal is coking or non-coking, and determine the strength, hardness, and density of the resultant coke. Coal is a most intractable substance in the laboratory. It is insoluble, and resists many re-agents, and except by the process of destructive distillation does not readily lend itself to examination. However, by the aid of certain solvents it has been possible to separate the resinous compounds from the coal, and it has been proved conclusively that coking coals, after treatment with these solvents, either would not yield coke, or yielded coke of very indifferent quality. For some purposes, it would be possible to classify the volatile matter of coal under two general headings, viz., humus and resinous. Probably a number of bodies, varying little in composition, whose exact composition, indeed, is probably unknown, would be placed under each heading. All would contain carbon, hydrogen, and oxygen, the humus bodies having the higher oxygen content. That is why in two coals of almost identical composition one will coke and the other will not. It has been stated that the resinous bodies produce coke owing to the fact that they leave behind a pitch which binds the coke. The humus bodies will not coke owing to their low pitch-forming nature. If the humus bodies are in excess, it gives a non-coking coal; if the resinous bodies predominate, it gives a coking coal. The humus bodies contain a heat value below the average; if, therefore, the heat value of a coal as ascertained by the calorimeter falls below the calculated value, as calculated from, say, Dulong's formulæ, it is certain that the humus bodies contain a greater percentage of oxygen. This is shown by the analysis of the three following coals, figures calculated out upon an ash and moisture free basis:—

Table I.—*Composition and Coking Properties of Coal.*

	No. 1. Non-Coking	No. 2. Semi-Coking.	No. 3. Coking.
Carbon	82.65	83.16	85.41
H.	5.55	5.18	5.36
O.	10.10	8.98	7.22

The coking properties of these coals as shown by the sand test were in the following ratios:—No. 1, 3,9; No. 2, 4.4; and No. 3, 13.5 per cent.

The relationship of the oxygen to hydrogen was as follows:—

	No. 1.	No. 2.	No. 3
Oxygen	10.10	8.98	7.22
Hydrogen	5.55	5.48	5.36
Excess oxygen ...	4.55	3.50	1.86

It will be seen, therefore, that as the excess oxygen increases the coking properties fall, because the humus bodies get more and more in excess. The same result occurs if for any reason coal takes up oxygen from the atmosphere. During a recent coal strike, when it became necessary to use up stocks which had been weathered for long periods, it was noticed that the coking power of the coal had been seriously impaired. Ash is another important factor in selecting a coal for coking purposes.

Ash and Sulphur Content.

Professor Kendall, during a discussion at the British Association, pointed out that there are three sources of ash in coal:—(1) The mineral constituents of the plant forming the coal; (2) detrital matter blown or washed into the deposit; (3) later infiltered veins. The whole of the ash in the coal carbonised remains in the coke, so that in order to keep the ash content of coke below 10 per cent., and assuming a coke yield of 70 per cent., the ash in the coal must not exceed 7 per cent. The whole of the phosphorus remains in the ash, so that the quantity is not reduced during carbonisation. A certain amount of sulphur is lost during the carbonisation process, passing off with the gas in the form of sulphuretted hydrogen, carbon bisulphide, etc. The distribution of sulphur during carbonisation was compiled by Short in 1907, working on a Durham coking coal having a sulphur content of 0.824 per cent. The results showed a loss in sulphur, so far as coke is concerned, of about 27 per cent, which, though it may not be strictly true for all coals, it is in line with personal experience. Working on a washed "Better Bed" coal with about 0.45 per cent. sulphur, and coke yield of 70 per cent., the coke will show a slightly higher percentage of sulphur than the original coal, say 0.50 per cent.

Coal Washing.

Coal is washed before coking in order to reduce the shale and dirt present, and this enables fine coal, too small for hand picking to be used. Coal washeries are based upon the principle that bodies of different specific gravities attain different velocities in falling through any media—in this case, in falling through water; the specific gravity of the coal being about 1.3 and that of the shale about 2.3. The impurities, therefore, sink first, and thus we get two layers, one of dirt, the top layer of pure coal. This top layer is carried away by the flow of water, and afterwards stamped and caked. It has been proved repeatedly that by crushing coal finely a far superior coke can be produced than by charging the same coal uncrushed.

By-product Ovens.

The distinguishing features of the by-product oven are, primarily, the recovery of the products of distillation, and, secondly, the external heating of the coal, the gaseous products being drawn out of the oven into flues, where they receive the air necessary for combustion, and thus produce the heat necessary for the carbonisation process. This, of course, increases the yield of coke because none of the coal in the oven is burnt to ash as in the older methods.

In 1861 Coppée produced an oven which was heated externally, and from which all air was excluded. In 1856 Knab and Carves produced apparatus for the recovery of tar and ammonia. These were first operated in France, and later introduced into England by Simon. There are many makes of ovens on the market, but most of them follow to some extent the original oven of Coppée and the Simon Carves oven. These ovens may be divided broadly into two classes, viz., the waste heat and the regenerative oven. In the former cold air is used for combustion. The air supply is obtained by means of the chimney draft being drawn into the flues from the atmosphere. In the regenerative oven the air is heated before combustion; the waste gases, after combustion being used to heat chequered brickwork placed beneath the ovens. The hot gases formed in the flues heat up the chequered brickwork to their own temperature, so that the hot products of combustion are reduced from about 1,150 deg. C. to 300 deg. C. before they pass into the chimney. An arrangement is provided whereby the fresh incoming air is conducted through the hot regenerator chamber before being used for combustion whilst the first regenerator is being reheated by the waste gases. This process is reversed every half-hour. In the waste heat ovens 85 to 100 per cent. of the gas produced is necessary to heat the ovens. This waste gas is, of course, incombustible, but contains considerable heat, and may be put to some use if used immediately and in the vicinity of its origin. It cannot be stored, and loses its heat quickly. Regenerative ovens only require about 50 per cent. of the available gas for heating the ovens, the other 50 per cent. remains for other purposes. It is combustible, can be conveyed any distance, and can be stored without deterioration. In Durham much of the coal is charged into the top of the oven. The coal comes from the washer, and is allowed to drain several days after crushing, and finally enters the oven with from 4 to 6 per cent. moisture. In Yorkshire the coal is compressed into a cake, and pushed into the oven through the door usually by means of a combined coal-compressing and charging machine.

This machine carries a box fitted with a movable side and a movable bottom of the same size and shape as the interior of the oven. The washed and crushed coal is dropped into this box layer by layer. It is then firmly compressed by means of an automatic stamper, which travels backwards and forwards throughout the entire length of the box. In order to cake properly, the coal should contain about 10 per cent. moisture. When made, the cake is conveyed on the machine opposite the oven to be charged, the oven door drawn up and the cake pushed into the oven by means of a ram. This ram also serves for discharging the ovens, pushing out the coke on to benches situated at the opposite side of the battery. With uncompressed coal the average carbonising capacity is 6 tons per oven per 26 or 28 hours, and with compressed coal from 35 to 37 hours, for about 10 tons of coal. In order to facilitate the discharge of the coke, the ovens are built with a slight taper, being usually about half an inch wider at the discharging or coke bench side than at the charging side. After pushing, the coke is quenched by means of a quenching hood.

Physical Tests of Coke.

The chief characteristics demanded from metallurgical coke are:—(1) Sufficient strength to withstand the burden in furnace or cupola and to withstand crushing strain; (2) a certain degree of hardness to allow of handing without undergoing fragmentation; (3) a certain degree of porosity in order that the coke will expose a maximum surface to the gases in the furnace; (4) an ash content not exceeding 10 per cent.; and (5) sulphur and phosphorus not to exceed 1.0 and 0.05 per cent. respectively.

It is to be regretted that physical tests for coke have not been standardised, although to some extent the methods employed are general. The apparatus used varies considerably.

Coke for cupola and crucible purposes calls for physical properties varying in degree from blast-furnace cokes, and we suggest that a useful line of inquiry might be made in this direction. But in order to find out the ideal hardness, porosity, etc., required in cupola and crucible coke it would appear to be necessary to first standardise the methods of making the physical tests.

Lancashire Branch.

THE PRODUCTION OF DIESEL ENGINE CASTINGS IN PEARLITIC CAST IRON.

By A. J. Richman, Associate Member.

Cast iron, having a maximum pearlitic structure, has always been looked upon as the ideal for castings, having to withstand heavy duty, such as wear, heat, or impact. In the past some thousands of tons have been produced under ordinary foundry conditions with an analysis within the limits of 1.2 to 1.4 Si; 0.6 to 1.0 P; 0.8 to 1.0 Mn; and 3.4 to 3.5 T.C.

For steam engine practice this class of iron gave good results as regards wear and physical test. The Admiralty transverse test of 30 cwts. on a 2 by 1 by 36 in. bar and 12 tons per square inch tensile could be obtained without much trouble. With the advent of the internal combustion engine, engineering firms turning over from steam engine to Diesel engine manufacture experienced a great deal of trouble from cracked cylinder heads, growth and distortion of pistons and cylinder liners.

It was found that the percentage of total carbon, silicon, and phosphorus must be kept as low as possible—the phosphorus most particularly, as, if the T.C. and Si were right and the phosphorus were high, the castings would not last long under repeated impact of an explosive engine. This experience caused research workers to look for a high duty iron that would stand up to the severe conditions.

Semi-steel was about the first high duty iron that came along to claim its superiority over all others. This was supposed to have originated in America, but has been proved otherwise by Turner. The use of steel in the manufacture of semi-steel was more for the lowering of T.C. and its effect on the condition of the graphite more than anything else.

Lanz Perlit.

More recently foundrymen have heard of Lanz Pearlitic cast iron. In the Lanz process it is claimed that by pre-heating the mould previous to or after casting, an iron can be used lower in T.C., P, and Si than in ordinary cold-mould practice. It is further claimed that the resulting iron is superior in most respects to ordinary cast iron. One can readily understand that by preheating a mould an iron can be used lower in Si and T.C. than would be possible in cold mould practice.

FIG. 1.—LANZ × 500 DIAS.

Together with the mould at a certain temperature, the iron must be of a definite composition to suit a casting of a certain thickness. It is claimed that this iron, when cast into a cold mould, gives a white fracture. The physical properties claimed for this iron are very high, and castings have the same structure in thick and thin sections alike; this fact is claimed to eliminate practically all wasters other than purely foundry wasters due to faulty moulds or cores

The actual analysis of Lanz iron we know very little of. One hears of Si well under 1.0 per cent. and T.C. 2.8 per cent., with phosphorus not above 0.1 per cent. If this is correct, it will be very interesting to hear how 2.8 T.C. can be produced at will from the cupola. It looks more like an air furnace iron for steel works rolls.

The Thyssen-Emmel Process.

Another process of producing a maximum Pearlitic iron is the Thyssen-Emmel process. Here, again, we know very little about it, other than its wonderful qualities. From a foundryman's point of view, if the claims are anything to go by, this method appeals to one, perhaps, more than the Lanz method, owing to the composition of the iron, except the T.C., being more in line with the irons used in most foundries.

From a test and analysis report on some Thyssen-Emmel iron by the Yorkshire Testing Works, the analysis is given as T.C. 2.64, C.C. .83, Si 2.14, S .159, P .25, Mn 1.37, which gave a tensile of 26.79 tons per square inch and 1 per cent. elongation, and a transverse test of a round bar gave a result equivalent to 45 cwts. on a 2 by 1 by 36 in. The test bar gave a Brinell hardness of 255. As to the analysis, the T.C. content is very low: it is the process of producing a low T.C. iron that is the secret of the patent. Most remarkable is the high silicon content; this is where it differs so much from the Lanz iron. The physical tests are exceptionally good, and are far above that claimed for Lanz iron. The Brinell number seems very high, and the author feels sure if foundrymen made castings as hard as 255 Brinell they would have the machine shop people complaining, as the author has found that 230 to 235 about the limit.

Basic Principles.

Definitely, to understand what pearlitic cast iron really is, one must closely examine what actually takes place when molten iron solidifies. Cast iron cannot be said to have a solidification point, but a range in which the different constituents solidify out. The analysis, mass effect, latent heat, and rate of cooling, all govern the length of the range. The lower the percentage of impurities in cast iron the shorter the range, and higher the temperature at which solidification commences.

At about 1240 deg. C. cast iron commences to solidify, and, just immediately afterwards, the iron carbide, which is not very stable in the solid form at high temperatures, starts to split up, forming primary graphite and ferrite, the latter depending on the composition of the iron.

The amount of graphite thrown out of solution depends on the amount of carbon, silicon, phosphorus, manganese, sulphur, and rate of cooling, the first two constituents and the last condition having the greater effect.

The rate of cooling is governed by the size and thickness of the casting, casting temperature, temperature of the mould, the latent heat of the iron employed, and the conductivity of the sand. Cooling continues down to about 940 deg. C. when the phosphide eutectic solidifies. This point is the end of the solidification range. The amount and condition of the phosphide present is governed by the amount of phosphorus in the iron and the rate of cooling. Being the last constituent to solidify out, it naturally tends to segregate into patches, but if the percentage is low and the existing conditions favourable, it forms into a meshwork formation around the crystal boundaries of the iron. To obtain this desired condition, the rate of cooling must not be too slow. Secondary graphite still continues to be formed right down to about 750 to 700 deg. C., but cannot grow very large owing to the material being completely solid.

The remainder of the carbon in the iron that has not been thrown out as graphitic carbon, and is still combined with the iron, is left as pearlite. This pearlite consists of alternate layers of ferrite (almost pure iron), and cementite, which is iron carbide in the proportion of 7 of ferrite to 1 of cementite, the whole having about 0.9 per cent. carbon unless other elements are present to affect this.

It can be readily seen from the foregoing facts that quite a number of changes in the ultimate structure of the iron can be made by slight variations of analysis and rate of cooling. Advantage is taken of this fact in the production of pearlitic cast iron. Pearlite and graphite are very closely associated with each other in cast iron; often in poor iron there is a layer of silicon-ferrite separating them, but under specially controlled conditions it is possible to obtain a wholly graphite and pearlitic structure without any free ferrite being present. This can only be accomplished by working to very fine limits as regards the actual analysis of the cupola mixture, melting losses, the conditions during the passage of the iron through the cupola the ultimate analysis and the rate of cooling through the critical stage, for a certain mass and size casting to be produced. The mass having a very large effect on the ultimate structure, it is claimed in the Thyssen-Emmel process that, no matter what mass is cooled, it is pearlitic.

FIG. 2.—CAST-IRON LINER × 500.

Superheated Iron for Heating Moulds.

The effect obtained by pre-heating the mould by the Lanz process can also be obtained by casting at a very high temperature into a warm mould; the mould being warm avoids a sudden chilling action of the metal when entering the mould.

The pearlite formed can be of a coarsely-laminated nature, or a fine unlaminated condition, depending again mostly on the Si content and rate of cooling. Sorbite is the name given to this unlaminated pearlite, and not able to be resolved at the highest magnifications, and is the most desirable condition in cast iron when accompanied with small, fine, curly graphite. To obtain this ideal structure, an iron having a very low

Si, P, and T.C. content must be used. Owing to the effect of the other constituents of cast iron and the rate of cooling on the condition of the carbon, total carbon should not be above 3.2 per cent., or large, straight flake graphite is likely to be formed. Phosphorus should not be above 0.3 per cent., preferably under 0.2 per cent., owing to its tendency to segregate.

Casting with a high percentage of superheat and the subsequent fairly slow cooling through the critical stage, even a small percentage of phosphorus is likely to segregate. When this happens, the resulting iron does not give such high physical tests as when the phosphide is in the most desirable fine meshwork formation. Moderately-high manganese is desirable, but not essential, as long as there is enough present to look after the sulphur, and help the stability of the pearlite, as the effect of the manganese remains to help to hold the carbon in the combined state. Sulphur is usually fairly high in low-Si irons, but this fact does not seem to have any detrimental effect on pearlitic cast iron up to about 0.13 per cent. Seeing that casting very hot is an essential condition in the production of pearlitic cast iron, it may account somewhat for the latter fact.

Internal Combustion Engines.

When investigating the physical properties of cast iron suitable for internal-combustion engine castings, one must consider the conditions to which the castings are subjected. The three most important conditions are:—(1) High temperatures; (2) repeated impact; and (3) hard wear.

Discussions upon the resistance of cast iron to high temperatures should take into consideration the cause of growth. The most potent cause of growth in cast iron is usually owing to the presence of *large graphite flakes* in the free ferrite of the metal structure. Free ferrite, which is silicide of iron in solution, when present in cast iron is in the vicinity of the graphite, and the hot gases burn out the graphite, and so access is made to the free ferrite, which is attacked and oxidised into silica and iron oxide. Owing to these substances having a larger volume than the substance from which it was formed, small cracks are formed, the sides of the cracks opening slightly, and so growth is made.

In conjunction with high temperatures existing in an internal combustion engine, the repeated impact of the explosion calls for a tough, strong iron. The two chief weakeners of cast iron are graphite and phosphide, the graphite being a non-metallic substance, filling up small cavities. The phosphide when in large percentages forms into patches, which are very brittle, and so lowers the resistance to impact.

An iron which has to stand up to hard wear must be free from large flake graphite and any substance of a soft nature in its structure, such as free ferrite, silicon ferrite being the softest constituent of cast iron

This sums up the points to be avoided in iron suitable for internal combustion engine castings. This leaves us with pearlitic cast iron as having none of the defects stated previously, and which is at the present time the best iron for high duty work.

Inherent Difficulties.

To produce a suitable iron from the cupola and repeat the result from day to day, and often have to vary the mixture during the same day's blow, for different thicknesses of castings, brings one up against a certain number of difficulties.

Take the T.C. content with low-Si and phosphorus, the tendency is to absorb carbon, and very often hematite iron has to be used to obtain the low-phosphorous content. Hematite iron is usually high in T.C., in fact all the conditions are favourable to carbon absorption. Another difficulty which all foundrymen will readily appreciate is repeating the same analysis from day to day.

To obtain consistent results it is essential to keep the analysis within fairly fine limits. Small variations in Si when the Si content is under 1.0 per cent. and T.C. when in the region of 3.1 per cent. to 3.2 per cent. make a very large difference to the resulting iron. Ordinary foundry pig-irons can be used as a basis for making up the mixture. By ordinary pig-irons is meant pig-irons other than special irons, semi-cold blast or cold blast irons, costing under £6 per ton. This point is very important as special pig-irons are high priced.

Steel Additions.

The economic situation in the engineering trade to-day calls for a good class casting at as low a price as possible. A point here that is of importance—often it is cheaper to buy with an analysis than " to " an analysis.

The drawback with all ordinary pig-irons to-day is the high T.C. content; one hears of this trouble on all sides. The cause of this is perhaps the unremunerative state of the pig-iron trade, which tends to the forcing of the blast furnaces to produce quantity instead of quality. To counteract the high T.C. and reduce the Si., raw steel additions are made in the mixture which lowers the carbon content within the limits required, this latter depending on the cupola conditions.

Very often one hears that the use of steel is condemned because it does not give consistent results. The Author's experience is that it gives consistent results if the cupola practice is consistent. The reasons for using steel are as follows:—Cheapness; slight reduction of T.C.; and its beneficial effect on size and shape of the graphite.

Melting Conditions.

When using steel in the cupola, the blast pressure and volume are very important, especially the latter. Low pressure with big volume is the best practice, and these should be kept constant all through the blow.

The Author uses a 30 in. cupola for the cylinder iron and blow 8 oz. pressure with a volume of 24 cub. ft. per sec., and a coke consumption of 8 to 1, the weight of the charge being 7 cwt. The metal should not be tapped out in small quantities, but as far as possible 2, 3 or 4 charges should be tapped at one time. All of these small details make for consistent results.

Some foundries run down a steel mixture into a pig bed, and then use this in the charge as a hardener. Both methods have been tried over long periods, but using steel direct into the charge gives the best results. The second melting gives the steel (or the steel mixture) the chance to pick up its surfeit of carbon and sulphur. The cylinder charges are made up of 20 per cent. to 30 per cent. steel scrap, No. 3 Scotch iron cylinder scrap and No. 4 hematite—the last-named is used to lower the phosphorous content for liners, pistons and cylinder heads.

Cylinder Metal.

Table I details the analytical results obtained between 16/7/25 and 16/9/25, and will illustrate the usual results for cylinder castings having a thickness of ¾ to 1½ in.:—

Table I.—*Analysis of Cylinder Metal.*

Si.	P.	C.C.	T.C.	Mn.	S.
0.93	0.2	—	3.2	0.56	0.11
1.07	0.23	0.79	—	—	—
0.98	0.2	—	—	0.6	—
0.93	0.2	0.85	3.18	—	0.1
0.93	0.21	—	—	0.49	—
0.96	0.2	—	3.2	—	—
0.93	0.23	0.86	—	0.56	0.12
0.93	0.27	—	3.22	—	—
0.89	0.24	0.9	—	—	0.1
0.90	0.22	0.87	—	0.7	—
0.93	0.2	—	3.21	0.68	0.115
0.90	0.21	0.89	—	—	—
0.89	0.19	0.87	—	0.6	—
0.90	0.2	—	3.19	—	0.1

For thinner castings the Si is brought up to 1 per cent., whilst for castings from 2½ up to 3½ in. thick the Si can be lowered to 0.85 per cent. This is as low as has been obtained having regard to a Si content consistent with producing a machinable casting.

Hardness.

One important test is the Brinell hardness as it indicates the machinability and wear. The Brinell hardness sought, and which gives the best results so far as wear and machining qualities are concerned, is 190 to 195 taken on the liner bore after being machined. The hardness is controlled by a number of conditions other than the combined carbon. The amount and size of the graphite present, the presence of coarsely laminated pearlite or a fine sorbitic-pearlitic structure, all affect the hardness.

The Brinell number may seem low, but according to the claims of Lanz iron, this is about the hardness that is claimed as giving the highest wearing qualities. Personal experience is that up to 200 Brinell hardness, no machining difficulties are experienced, but after this point the speed and feed of the machines have to be reduced.

Representative test bars for transverse and tensile tests cannot be cast separate from the casting as this iron when cast in a cold mould has a white skin and mottled centre. When cast in a dry-sand mould at the same temperature as the casting it represents, it is much harder than the casting, having a C.C. content of 1 per cent. and a hardness of about 220. The best way is to cast it on the casting as near as possible to it with a number of runner inlets from the casting into the bar so as to obtain as far as possible the mass effect and slow cooling of the casting. Thirty-eight to 40 cwt. transverse on a 2 × 1 × 36 in. bar with 0.7 in. deflection can be obtained fairly regularly: naturally the test varies, but the figures given represent an average.

Tensile Strength.

The tensile bars taken from the 2 × 1 × 36 in. machined down to $\frac{1}{2}$ sq. in. area gives an average of 17 tons tensile. All castings cast in this class of iron are cast very hot: the metal is never held up owing to its being too hot; pouring temperatures taken at various times with an optical pyrometer average 1,380 deg. C. Naturally this metal "goes off" very quickly and requires to be handled expeditiously. Any spare metal is poured into pig so that it will not effect the next tap.

Cylinders.

These weigh from 5 to 35 cwt., and are all rammed up on the large jolt-ramming mould machine, the medium and small sizes of cylinder being rammed up in two halves at one time. These castings have three machined belts in the centre bore. The centre belts are water-cooled, the length of the central belt in the large size of cylinder being 20 in.

The cylinders are cast on the flat, with a riser off each foot and one off the opposite end where the cylinder heads fit on. The job is run on the bottom with two $\frac{7}{8}$-in. round runners; two flat down runners from the joint connecting the two round runners. The metal enters the mould directly under the jacket core in the bottom half mould. One runner through the top part is connected to the bottom runners by means of a cross-gate cut in the joint of the top part. This is made so as to trap any dirt which might enter the runner. This method of running has proved very successful in actual practice.

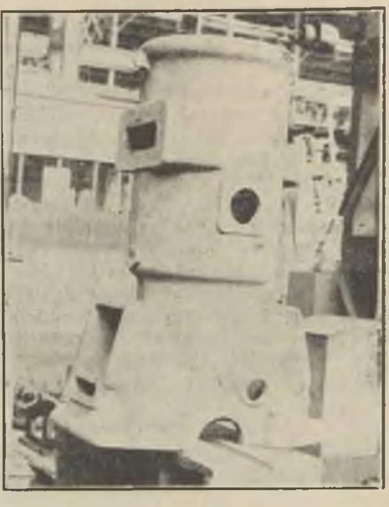

FIG. 3.—CYLINDER CASTING.

The main body-core is not jointed previous to assembling the mould. The bottom-half core is lifted off the core plate, with beam and pulley chains; it is then turned over and placed into the mould. The bottom-half port-cores are placed in position, and the top-half core placed on. The vent from the port cores is taken through the bottom of the job. The air from the main bore core is taken up through the top part.

For convenience in making the two ends of the cylinder secure, the top part is cut away at the back of the prints. Tubes are inserted through the top part into the vent from the main bore core, and the back of each print is rammed up securely (Fig. 3).

Fig. 4.—Assembled Cylinder Mould.

Cylinder Cores.

The main bore cores are made in the usual manner on a cast-iron grid. The grid is so made that the centre bar protrudes about 4 in. outside of the core at each end; this is used for lifting and turning over the cores.

The water-jacket cores are made in oil sand, and are dried and assembled on the main body core before it is dried; by this means the half-core can be blacked complete, so that when dry the assembled cores are ready for the mould. The water-jacket and the belt cores are made on cast-iron grids wherever possible. These cylinders are cast with metal at a very high temperature, and are fed in all cases at the cylinder head end. Figs. 4 and 5 show the set of cores used, the mould as it is assembled, and also the cylinder casting itself.

Cylinder Heads.

Large cylinder-heads are rammed up on the "bumper" moulding machine, only the small types being plate-moulded. The heads weigh from 1½ to 9 cwts., and are made to a number of different designs. In all cases the surface to stand the explosion is cast face-up, which may appear to be a risky procedure, but with proper attention to methods of gating and pouring exceptionally good results have been obtained. The difference in the cost of production between the method used and, on the other hand, of casting the explosion-face-down is very large when the large numbers made is taken into consideration. Moreover, the purely foundry risks are much greater by casting face-downwards.

FIG. 5.—CYLINDER CORES.

The method of running all cylinder-heads is based on the idea that the position of the runner is such that in the event of dirt or dross entering the mould it will be situated where it is of least importance. In all cases when deciding the best position for a runner it is always safest to assume that a certain amount of dirt will find its way into a mould, and so place the runner that it is located if possible in a position of little importance.

All cylinder-heads are run at the bottom, with as small a runner as possible consistent with filling the mould at the correct speed. The runner is placed as far as possible away from any thick sections or bosses, as often a badly placed runner is the cause of a casting leaking under the water test. These castings have been exceptionally free from shrinkage trouble and blow-holes, largely due to the use of hot metal and slow running.

When it is considered what heavy impact and high flame-temperatures these cylinder-heads have to withstand when running in the engine, the importance of this casting may be realised. The force of the blow between the top part of the piston and the cylinder head of an engine having an 18 in. diameter is about 20 tons, occurring 350 times per minute with a very high explosion temperature.

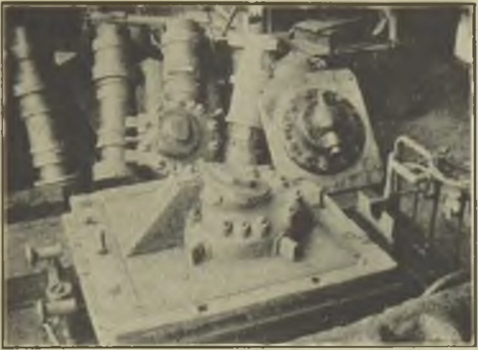

Fig. 6.—Cylinder Head on the Moulding Machine.

Head Cores.

All cylinder-head cores are made in oil sand, and thin cast-iron grids are used in all except the very small sizes. In most of the water-jacket cores four round arms are provided to bring off the vent and support the core in the mould. These four points are the only places where the jacket-core cuts through the outside wall of the cylinder head. Figs. 6, 7 and 8 show the various forms of cylinder heads with their cores and the moulds as prepared for casting.

Cylinder Liners.

These liners are of two types; one is the ordinary straight liner for the four-stroke engine, and the other is for the two-stroke design having two nests of ports, or a continuous row of ports all round the circumference of the liner, thus acting as inlet and exhaust ports. The latter design, with two nests of ports, constitutes the great part of the output being described, and these liners weigh from 2 to 12 cwts. each. (Figs. 9 and 10.)

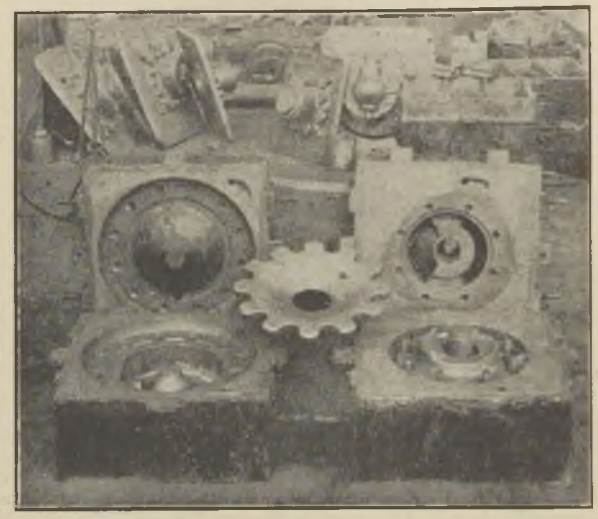

FIG. 7.—CYLINDER HEAD MOULDS.

The liner pattern is in halves, and is so constructed as to form the runner basin and the two top runner-inlets. The box-parts are cut away at one end to fit the runner head on the pattern. In the bottom half of the mould a bottom runner is made, the idea of which is to form a combination of top and bottom runner.

The port cores are placed in the green mould and set in position with gauge sticks, and then dried in position. The moulds are taken from the stove and closed as soon as possible, so as to keep the moulds warm. The aim is to cast the metal into the moulds while they are still at about 90 deg. C., although this temperature varies a little, but it is always between 80 and 100 deg. C.

The two top runners are plugged, and a piece of block tin is placed over the bottom down runner. When the liner is being cast the tin holds up the molten metal for a sufficient length of time to fill up the runner basin with the molten iron. Before the two top plugs are lifted a certain amount of metal is allowed to enter the mould, after which the top runners are opened.

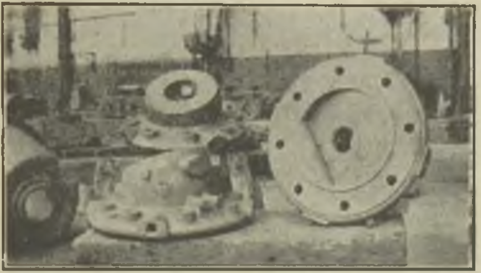

Fig. 8.—Cylinder Head.

Principle of the Runner.

When sufficient metal has entered the mould through the bottom runner as shown in the illustration (Fig. 11), the two top plugs are lifted. The two streams of metal from the top runners drop between the two rows of port cores, this having the effect of breaking up any accumulation of dross or dirt on the top of the metal already in the mould, and draws this away from under the port cores (as shown by the arrows), and so brings it up between the port cores as the mould fills, and thus up to the sullage head instead of lodging below the cores. A number of different methods were tried before this method was adopted as standard for this type of liner.

For liners with a continuous row of ports all round the circumference the same type of runner is used, but with the following difference: the bottom runner is used to fill the mould up to a level above the ports before the top runners are opened.

Trouble is sometimes experienced with the liners having two nests of ports. The ports practically cut the casting in halves, excepting the two fairly narrow partitions between the inlet and exhaust ports. In these two places, shrinkage sometimes occurs owing to the casting below the ports taking the metal to feed its liquid shrinkage from it. The design of this type of casting would naturally lead one to expect shrinkage trouble at these two points, but it has been found that the problem is a purely metallurgical one, and only evinces itself when the phosphorus content of the iron is too high or the total carbon below 3.1 per cent. It is a peculiar fact that this design of liner would be very difficult to produce in an ordinary foundry iron without resorting to denseners on account of the shrinkage at these two points. Figs. 9, 10 and 11 show the liner mould, the finished casting and also the method of arranging the runners.

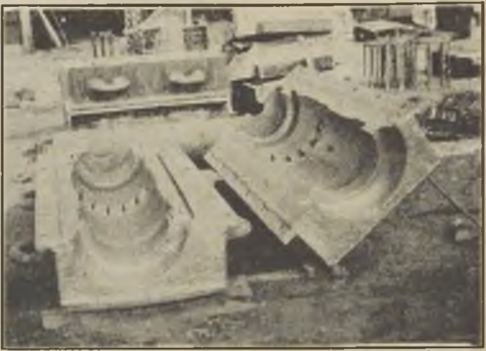

FIG. 9.—LINER MOULD.

Pistons.

These may weigh from 2 to 10 cwts. each. The large sizes are moulded from a pattern made on the same lines as the liner pattern, the runner head and runners being made a part of the pattern. The method of moulding is the same as the liners, *i.e.*, made on the flat and then turned up for casting vertically.

The runner is formed so that there are two gates from the runner head, each feeding a radial runner in each half mould. From these two radial gates a succession of small inlet runners are made all round the circumference of the piston walls, except over the gudgeon-pin boss cores. This type of runner breaks up any dross or dirt floating on the top of the metal which is apt to lodge in the mould during its passage up into the sullage head. The runners are kept very small so that when pouring the job, no difficulty is experienced in keeping the runner full of metal.

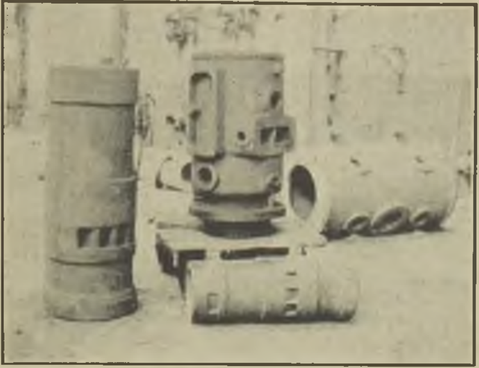

FIG. 10.—CYLINDER AND CYLINDER LINERS.

The cores are made in halves on cast iron grids with a thick prod to carry the gudgeon pin core. The half cores are jointed while warm and placed straight into the mould. The gudgeon pin cores take the weight of the core while the mould is being closed, but when the mould is turned up vertically for casting the core requires to be supported. To take the upward lift when the piston is cast, a bar 2-in. square is inserted through two wrought-iron eyes, one in each half box part and through the two half core grids which protrude through the end of the piston core. Wedges are placed in where required to keep the core steady.

Smaller pistons are made by a different method; the pattern is a solid one and is made to mould vertically. The core is supported and located by a wide and deep tapered print. On the underside of this print a circular runner is made with a number of small inlet-runners into the walls of the piston. To connect up the circular gate, a down runner is made through the print of the core. No top part is required by this method. A narrow plate is placed across the top of the core and cramped to the lugs of the box part to take the lift of the core when the piston is being cast.

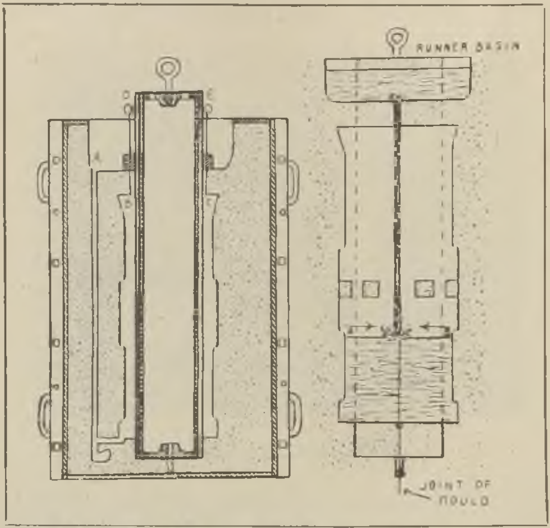

Fig. 11.—Method of Running Liners.

The only difficulty occasionally experienced with pistons is a small accumulation of dross which lodges directly above the gudgeon pin core, at a point where the piston tapers down rather suddenly at the skirt. It is not possible to place runners at these two points, as the metal would drop on to the gudgeon pin core which would likely cut up badly. A well-known piston trouble which does not manifest itself in this case is shrinkage in the gudgeon-pin bosses, on account of the kind of iron being used which obviates that particular trouble.

Figs. 12 and 13 show the piston mould and cores, and also arrangement of core lift and support, and the final casting.

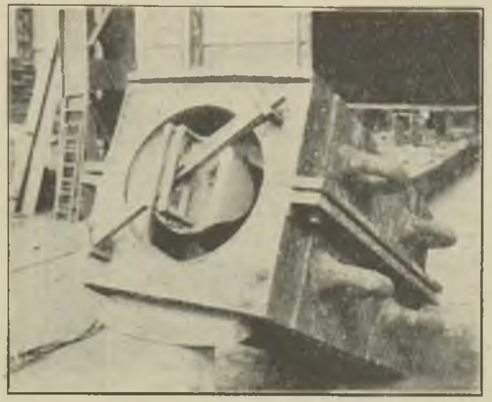

FIG. 12.—PISTON MOULD.

Mould Temperature.

The mould used for casting the more particular items of castings made in improved cast iron are not pre-heated to any special extent other than the ordinary drying process. Moulds are closed and cast as soon as possible after leaving the drying stove. In this way the mould temperatures may vary between 80 and 100 deg. C. To take an example of a large liner weighing 12 cwts., the casting having an average thickness of 1½ in. of metal, the mould temperature is about 95 deg. C. No cylinder iron is cast into a perfectly cold mould, as with the character of the metal used the resulting casting would not be commercially able to be machined. Too low a mould temperature is indicated by hard metal in such places as the edge of bosses or any section of the casting which protrudes from the main body of the casting. Taking the liner casting just named, which would be made from metal having an analysis of silicon 0.97, phosphorus 0.2, manganese 0.6, and total carbon, say, 3.2 per cent., even although this casting made in the warm mould would be perfectly grey, the runners are very hard, and vary from white to mottled in fracture. The bottom runner from the runner head down to within 2 in. of the actual casting is only 1 square in. in section.

Fig. 13.—Piston Mould.

This runner fracture is often taken as a quick and rough guide to the result of the previous day's mixture.

Gating.

The Ronceray method of gating is used in many of the small, highly-machined castings which have to withstand high pressures, hot fuel-oil at a pressure being the liquid which many of the castings have to withstand. This method of running has been the means of curing much shrinkage trouble in small castings, such as air-valves, air-valve starting bodies, oil pump-bodies, atomiser-bodies and sleeves: in fact any casting where a perfectly solid casting is essential.

This method cuts out a great deal of rod feeding, besides giving better results than can be obtained by rod feeding. Rod feeding is often not a practical proposition when one has a large number of such jobs to cast at one time. One job in particular, of which large numbers are made is a small air starting-body. The casting consists of four bosses, two of them round and two oval, which form a small solid body. The casting is faced on each boss and bored four ways to the centre with a valve seat in the centre of one bore. The job is moulded four in a 12-in. box part, and often a dozen boxes are cast at one time. To feed all these would not be a practical proposition.

Engine Beds.

These are made to take from one to six cylinders in the largest size, and one to four cylinders in four other sizes, *e.g.*, marine and land type. The weight of the beds may vary from 8 cwts. to 8 tons. All the sizes up to four cylinder are rammed up on the bumper moulding machines.

In all the beds the bearings are water-jacketed, and owing to this class of engine being arranged for crankcase compression, the crank-well must be air-tight. The method of running the beds is the same in all cases, but the position of the runners varies a little with the size. Up to the two cylinder size in all cases the beds are run at the fuel pump extension end. All the beds above that size are run along the side, the number of runners varying with the length of bed.

The runner inlets are placed at the bottom of the mould, and down runners from the joint connect up with these. The moulds are cored up previous to being dried. Vents can be made secure and the mould can be finished and made a much cleaner job this way than by drying the mould before coring up. The back of the beds is formed entirely of cores, and these are bolted into a top core-print which is the same size as the bed-pattern. A four-cylinder bed-mould contains sixty cores in its construction, the casting itself weighing five tons.

Bed Cores.

The bed cores are all made with cast-iron grids. The bearings and water-jacketed cores are made in oil sand and the others are made in ordinary core sand.

Water-cooled Silencers.

These are of two types, cylindrical boiler form and box type. These are made in single, double and triple for all sizes of engines.

The largest size is 9 ft. long and 2 ft. 9 in. in the bore, with three tangential branch connections and a 4-in. internal flange at each end. This type is used for a 3- or a 6-cylinder marine type of engine. The job is moulded in halves on its flat, and then turned up into a vertical position for casting.

A bottom runner is used in conjunction with top runners. The top runner is cut around the print of the main bore core, with a succession of small ingates all round the bore except directly over the branch cores. The bottom runner is opened first so as to allow metal to enter the mould and act as a cushion for the metal dropping down from the top runners.

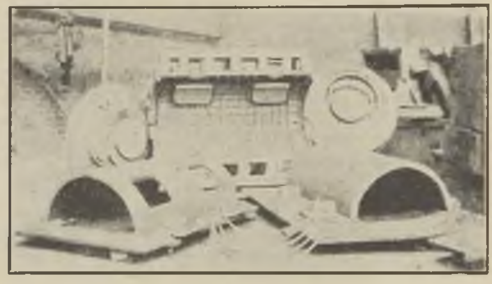

FIG. 14.—WATER JACKET CORE.

The water jacket cores are made on a built-up grid, consisting of light cast-iron segments wired up to a wrought-iron rod running the length of the core. The small sizes are made in oil sand and the large ones in loam sand. The cores made in loam sand do not need bedding out; the core is turned out on a flat plate in the usual way. To avoid any chance of the core opening out with its own weight while drying, two binding wire stretchers are strained across from the tips of the cast iron grid segments previous to the core being turned over.

Assembling the Moulds.

After the mould has had one night's drying, the branch cores and the half-jacket cores are placed in position in the mould. The top half-jacket-core is wired in position at the back of each of the four core-prints. By this method the vents can be made secure, and core-prints made good. After the mould has been stoved again, the barrel-core is placed in and the mould is closed. One point which must be carefully watched when this method is used is that a "touch" is made where the top and bottom half-jacket-cores meet, as it is difficult to chip out any fins which may form at that point.

Fig. 14 shows the water-jacket core and grid, as well as the finished silencer casting.

Flywheels.

All flywheels up to 7 ft. dia. are machine-moulded from a half-pattern. The wheels are of the disc type with a solid rim for electric type and a recessed rim for standard type. The recess in the rim is formed by cores, six of which are placed in the bottom half and six in the top. A fairly wide print on the pattern gives the core a good seating. The cores are made on a cast iron grid segment, and are placed in the mould in the green state. After the pattern is drawn from the bottom half of the mould, the barring hole cores are placed in position, and the rim finished and blacked. The cores are then placed in position, and the whole finished and blacked. Very much the same procedure is gone through with the top half of the mould. Extra machining is allowed for by using wood segments round the rim.

The wheels are run on the rim by three flat runners about 6 in. apart, so that the metal drops down into the rim of the wheel so as to miss the recess cores. The risers are taken off the rim. The recess cores in the top half-mould are held in position by hook bolts. Twelve holes through the top part are arranged round the core print. The hook bolts are hung on to the wrought iron eyes cast in the grid previous to the cores being placed in position.

After the mould is dry, the bolts are tightened up to fish plates. This method of putting the green cores into a green mould has proved to be the cheapest and cleanest method of mould-making. Dry cores have been tried in a green mould, and dry cores in a dry mould, but both these methods are not only more expensive, but they do not produce such a clean casting.

A 4-cylinder bed casting weighing 3 tons 5 cwts. is made on the moulding machine, the dimensions being 14 ft. by 6 ft., with a lifting capacity of 12 tons. Another size of moulding machine measures 7 ft. 6 in. square, on which all flywheels up to 7 ft. diameter are made, taking up to 10 tons. Four smaller machines range from 4½ ft. square down to 3 ft. The type of plate pattern used for plate moulding is in most cases a half-pattern on each side of a wood board having jigged brass bushes in which loose pins are used.

DISCUSSION.

Grey Castings with White Runners.

The Chairman (Mr. J. Masters) said the Council was to be congratulated on having secured the services of Mr. Richman, and induced him to put before the members the results of his investigation of an important subject, on which there had been a fair amount of discussion during the last few months. He had given them much food for thought.

Mr. Richman had made reference to what were termed freak fractures, the test bars coming out white and the castings quite grey. He had had a similar experience, more especially in castings that were run slowly. In one case, with a casting weighing about three tons, they were trying to get the pearlitic structure, and examination under the microscope showed that they had been very successful. Yet every runner that was broken showed the white iron. In other respects everything was satisfactory.

In connection with the running of the cylinders a point which would appeal to those members who are interested in the manufacture of internal combustion engines was that Mr. Richman ran the cylinders on the flat. In the Manchester district most people cast them on end. If Mr. Richman had cast them in any other way than flat, perhaps he would tell the members what his experience had been.

Pencil Runners.

The Ronceray method of running had been mentioned. Without doubt in some castings this was essential in order to get good results. He had himself made many experiments with that particular type of runner, and found that was the only way; there was no feeder, and no riser, yet everything came out satisfactorily, there being not a single reject out of 150 made. The casting weighed 1½ cwts. The runner was ⅜ in. diameter.

Fracture of Runner as Quality Index.

Mr. Richman said the size of the bottom runners on the liners were all a standard size, and, from examination of the fracture of these runners, one could get a good idea of the result of the previous day's cast. If the fracture of the runners were white, gradually merging into a mottled centre, they knew they were right; if it was white right through they were a bit dubious as to the machining qualities of the iron; if they were grey they knew it was slightly soft.

The casting of cylinders on the flat may seem contrary to the usual practice, but when the method of running, the position and size of runners, and casting temperature were all correct, no trouble was experienced. It was found that the slower the running and the hotter the metal, the better the results. The difference in the cost of casting on the flat from casting vertically was very great. Probably the latter method would cost quite 50 per cent. more than the former.

Mr. Masters had mentioned the Ronceray runner. The speaker used this type of runner on a number of castings. He himself, for very small castings used a ¼-in. runner, but he did not put it near the bottom of the casting. In a number of Ronceray castings a small runner was put right at the bottom. Well, if the runner was put near the top so that the runner was practically bonded through the casting, one could use a smaller runner. But with it, in order to get the best results, the job had to be very carefully watched; it must not be left to the men. That was the only drawback in the Ronceray method.

In a number of castings, which would otherwise have to be rod-fed, the results were satisfactory. A $\frac{1}{4}$-in. round wound runner was used, being placed at the top of the casting. In order to obtain the best results, such jobs have to be very carefully supervised to ascertain that the metal was very hot.

High and Low Phosphorus Iron for Liners.

Mr. A. L. Key asked whether Mr. Richman could give any definite data as to the relative values of high-phosphoric iron and low-phosphoric iron for liners. Mr. Hurst went to a great deal of trouble to acquire information which, according to that authority, proved conclusively that high-phosphoric iron gave the best wearing properties on account of the phosphoric nodules standing out all along the line. He himself (Mr. Key) had worked along those lines, the phosphorous content being above 1 per cent., and they had no trouble with the liners; but whether his liners were better than others in which the phosphorus was at a minimum he could not say, and he would be very glad to know what data Mr. Richman could give as to what was the best wearing material for liners. The majority of people considered that the harder it was, the better it would wear, but one read accounts of cases where relatively soft material had given better duty than the harder material.

Mr. Richman had suggested running cylinder liners slow and extra hot. He himself had made thousands, and found that hot metal was essential—one could not get a good liner without it—but in his opinion he had proved that the quicker they could get it in the better the results.

Thyssen-Emmel Iron.

Mr. Richman had told them of a bar of Thyssen-Emmel iron which stood a test up to 45 cwts. In his own experience a bar of similar analysis was tested, and the machine would not break it at 49 cwts.; they then used a bit of leverage, and it broke. Had Mr. Richman any record of the deflection of his Thyssen-Emmel bar?

Mr. Richman replied that he had not any figures relating to the influence of phosphorus on cylinder liners. He could only generalise from experience. In the liner castings he had shown, one could easily imagine that the port bars on the exhaust side of the liner had to withstand a very high temperature. If the phosphorus was high, the bars would crack.

Mr Key having concurred, Mr. Richman continued by stating that, with a number of cylinder heads, pistons, etc., his experience was that the cause of the trouble could be traced to high phosphorus every time. He was not insisting that his methods were unassailable, but his conclusions were based on practice. In saying that he could not imagine anyone who had experience of internal combustion engine castings insisting that the phosphorous content was unimportant. He found that the liners must be run at a certain speed, as the effect of the runner was lost. The object of the runner was to draw the dirt away from under the port cores to the wall separating the two nests of port cores and so up into the sullage heads.

The Running of Liners.

Mr. S. G. Smith said he had not recently been in contact with practical work to the same extent as some others in the audience, but he had a fairly long experience of castings of this kind, and he had been up against the troubles which Mr. Richman experienced. They had to be solved, and while he did not know that he had always adopted the best method, he had at all events arrived at a solution, which was the chief thing.

They knew that the Lanz iron was made in hot (500 deg. C.) moulds. Mr. Richman had also told them about the Thyssen-Emmel iron. He did not know, and therefore would ask Mr. Richman the question, whether the metal was cupola melted, and a special mixture. Was that also run in hot moulds? The temperature usually adopted by Mr. Richman was an easy temperature. Another point on which he desired information was whether in any of the castings which had been shown denseners or chills were applied to the heavy parts.

The method of running the liners which had been depicted was used in some of the foundries in the Manchester district. But why did Mr. Richman open out the top runner before the metal reached the ports in one case and in the second allowing the metal to come over the ports before he opened out the top runner? It might be an advantage to do it in that way, and Mr. Richman might have a special reason for it.

Experience with Thyssen-Emmel Iron.

Mr. Richman said it was claimed for the Thyssen-Emmel method that the metal could be cast in a cold mould. The bar he had examined looked as though it was a green-sand casting. It was a $1\frac{3}{8}$-in. bar, and gave as much as $26\frac{1}{2}$ tons tensile. Certainly there was a considerable scope for this Thyssen-Emmel iron. In the future their own line of experiment was going to be on the lines of altering the tuyere area, the blast pressure, the volume of air, and try to lower the total carbon and raise the silicon content. That would come more into line with the Thyssen-Emmel iron.

Low-Carbon Cast Iron.

The low total carbon was a feature of their cylinder castings, which were very free from shrinkage trouble. Buchanan always insisted that if one had a No. 4 fracture with this type of iron it gave less trouble from shrinkage than any other iron. He thought Mr. Smalley's researches proved the same thing, that with the pearlitic structure, for that was what it was, it gave a least minimum shrinkage. With their 3.2 total carbon, if they lowered that total carbon slightly they induced shrinkage troubles. Whether that was because they ran so low in silicon he could not say, or whether they could raise the silicon and lower the total carbon and still get good results. He thought it was possible; in his opinion those were the lines on which great success would be achieved.

Influence of Chills.

He had never been partial to chills. They cured the trouble in one place, but it appeared somewhere else; it was only shifted or spread out over a wider area. With their iron one could not use a chill, as it would produce a white fracture. He remembered a case where hard spots occurred at the same place on liners time after time, and he found out that the box part was just touching the casting, and it struck a $\frac{3}{8}$-in. chill, just the shape of the wedge end of the bar in the box. It was a $\frac{3}{8}$-in. chill into a liner $\frac{3}{4}$ in. thick.

Mr. Smith had asked why he opened the top runner when the metal was below the ports, and his methods when the ports were situated all around the liner. The object of the runner was based upon drawing away the dirt from underneath ports, but when the liner had ports all the way round there was no place to drop the metal down, so that the bottom runner was used to fill the mould just above the ports before the top runners were opened.

The Influence of Hot Moulds.

Mr. Poole (Keighley Laboratories) asked whether the pearlitic structure depended upon the temperature of the mould. Would 100 deg. make all the difference?

Mr. Richman insisted that it would make all the difference. Suppose for some reason or other the temperature dropped. When such a casting got into the machine-shop the edges of the bosses or any protruding part of the casting were hard, and usually had to be ground off. That was quite all right, but it showed what one got from a warm, yet insufficiently warm, mould, and they could imagine what they would get with a cold mould. He had never cast with a cold mould, so he could not say exactly what happened, but his experience was that if test-bars were cast in a mould at the same temperature as a liner casting, the bars were white right through, so that it was a pretty foregone conclusion what the casting would be like if the mould were cold.

Making Low-Carbon Cast Iron.

Mr. Brierley asked how Mr. Richman proposed to get iron with the desired proportion of total carbon, that is, not exceeding 3.2 per cent. from hematite pig-iron which contained 4.25 per cent. total carbon. Did he use a special cupola for melting the cylinder iron? It was not easy to imagine that he was melting this special iron with common iron in the same cupola; otherwise a good percentage of the special iron would be spoiled by high phosphorus. Were the combined carbon figures in the analyses the percentages in the castings themselves, the liners, or were they the percentages in test-bars?

Mr. Richman said the 3.2 per cent. was not very low when one remembered that Mr. Young had 2.8 per cent. He might say they did not use any foreign scrap; it was cylinder scrap. The one drawback was that they did not get enough of it to carry on from day to day. Their first charge they always ran down into a pig. If they were very short they ran down two charges, or three charges; so that they started with a scrap which was very low in total carbon, the steel, and the cupola conditions were regulated to give this. Very often they ran an ordinary iron after the cylinder iron was cast up. If they put on more cylinder iron than they wanted and the phosphorus in that was not too high, they used it as cylinder scrap. If they had a suitable casting, a dry-sand job or similar work, they generally put it in there to get rid of it. That was how they got over the trouble of parting the charges. They had tried putting in an extra deep coke charge, but the total carbon increased straight away. It had been proved conclusively that a thick coke charge would give high total carbon directly after the incoming charge.

In all cases the combined carbon was taken from liner borings. There was a roughing cut through, then a reamer cut, and these were taken off the reamer cut. It was only fair to take the combined carbon in the borings. If the combined carbon was taken from the test-bar and in the liner the percentage was 0.85 in the liner, and probably nearer 1 per cent. in the test-bar.

Answering a further question, MR. RICHMAN said the mould was about 90 to 100 deg. C., which was not very hot.

Working Conditions.

MR. KEY put this question, supplementing what Mr. Brierley had said. Supposing Mr. Richman wanted three tons of special iron, how much would he consider he was safe in charging so that he would not get the contents of the softer material following? It was a very difficult matter to separate charges. If the charge of the mixture was put on and then taken away in sections there were wide variations, not in the actual analysis, but in the degree of hardness. In this connection Mr. Key referred to his own experience with a mixture containing about 60 per cent. steel, 10 per cent. hard iron, and 30 per cent. soft iron. One part of the casting had to be so hard that neither a chisel, file nor hammer could make any impression on it, the rest had to be machinable. The weight was 6 cwt. They could not get the metal hard enough for the purpose by charging at the commencement of the blow, for just a little bit of metal from the succeeding charge spoiled it. By charging up this mixture after the day's blow and adding the ordinary coke charge they obtained what they sought, that was 0.7 silicon and 0.15 per cent. phosphorus.

MR. RICHMAN replied that one charge was used more than was required, but they did not drop into very common iron; they changed into iron with 0.8 per cent. phosphorus. They had to be very particular, because there were a number of different thicknesses, and they had to soften off gradually. In cylinder heads the phosphorus must not be high, and they kept a careful watch upon the phosphorus.

Taking Test-bars.

MR. KEY asked whether the test-bars were taken out each day practically from the same position in the blow? Had Mr. Richman tried taking a succession of test-bars from the furnace and analysing them?

MR. RICHMAN: He never used the first tap.

MR. KEY: Take the first metal you use. Say you take a ladle full for two or three liners, and then you take another ladle away and cast some more. Have you tried taking a succession of test-bars from each tap?

Mr. Richman: No.

Mr. Key thought there would be a remarkable inconsistency in the figures from one blow. He would like the author to make that observation.

Mr. Richman said for a large-sized liner they sometimes cast the bars first, second or third tap. He did not take the trouble to ascertain what tap it came from; if the mixture was right, that was all that mattered. The results he had given were not from test-bars, but from the liners.

Mr. Key said his experience was that from the first ladle taken away they could get a fairly good consistent analysis, but if they took three ladles out of that one blow the analyses would vary, because if steel was being used and was put on the first charge the steel would come through first, and the first ladle would be much harder than the succeeding ladle.

If three liners were cast from the first ladle they would have the same analysis, but if from another ladle they would be different.

Mr. Richman insisted that it was preferable to take away metal in large quantities, the bigger the quantity the more consistent were the results.

In answer to a question by Mr. Smith, the Lecturer pointed out that there are foundrymen who state they can obtain cupola metal carrying 2.8 per cent. carbon.

Mr. Key: We frequently have pig-iron with 2.8 total carbon.

The Chairman: 2.8 total carbon has been obtained on several occasions when we were not altogether conversant with pearlitic iron.

Mr. Smith: Put through the cupola?

The Chairman: Yes; put through the cupola and cast in moulds.

Vote of Thanks.

Mr. J. S. G. Primrose proposed a vote of thanks to Mr. Richman for his Paper. It could be regarded as a model for future Papers to be read before the Branches; it was an admirable combination of metallurgical theory, with an exposition how to put it into practice.

In seconding the motion Mr. H. Sherburn remarked that apparently the question of pearlitic cast iron was going to take a prominent place in the deliberations of the Institute, and they would look forward with interest to Mr. Richman's contribution to an aspect of importance in foundry practice.

The vote of thanks was carried unanimously.

In replying, Mr. Richman remarked that he had to thank Mr. Primrose for the micrographs and lantern slides, and Mr. R. H. C. Weekes for the analyses cited.

London Branch.

MACHINES IN NON-REPETITION FOUNDRIES.

By G. Edgington, Member.

In introducing this subject of "Machines in a Non-repetition Foundry," it is probable that foundrymen always associate moulding machines with the production of large quantities of repetition castings. But competition is so keen in these times that founders are turning their attention to machines that will help to produce bigger and more varied types of castings. Already great strides have been made in this direction, which has materially helped to reduce the cost of castings to the customer. Also the skilled moulder is losing some of his conservatism and taking more kindly to these machines, which are helping to cut out some of the drudgery of his trade.

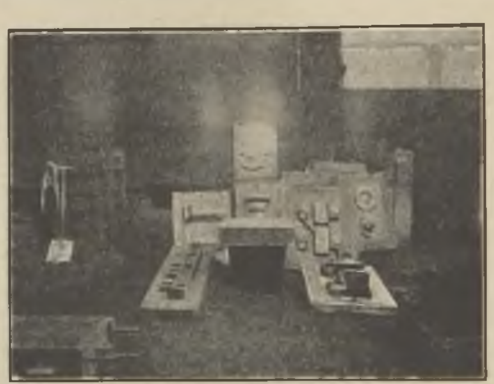

Fig. 1.—Showing various Pattern Boards and Type of Jolt Machine used.

The need is becoming greater for the use of machines, as really skilled moulders are getting more scarce as time goes on, and it is therefore essential that machines which can be operated by semi-skilled men after a few weeks' training should be more widely used to meet foreign competition.

The foundry in the past has been badly neglected by the engineer, but the signs are that more attention is being given in this direction, and mechanical appliances are being introduced in many forms. But even in these times one frequently hears practical founders say that their's is a jobbing shop, and therefore can find no use for moulding machines, as the class of work they are producing is too varied, and not enough off to warrant the use of machines. It is not proposed to enumerate all the different types of machines in use at the present time, but to show what the Broadoaks foundry is doing, which may possibly be of some interest and help to those who have not up to the present time given this matter serious consideration.

FIG. 2.—SHOWING A FEW PATTERNS FOR STEEL CASTINGS.

There are numerous kinds of jolting machines, all of which are claimed by their different makers to be the best, but the author is of opinion that the best machine is the one constructed on simple lines, and which gives greatest service and efficiency without being in the fitters' hands one or two days each week. The plain jolt machine, without any turning-over gear or other complications is the one which is favoured at the Broadoaks works. This being a non-repetition shop, is best served by a machine whose only operation is to ram the sand. There are eight machines (Fig. 1) with 6-in. dia. cylinders, the lifting capacity being about 12 cwts., and the table 24 in. × 18 in. The method employed is to have several jobs on plates (Fig. 2), operating simultaneously. For instance, while the operator jolts up one box, a man or boy, according to the job, draws the pattern, so that the machine is kept ramming all the time, and as long as required. From Fig. 3 it will be noticed tnat the boxes have fairly long pins, and this keeps the pattern quite steady and ensures a good draw. These pins have a slot through which a cotter is passed, and this serves to fasten the box down to the pattern board whilst it is being jolted.

Fig. 3.—A number of Moulds showing the Long Pins used with Cotter Holes.

By not having a pattern-drawing arrangement on the machine the necessity is eliminated for machined boxes, which are a considerable cost on the foundry. For making the moulding boxes the jolting machine is also used. This gives them very good faces, which in many cases are almost as good as machined ones. An arrangement (Fig. 4) which has been found to work satisfactorily is to put the hand boxes on benches. The men are able to stand up to their work, and are much more comfortable, and work better than when kneeling in the damp sand on the floor. It is not wished to discredit in any way the excellent arrangements on some machines which are doing the same jobs day by day for weeks at a stretch. There is much to be said for them, but it seems desirable to emphasise that good work can be obtained from jolt machines without any expensive tackle being first prepared. This will best be illustrated by illustrations of bigger machines in use in the Broadoaks Foundry.

FIG. 4.—SHOWING THE ARRANGEMENT OF BENCHES FOR HAND BOXES INTRODUCED FOR THE PURPOSE OF ELIMINATING THE KNEELING OF MOULDERS IN DAMP SAND.

There are two large machines, one with a 20-in. dia. cylinder, capable of lifting 8 tons, another with 16-in. dia. cylinder, which lifts 5 tons, the tables being 6 ft. square. This does not mean that anything longer than 6 ft. cannot be rammed, as frequently boxes are used up to 12 and 14 ft. long. Around these machines there are a number of plates of various sizes to take different sized jobs. These have a series of tapped holes 1 in. dia. pitched at equal distances around the edges. This allows the putting of various size boxes on the same plates, and at the same time ensures being able to fasten down the box. The plates have machined faces, and when the jobs come off the machine they present a perfectly true joint, and the moulder has only to draw the pattern. If the job has several off, dowel pins are located along the

Fig. 5.—Here the Patterns are Mounted on Plates previous to the Boxes being Placed over them.

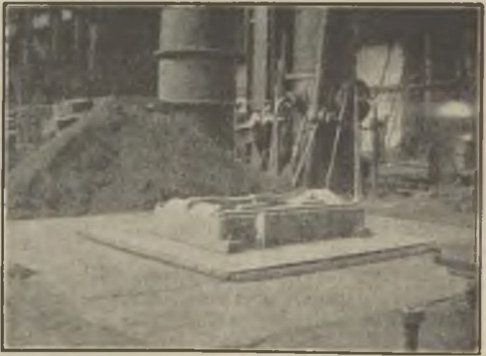

Fig. 6.—A Pattern Mounted on the Plate Ready for Receiving the Box.

centre line of the plate, and the patternmaker has jigs, which suit the different lengths of patterns. In most cases no locating pins are used where only one or two castings are required. The two half-patterns are set equally in the box top and bottom. Then before the core is put in the bottom half of the mould the top is set accurately over it and either pinned or marked. The core is then put

FIG. 7.—A MOULDING BOX BEING RAMMED ON THE LARGE MACHINE.

FIG. 8.—SHOWING A HALF PATTERN FOR AN ADAPTER CASTING.

in and the cope replaced to the marks. To work this machine there is what is called a machine squad, which consists of two moulders, or three when busy, and three labourers. The pattern is placed on the plate, the labourer puts on the box, and whilst the moulder is putting in lifters or looking after parts requiring special attention, the labourer fastens the box down to the machined plate with clips and screws. This is then put on machine, and the other labourers then fill up with sand and ram the job. By this time another job has been prepared by the moulders and is ready for the machine. This continues, and as the moulds come off the machine they are handed over to the men in the shop who draw the patterns and finish the mould ready for casting. By having these various plates the machine is not kept standing, and therefore much more work can be done. The several illustrations will illustrate the above (Figs 5 to 10).

Fig. 9.—Showing Two Half-moulds for an Adapter after being Rammed.

This cylinder (Fig. 11), weighing 11 tons, as cast is 36 in. dia., bore 11 ft. 6 in. deep, with head, is rammed up on the big jolt machine, the boxes are made in sections 24 in. deep, and when full of sand are just under the lifting capacity of the machine. The patterns are dowelled on to a machined plate, and the boxes are pinned to centre lines, which are also used when assembling the job. After ramming the sections, which make up the bottom half of the cylinder to the centre

Fig. 10.—Moulds Made by the Large Jolt Machine.

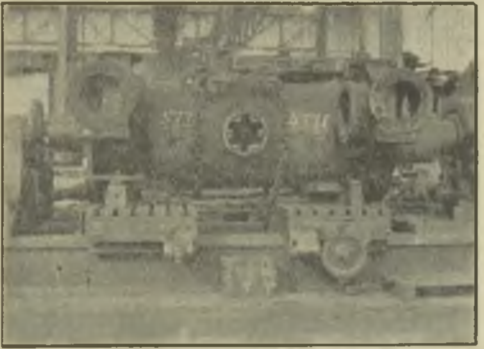

Fig. 11.—Showing Cylinder Casting.

line, the plate is then turned over, the same holes being used on the other side of plate. This allows for no discrepancy, and the job comes together accurately when being assembled. Before adopting this method, these cylinders were swept up in loam, and the valve boxes set as the moulders bricked up the job.

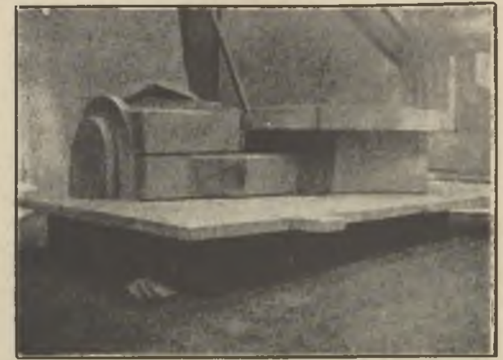

FIG. 12.—COMMENCEMENT OF MAKING A CYLINDER, SHOWING THE FIRST PIECE OF PATTERN MOUNTED ON THE PATTERN PLATE.

FIG. 13.—PARTIAL ASSEMBLY OF THE MOULD.

It will readily be understood that it gives a much more accurate casting, and the cost is reduced very considerably. Some of the moulders do not use a rammer during the day, they draw patterns, finish, and assemble the moulds. The moulder who has not to use the rammer becomes more adept at finishing his work, therefore doing it quicker and cleaner. Better castings are produced by the use of jolt machines, being more true to patterns, also what is important, are less liable to scabbing, as the machine rams more uniformly than when it is done by hand, as scarcely two moulders ram alike.

Fig. 14.—Showing the Mould in the Pit, with the Cores in Position Ready for the Top Part.

The Sand Slinger.

The Broadoaks Foundry has now another machine, which is a considerable asset to its equipment, as it has installed one of the portable types of sand-slinging machines. This is proving very useful, and the method followed is to ram deep bottoms on the jolt machine, turn the job over, and put on the top part or cope, then place it under the sand slinger for ramming (Figs. 15 and 16). It is then passed to shop moulders. This denotes that very little ramming by hand is being done. Certain parts, under bars, etc., are tucked by hand. The pleasing part is, no special rigs are required, being handled by the slinger in the same way as if rammed by hand.

This machine can be taken anywhere in the shop, to the bigger jobs, and is proving very useful indeed (Figs. 17, 18, 19 and 20). The bedframes shown in Fig. 21 are a fairly big job, and

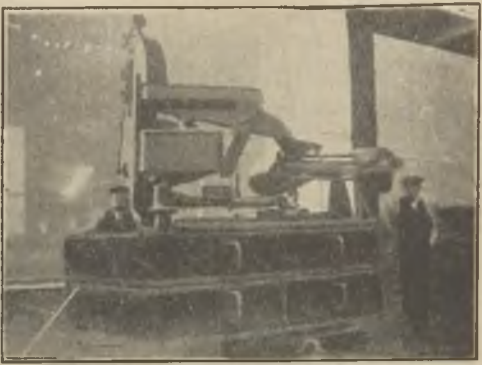

FIG. 15.—SHOWING THE SAND SLINGER AT WORK.

FIG. 16.—THE SAND SLINGER MOUNTED ON A MOULD.

they are made in various sizes, up to 19 tons. The one shown is about 15 tons, its length being about 18 ft., varying according to the stroke of the engine.

FIG. 17.—SHOWING THE SAND SLINGER LIFTED UP TO RAM A LARGE BOX PART.

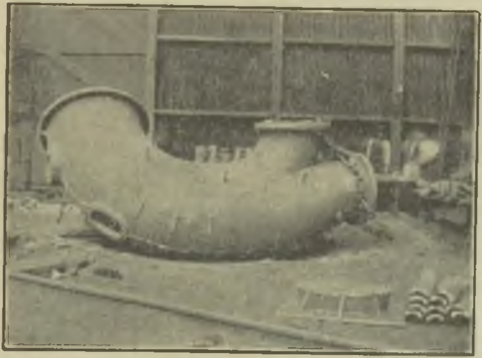

FIG. 18.—LARGE PIPE CASTING TAPERING FROM 42 IN. DIA. TO 24 IN., RAMMED ENTIRELY BY THE SAND SLINGER.

It is about 7 ft. wide, and 5 ft. deep. After the pattern is on its bed, and the ramming underneath is finished, it is usual to bring the sand slinger on the job, and practically the whole of its sides, inside drawbacks, and top-parts are rammed by the machine, which is moved from one part to another as required. A considerable saving in time is effected on a big job like this. When ramming the top parts, which are over 20 ft. long, work is commenced at the end of job, then after the first 8 ft. is rammed the machine is moved along, standing on the part that has already been rammed.

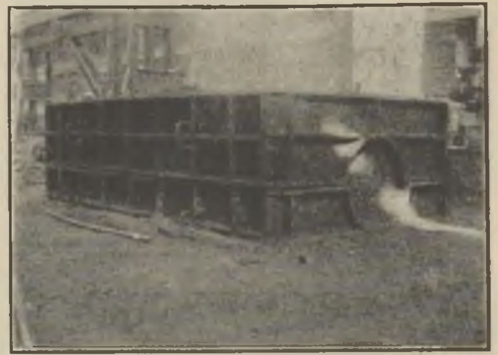

Fig. 19.—Box Parts Used for Making Pipes. Each Part is 15 ft. × 8 ft. × 2 ft. 8 in.

This machine will also ram big cores equally well. In making a large speed-ring, for a hydro-electrical job, where the middle portion was formed with heavy cores, the first set of cores was made in two weeks by four men ramming by hand. The sand slinger was then used for the 2nd and 3rd castings, and reduced the time just by one week, making a saving of 50 per cent. on the time. It has not been possible to get an illustration of this job, but the cores were 5 ft. deep in the deepest part, the diameter of the job 18 ft. 6 in., and weighed 28 tons. This machine is doing very well, and gives very little trouble mechanically. The blades require to be renewed fairly frequently some days, other times they last three or four days without changing. Changing a blade can be accomplished in three or four minutes. At the Broadoaks works, these blades are cast in a chill mould. They are then annealed,

Fig. 20.—Showing Half of a Big. Trunk Guide Mould made in the same Box as the Pipe by the Sand Slinger.

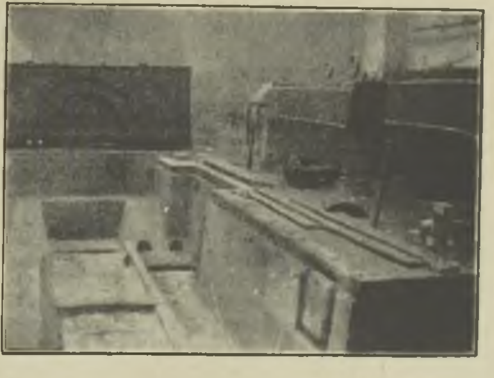

Fig. 21.—Showing Bedplate Mould with Cores and Drawbacks Lifted Out. It has been Rammed by the Sand Slinger after making the Underside of the Pattern by Hand.

and providing no pieces of scrap are put through the machine they give good service, and cost very little. The top cover is also cast on a chill. This gives a nice level surface each time, enabling the blade to be set very close to it, which is necessary and important for hard ramming. The cover lasts about four or five weeks.

Shake-out Table.

Another useful tool, which is of considerable interest is the shake-out table. This machine consists of a table with a cylinder and piston at one end, the other end works in a knuckle joint. On this table the boxes are placed, after casting, for knocking out the sand ready for use again. They are picked up by the crane, shaken out on the table, then placed over the pattern again. This machine saves a considerable amount of time and heavy labour. Foundrymen are aware of what it means to knock out deep top parts, which have been dried with lifters in. By the side of this table are big hoppers with mechanical riddles over the top. The sand which has been shaken out is watered and passed through the mechanical riddles, which mixes it. The hoppers are then picked up and dumped into the bigger boxes and filled by hand into the small ones.

Fig. 22.—The Shake-out Table.

DISCUSSION.

The Branch President (Mr. G. C. Pierce), opening the discussion, expressed to Mr. Edgington the appreciation of the members for his Paper. With regard to the 18ft. long bedplate which had been mentioned by the author, he asked how long it had taken to ram that with the sand slinger. He had noticed, he said, that Mr. Edgington still stuck to jolt ramming, though he had a sand slinger in his shop, and he asked, therefore, why the sand slinger had not taken the place of the jolt rammer to a greater extent. He asked the question because the trend of the Paper seemed to be to point out the advantages of the sand slinger over pretty well everything else, and it did seem a little peculiar that the jolt rammer was used to so great an extent.

Mr. V. C. Faulkner (past Branch President) referred to the remark made by the author, in connection with some jobs rammed by the sand slinger, that certain parts, under bars, etc., were tucked by hand. The use of previously prepared oil sand cores for such soft spots suggested itself as being a means of overcoming the difficulty.

Mr. M. J. Cooper asked for information with regard to the cost of mounting patterns for jobbing work, and whether the cost of putting many of these jobs on the jolt rammer was warranted. As an example, he mentioned a box 4 ft. square, and upwards. He also asked the thickness of the plates used on the jolt ramming machine for the various sizes of boxes, and what was Mr. Edgington's experience of the use of green sand on jolt ramming machines. Did he find that it was necessary to dry work which was originally done in green sand, and to use any special class of sand for this type of machine? The point of the greatest importance, to his mind, was that of how the cost of production by these machines compared with the cost of production by hand labour. They must take into consideration that the overhead charges in connection with these machines were very high, and, in addition, there were maintenance and power charges. Mr. Edgington had referred to a case in which it had taken four men a fortnight to ram up a number of cores by hand, whereas two men had rammed them up in a week by machine. Would the overhead and maintenance charges in connection with the machines increase the costs to a higher figure in the case of the cores rammed by two men in a week, than in the case of the cores rammed by four men in a fortnight?

Mr. A. S. Beech was rather disappointed that Mr. Edgington had not said more about the transport problem, which was one of the greatest bugbears in the foundry, not only of the sand, but of the boxes, to and from the machines, as well as the boxes from the fettling shop. He asked for information, therefore, in that connection. With regard to the ramming jobs dealt with in jolt ramming machines, he supposed that Mr. Edgington had referred entirely to flat-backed jobs. He would also be interested to know the methods adopted with a big box for flat ramming the job after the jolting was over. Recently, when in Scotland, he had seen pneumatic rammers used, and he wondered whether Mr. Edgington had had any experience in that connection.

Mr. Edgington, replying to the Branch President's question as to the speed of ramming in the case of the 18-ft. bedplate, pointed out that, when they reached a certain point, they had to make the joints of the big cores, and, naturally, the machine could not be used on the job the whole of the time. The job was rammed to a certain point, and then left to the moulders, the machine being used for some other job in the interval. On the ramming of the big bedplate mentioned, he had saved something like three days.

Replying to Mr. Faulkner's suggestion as to the practice of tucking under by hand in parts which could not be rammed by the sand slinger, he said this had been his practice for a considerable time even on jolt machines. He made use of oil sand cores very considerably for that purpose, because he could make oil sand cores very much more quickly than he could finish or iron an undercut job, or make a grid to go over it. There were no core irons made for the oil sand cores.

Dealing with Mr. Cooper's question as to the mounting of patterns for some of the big jobs, he said there was no mounting required. They simply brought out a half pattern or a whole pattern, and dropped it on to the plate. The patterns he had discussed had been working for twelve years, and were still good, but in time the screw-holes, used for the screws for holding the jobs down, became larger, and when that happened the next size of tap was used. He had started with 1-in. holes, but in some cases the holes were now $1\frac{1}{8}$ in., and when they wore out he would go to $1\frac{1}{4}$-in. holes. The thickness of the plates was about $1\frac{1}{2}$ in., and both sides were machined. That was necessary on jolt machines, because, without a flat surface on the table, the job would shift somewhat. The cost of production was much less when using machines as against hand labour. It would be out of place, however, for him to give figures. Machines went wrong very rarely, and they often went six months without being stopped at all for repairs; in fact, he often wondered how he had ever managed without machines, because he had become so used to them. Machine ramming was much better than hand ramming for green sand work, as there was less scabbing. He had not to dry moulds, as he had had to do formerly in many cases, and quite big jobs were made in green sand—much bigger than the 4 ft. square boxes mentioned.

Transport Problems.

With regard to transport, he agreed with Mr. Beech that this was a bugbear where there were a lot of machines; they could only get one crane up at a time. He had one crane at his foundry which did nothing else but work round one machine. It was a 10-ton crane, geared rather fast, and, as the men did not draw any patterns or put any moulds together under that particular crane, they could work fairly fast. As to the jobs dealt with in the jolt ramming machines, he said he did not stop at anything. The jobs were not by any means all flat-backed ones. If he had a plate with an uneven surface, he rammed up the top part first and put the pattern on the top part, and then rammed the bottom part over the top part in that case.

Mr. D. G. Mather (Messrs. Mather and Smith, Ashford, Kent) said he had been a little disappointed that Mr. Edgington had not said more about small hand machines, because in the South of England there was much more small work done than large. He asked if Mr. Edgington would give his views on the machines which had been illustrated recently in THE FOUNDRY TRADE JOURNAL, namely, the hand jolt machines, as compared with hand squeezers.

MR. EDGINGTON said that, as between hand squeezing machines and small jolt machines for repetition work—and by "repetition work" he meant jobs from which a large number had to be taken—he certainly preferred the small jolt machine, because, with the hand squeezing machine, if the pattern were not very shallow, one did not get the same hardness as with a jolt machine. There were jolt machines with turnover gear which were doing some good work, and he preferred them to the hand squeezers.

MR. R. J. SHAW said the lecturer had referred to "setting the patterns in the moulding boxes by means of wood strips" when preparing to ram them up with the "sand slinger," and he had been wondering what sort of accuracy was obtained and in what type of job that method was used. He presumed it was something that was not very important, as it appeared to him that to match the top and bottom halves of the mould would be rather difficult even if only moderate accuracy was required.

MR. EDGINGTON illustrated the point by means of a sketch, and said the method was used only for large jobs. The man in charge of the machine cut two very small strips, say 1½ in. wide and perhaps ½ in. deep, and those strips were placed in the box between the sides of the box and the pattern. That method gave him some degree of accuracy in the setting of his pattern, so that he did not get the job an inch over on one side or the other.

MR. J. W. DUNN asked Mr. Edgington if he preferred the sand slinger to the jolt rammer. His own experience was that the jolt rammer was much superior. He had not actually had experience with the sand slinger in the foundries with which he had been concerned regularly, but he had spent a period in a foundry in which these machines were in use, and his impression was that they did not give a uniform job; there were too many joints. The deeper the job, the softer was the ramming at the bottom; when the sand was rammed at the bottom of the box it spread out, and it was harder towards the top of the box. In what way would Mr. Edgington apply the sand slinger to oil sand cores?

Mr. Edgington replied that in this country we were not yet educated up to the sand slinger, and we were not getting out of it all that was possible, but we should do in time. His practice was to ram deep bottoms on the jolt machine in preference to the sand slinger. He had not yet made any special tackle for the sand slinger, but in course of time he would make the bottoms with a loose plate, so that there would be an open box to ram into with the sand slinger. When that was rammed up, the plate would be put on and bolted to the box. In many cases, instead of using lifters, he believed it would be advisable to use joint plates. In that case one simply had staples up the box instead of lifters. In a long box one would perhaps get four or five staples standing up when the ramming was finished, instead of 100 or 200 lifters, and in that way he believed we should get over the difficulties with the sand slinger. With regard to ramming up cores with the sand slinger, he had not attempted that yet, and he did not think he would for a time. Oil-sand cores did not require much ramming, and it was sufficient, in some cases, for a man to put the sand into a box and ram with his feet. There were some jobs which would never be made on machines: it must be recognised, of course, that machines had their limitations, but, if a man could use a machine and effect a saving of 25 per cent. thereby, it was up to him to use that machine. There was no doubt that they could be used a great deal more than they had been up to the present, in spite of the difficulties in the foundry.

Mr. W. B. Lake, dealing with the respective merits of the sand slinger and the jolt ramming machine, said he had them working side by side on the same job. That job was a comparatively small one, but his experience was that there was very little to choose between the castings produced by either machine. So long as the head of the sand slinger was kept in the proper condition, he obtained as good a ramming from the sand slinger as from the jolt rammer. He used a steel sand, which was different from green sand.

Mr. E. H. Brown asked whether it was really a paying proposition to use these machines for odd jobs in smaller work, such, for example, as small slide rest sections or similar simple parts, weighing, perhaps, 7, 14 or 28 lbs. apiece. Were the advantages to be derived from the use of machines on that class of work worth the extra expenditure involved?

Mr. Edgington said he did not think it would be worth while to use the machines for one job in that class of work, but there was no doubt that when six or a dozen were taken off it was worth while. It must be recognised that every job had to be considered on its merits. It did not follow that, because one had a machine, one must use it for every job, whether it paid to do so or not; every job must be made to stand on its own feet, and it was up to the foundry foreman to use his common sense. It was a question of shop management.

Mr. Bartram proposed a very hearty vote of thanks to Mr. Edgington for his Paper.

Mr. J. Ellis (Past Branch-President), who seconded, said he had had a good deal to do with moulding machines, and had met with some very curious experiences. He referred to one case in which a man was making a job, at 2d. apiece, on a hand-rammed turn-over moulding machine; in the same foundry the same job could be made on the floor for 1½d. each. In another foundry there was a very elaborate power machine, and motor flywheels were being moulded. At the same time, another foundry not far away was making the same things at a cost which was less than the cost of upkeep of the moulding machine used in the former foundry. He was not antagonistic to the use of moulding machines, because he believed that, rightly applied, they were going to be the salvation of the foundry, but the great difficulty was to get the management of a foundry to appreciate their proper application. Some people installed moulding machines, regardless of the work they were going to put on them, and that was the great fallacy. There were some machines, no doubt, which would give far better results than hand moulding could do, but, on the other hand, there were some which could not, and it was up to the foundryman to have a voice in the selection of these machines. In conclusion, Mr. Ellis expressed the hearty thanks of the meeting to Mr. Edgington.

The vote of thanks was carried with acclamation.

Mr. Edgington briefly acknowledged the vote of thanks, and the meeting closed.

Birmingham, Coventry and West Midlands Branch.

THE MANUFACTURE OF SPECIAL CAST IRON.

By A. Marks, Member.

Mr. Marks said the problem of obtaining perfect castings was one which involved the co-operation not only of the metallurgist but of the foundryman. In that connection it must be remembered that the definition of a practical man was rapidly undergoing a change. It was like the old German chemist's definition of a chemist, that a chemist who was not a physicist was not a chemist at all. Perhaps it was now being realised that the metallurgist was not a metallurgist who was not a physicist. The metallurgy of cast iron and the structures of the diagrams had been worked out largely by physicists. Alluding to high-tensile cast irons, Mr. Marks said that in the case of automobile engines they did not reach such stresses or temperatures that anything very special was required. He had run air-cooled engines at red heat, though one did not do it as a regular thing. Diesel engines frequently attained red heat, so that high-tensile cast iron was mostly considered from the point of view of the Diesel engine, automobile engines not being so important from that aspect. They could have an absolutely flawless automobile cylinder any time they liked provided they were prepared to pay the price of it. He contended that owing to lack of real technical training in the people put on inspection of automobile castings, automobile cylinders were scrapped which for practical purposes were perfect. He had made automobile castings for every well-known car in the Midland area, both air-cooled and water-cooled, and he was speaking out to the automobile trade in general when he said that the inspection of automobile castings was not done on a technical basis, nor was it done on a business basis. Material which for practical purposes was perfect, was scrapped on account of technical ignorance in the inspection departments.

Cast Iron for Automobiles.

Cast iron for automobile purposes did not really demand an exceptional iron. What it demanded was an iron which could be cheaply machined and which would be sound and have a reasonable amount of wear. Cast iron which could be machined at a reasonable speed had a reasonable amount of wear, but if high wearing qualities were required it could not be expected that they could run their tools at the speeds which could be put on to common cast iron. The automobile engineer got it into his head that he must have specially good cast iron, and laid down a Brinell hardness test of 220. Then he designed his automobile cylinders with a barrel thickness of, say, ⅝ in., and his outside casing 5/32 in. If he got 232 hardness on his barrel casing, by the commercial methods in use at the present moment, he would get on his water casings a white iron which would very soon crumple up. That demonstrated one of the follies of laying down a hardness specification in a job of that kind. There were many automobile engineers within fifty miles of Birmingham who were insisting upon a hardness test in the case of automobile cylinders, and blaming the foundryman if the test was not met, and scrapping them, and who yet had not the most elementary knowledge of the relation between Brinell hardness and wear. For practical purposes there was very little connection between Brinell hardness and wear. There was nothing more painful to him than to see an automobile casting sent round to the various foundries with a chemical specification on it.

Fords Cylinder Specification.

The only specification for automobile castings he had seen which was worth the paper on which it was written was one which emanated from Fords for automobile cylinders. In that case the man who wrote it evidently had some idea of what was required in the composition of cast iron. Certain schools of engineering held the view that combined carbon was a measure of wearing qualities, and they would specify a minimum combined carbon. It might be 0.6 per cent. The combined carbon might be 1.2 in the jacket, but as low as 0.6 per cent. in the barrel, because the rate of cooling for the barrel was totally different from the outside jacket wall. It was possible to have combined carbon 0.4 or 0.3 per cent. and still have wearing qualities as good in the iron as with the combined carbon at 0.8 or 0.9. After specifying a certain hardness figure for the cast iron, the automobile engineer would put his piston into the cylinder with a set of piston rings—sometimes two, sometimes three—and he would put on those piston rings a definite pressure. He then argued that so long as he had a certain pressure on the rings, provided the pressure per square inch was not above a certain amount, his automobile would be all right. It would be all right from the point of view of the escape of gas. But at the ends the rings were narrow, and so long as they were free to oscillate slightly they would act as scrapers on the cylinder wall, so that the design of the ring on the piston was of far more importance to the wear of the iron than the question of the composition. In the case of Diesel engines they were working at higher temperatures and stresses, so that the tensile strength and resistance to heat were of the first importance. It had been found that strength at high temperatures was chiefly a question of keeping down two factors, namely, the graphite and the silicon. Ordinary 3 per cent. or 2 per cent. silicon iron would, if heated continually, decompose and give what was termed growth—that was assuming the temperatures were fairly high. Growth had been known in a super-heated steam-engine casting where the silicon was as low as 2.0 per cent., but the movement was in the right direction when they reduced the silicon. It was not usually a commercial proposition to put into an automobile engine an iron with much less than 1.6 per cent. of silicon, and a commoner figure was of the order of 2.0 per cent. That iron, if heated, would decompose, but the reduction of strength was not very important, because most of the engines were sufficiently well water-cooled to keep the temperature well below anything serious. In Diesel engines it was not possible to keep the temperatures down. One of the chief faults of the Diesel engine was that it was cooled with sea water, and therefore very soon after it left the builder's hands it began to silt up. He had frequently seen deposits taken from the cylinder head which were 8 in. thick. Where the iron was underneath such a deposit as that and was subjected to the temperature of a Diesel engine it was not likely that the iron was going to be affected by the cool water. The engines were run at a warm temperature because the knock sounded a little more gentle. No engineer would think of running a steam boiler with his furnaces caked with a quarter or half an inch of scale. Therefore the design of the engine should be altered or the cooling should be effected by means of purer water than sea water. No foundryman or metallurgist could produce iron which would stand up to conditions of that kind, although they tried to, and got blamed for failure. The engineer ought to come to their rescue by making conditions impossible in his engine which necessitated special iron. Instead, the engineer judged cast iron on those conditions, and in some cases he resorted to steel. He had known where Diesel engines of certain types had been built with a steel cylinder head and cylinder, with the result that the foundryman had had to make five or six of the heads before he obtained a sound one, on account of the difficulty of casting in steel.

Establishing Suitable Compositions.

In trying to meet the conditions put up to them by the engineer they first of all had to get their silicon suitable. Cast iron contained six elements—relatively a small amount of iron, combined carbon or graphitic carbon, silicon, sulphur, phosphorus and manganese. The part of the diagram with which they were concerned ran from about 1.7 per cent. of carbon—the border line of the steels—up to the maximum solubility of carbon, about 4.6. An iron containing a percentage of, say, 1.7 gave a structure when it was cold showing three main things—graphite, cementite and pearlite. That took no account of the silicon, sulphur, phosphorus and manganese, and no diagram was possible. A great deal of work in connection with cast iron was based upon considerations not of the whole of the elements, but upon considerations of the influence of each element, and then the application of experience to the settling of the exact composition to use. Manganese was one of the most useful agents for giving toughness and wearing qualities. The absence of phosphorus contributed to strength; they therefore brought that down to a minimum. On the other hand, by bringing it down to a minimum the foundryman met with difficulties. Therefore, they endeavoured to run it at about 0.3 per cent. The sulphur was a function of cupola practice and of the iron. The iron as delivered to them rarely contained any percentage of sulphur that it was necessary to worry about; they added to it in the cupola. The silicon was a factor they controlled, and should be about 1 per cent. Diesel castings, according to thickness, could be run at from 0.5 of silicon or even less, up to 1.4 or 1.5. For Diesel cylinder-heads they ran the silicon round about 1 per cent., and what he might term Diesel iron frequently contained about that percentage of silicon. They controlled the combined carbon and graphite by manufacturing the iron in an open-hearth furnace or cupola with suitable variations in the amount of coke and the amount of steel added to the iron. The amount of graphite present was the chief factor in strength, and consequently the amount of silicon, because the silicon decomposed the cementite when the temperature began to get up. In moulds of a complex character they had to use chills to overcome the troubles known as shrinks and draws. Shrinks were usually due to gas, and whilst chills were useful even in removing the gas they were only an indirect means of producing the result required. A mould which would be perfectly satisfactory when it did not contain a chill at all would be useless in a mould containing chills. As they approached a steel character in order to get up the strength they had a material which would chill more rapidly. Further, as they reduced the graphite the iron became more sluggish. They balanced that by putting up the phosphorus slightly. If there was a high phosphorus-content, however, they obtained a metal which was brittle. About 0.3 per cent. of phosphorus would give them a satisfactory composition. Where the mass of the metal was relatively large to the mass of the mould as it was when they were casting a large standard Diesel engine casting, the mould had no chilling effect, and they got a pearlitic iron without any special precautions.

Before showing a number of lantern slides, Mr. Marks gave the composition of two strong irons as follows:—(1) Combined carbon, 0.72; total carbon, 2.6; silicon, 1.5; sulphur, 0.08; and manganese, 0.63 per cent. (2) Combined carbon, 0.64; total carbon, 2.74; silicon, 1.1; sulphur, 0.07; and manganese, 1.1 per cent.

DISCUSSION.

Referring to the inspection of automobile cylinders, the CHAIRMAN said it broke one's heart to see perfectly usable castings thrown out because perhaps on the foot there was a little sandhole. The relation between hardness and wear was a very much debated subject upon which there seemed to be no agreement whatever. There was also a variation of opinion with reference to machining speeds. He regarded the Paper as quite one of the most interesting that they had heard.

In proposing a vote of thanks to Mr. Marks, MR. A. HARLEY alluded to the relation of hardness and wear, remarking that it was not only a matter as to which there was a great deal of difference of opinion, but a great deal of ignorance. He wondered if Mr. Marks had noted whether ordinary 20 per cent. semi-steel was more subject to wear than ordinary close-grained cylinder iron. Machine speed was a very important factor in automobile work. The engineer wanted to machine his castings at good machining speed, and they had to compromise to some extent in that matter. He sympathised with the remarks that had been made on the subject of the scrapping of good cylinders.

MR. D. WILKINSON said there was no questioning the fact that very serious losses occurred to the community at large through the super-inspection of automobile cylinders. He thought the average inspector ought to rid his mind of the idea that it was his duty to throw material away. At the same time, it was possible that the existing super-inspection had had the effect of making the foundryman much more capable and careful. As regarded Diesel engine castings, the only experience he had had was in the making of steel heads, and he could not agree with Mr. Marks' views regarding those of steel heads. About a couple of years before the war the foundry with which he was then connected received a blue print from a firm in a neighbouring town which used a Diesel engine. They explained that they had had continual trouble with the cylinder head, and wanted to know if a steel one could be made. His firm undertook the task, and made four. They were about 8 cwts. each; all the four were good, and they answered very successfully. They certainly had a fair number of chills in them, but the way they overcame the trouble which they anticipated, which was that definite cracks would develop in the thin dividing sections, was by heating the mould to the highest possible temperature. Then, during the war, at another steel foundry, they did quite a number of heads, but for a smaller type of oil engine, weighing about 3 cwts. They made eighteen or twenty, and out of the lot only one was defective, and they were said to function in a perfectly satisfactory manner. He had on more than one occasion expressed the opinion that if some of the more intricate and difficult Diesel engine castings where the parts were not subject to wear were made in steel, the Diesel engine might be more reliable than it was to-day. The tendency in Diesel-engine-castings, with the low carbon they had, was to approach a steel character. Personally, he had never been able to get down to 2.8 per cent. carbon in any cupola-made metal. He would like to know whether the figure quoted by Mr. Marks was a laboratory figure or an actual practical figure.

The vote of thanks was heartily accorded.

Replying to some of the points raised in the discussion, Mr. Marks said there was a sample of pig-iron on the table which had been produced in the blast furnace. Mr. Wilkinson could have a sample and analyse it, and so satisfy himself that even in the blast furnace it was possible to produce as low total carbon as 2.8.

On the proposition of Mr. D. H. Wood, seconded by Mr. Starr, the Chairman was warmly thanked for presiding.

Sheffield Branch.

THE INFLUENCE OF SPECIAL ELEMENTS ON GREY CAST IRON.

By J. W. Donaldson, B.Sc. (Associate Member).

The effect of the addition of special elements to grey cast iron has received a fair amount of attention during recent years. This has been due to two causes. First, the attention of foundrymen has been directed to this question by the extensive use of alloy steels on account of their special properties. Second, the ironfounder, in common with other manufacturers, has been called upon to produce castings of complicated design to meet the demands of modern engineering practice. In this Paper an attempt is made to summarise and review the work that has been done and to arrive at some conclusion.

The normal constituents of cast iron are carbon, silicon, sulphur, phosphorus and manganese. Most commercial irons contain traces of other elements such as nickel, chromium, copper, arsenic and titanium, but the amount present is usually so small that the irons cannot be regarded as alloy cast irons. There is sold, however, a commercial pig-iron known as Mayari pig-iron, which contains about 2 per cent. of chromium and 1 per cent. of nickel.

The investigations which have been made on the influence of special elements on cast iron have usually been confined to the influence of small amounts of these elements. This is no doubt due to the high cost of the special elements, together with the difficulties experienced in melting and casting irons containing high percentages of those elements. The elements which have been investigated and which are now considered are manganese, chromium, nickel, chrome-nickel, tungsten, molybdenum, vanadium, copper, tin, aluminium and titanium.

Manganese.

The influence of manganese on grey cast iron has been investigated by Coe, Keep, West, Hamasumi, and the author. As regards the effect of manganese on the strength of cast iron, Keep concludes that it has little influence, while the other investigators show that both the strength and hardness increase with increasing percentages of manganese. As the amount of combined carbon remains practically the same, it has been suggested that the increase in tensile strength of high manganese iron is due to a matrix change, namely, pearlite changing to sorbite. The shrinkage increases with increasing manganese content, and irons containing over 3 per cent. of manganese are difficult to machine unless the silicon is over 2 per cent. The casting properties of those irons, such as fluidity and freedom from gases, are good, and sound castings are obtained.

Chromium.

The earliest work on the influence of chromium on cast iron is that of Keep, who experimented on grey cast iron with chromium additions up to 2 per cent. His results show a slight increase in strength up to 1 per cent., then a decrease. The shrinkage was increased when less than 1 per cent. was added. Campion, in a later investigation, found that 1 per cent. of chromium increased the strength and hardness and also the proportion of combined carbon. Hurst states that in a cast iron containing 1 per cent. of silicon an addition of 0.9 per cent. chromium rendered the fracture quite mottled, and 4 per cent. chromium added to an iron containing 1.5 per cent. silicon rendered the fracture perfectly white; and that drastic annealing at 900 deg. to 950 deg. C. failed to produce graphite. He also states that increasing the silicon content tends rapidly to reduce the stability of the carbide. A cast iron containing 3.15 per cent. silicon and 6.94 per cent. chromium gave a Brinell hardness of 460 on a sand-cast bar, and a chill-cast bar could only be filed with difficulty. The same alloy containing 1.46 per cent. silicon was glass-hard and white. The systematic investigations of Smalley with chromium additions to ordinary grey cast iron and cylinder iron showed that with both irons small additions of chromium 0.11 and 0.15 per cent. increased the strength and hardness slightly, while with the larger addition of 0.78 per cent. to the ordinary iron the tensile strength fell. The transverse strength is little affected, and the Brinell hardness increased. A similar addition of chromium to the cylinder-iron produced an increased transverse strength and Brinell hardness, but little change in the tensile strength. Piwowarsky's experiments show that with up to 0.5 per cent. of chromium the strength and shock-resisting properties of cast iron are increased to the extent of about 10 per cent., while the hardness increases from 20 to 25 per cent. The author's investigations carried out on a good cylinder iron with chromium additions of 0.19 per cent. and 0.39 per cent. show an increase of 5 per cent. and 10 per cent. in the strength and 5 per cent. and 11 per cent. in the Brinell hardness respectively. Recent experiments of Hamasumi show that chromium strengthens cast iron from 16.5 to 22.8 tons per sq. in. in an alloy containing 0.4 per cent. of it without materially altering the structure.

Summing up the results of those investigations, it appears to be definitely established that 0.5 per cent. of chromium in the presence of 1 to 2 per cent. of silicon increases the tensile and transverse strengths and the hardness of grey cast iron. This increase in strength is brought about by the chromium preventing the formation of graphite and producing a more stable double carbide of iron and chromium, which crystallises out with the pearlite.

Nickel.

Experiments on the influence of nickel on grey cast iron have been numerous. Keep added metallic nickel up to 0.75 per cent. to a grey machinery iron, and came to the conclusion that no advantage could be expected from small additions of this element. Guillet found that nickel caused precipitation of graphite, pearlite disappeared as the nickel increased, and cementite became more or less acicular in form. Thaler stated that the addition of 1 per cent. of nickel caused the separation of 50 per cent. of the graphite, and with further additions up to 48 per cent. nickel, graphite gradually increased until 85 per cent. of the total carbon existed as such. Hatfield also expressed the opinion that the precipitation of graphite is facilitated by nickel, and by doing so nickel acts as a softener, but is useful in no other direction. Campion found by adding 1 per cent. of nickel to grey cast iron the graphite was increased from 2.54 to 2.77 per cent., also that there was an increase in strength but a decrease in hardness. Smalley's grain-refining experiments show that 0.5 per cent. of nickel have a densening effect on the structure of grey cast iron. Such a quantity, however, does not affect the hardness. The experiments of Piwowarsky confirm the influence of nickel in producing graphitisation. They also show that a moderate nickel content of 0.5 to 1 per cent. improves the mechanical properties of grey cast iron by 20 to 30 per cent. With a higher content up to 2 per cent., owing to too favourable graphitisation, a falling off takes place. This improvement of the properties by nickel is attributed to mixed crystal formation. The author's own experiment of adding 0.75 per cent. of nickel to a cylinder iron produced no increase in either strength or hardness. Generally speaking, the influence of nickel on grey cast iron is to produce no material advantage.

An investigation on the combined effect of chromium and nickel by Piwowarsky showed that certain relative proportions of these elements increased the tensile and transverse strengths, as well as the hardness and compressive strength, without diminishing the resistance to shock and deflection. It was also shown that in the presence of chromium, nickel has nothing like such a powerful effect in precipitating graphite as when present alone. The author's experiments with two chrome-nickel irons indicated that adding chromium and nickel in the proportion of 2 to 1 allows of the use of a higher percentage of chromium, although the benefits derived from the increased chromium were more than diminished by the accompanying nickel.

Tungsten.

The influence of tungsten on cast iron was first investigated by Campion, who found that 1 per cent. of tungsten increased the strength but reduced the hardness. He also stated that 1.5 per cent. of tungsten added to a grey iron containing combined carbon 0.65 per cent., graphitic carbon 2.70 per cent., manganese 0.5 per cent., raised the tensile strength from 11.8 to 17.9 tons per sq. in., and in another case the result was 20.8 tons per sq. in. with 1.28 per cent. tungsten against 13.4 tons in the ordinary iron. In Smalley's grain-refining tests, where from 0.1 to 1 per cent. of tungsten was added, only a slight improvement was obtained on ordinary iron. Piwowarsky's experiments indicated that 0.5 per cent. of tungsten favourably influenced the mechanical properties of cast iron. In addition to increasing the tensile, transverse and compressive strengths, there is also an increase in the shock-resisting properties. The effect of tungsten on the carbon is to promote feeble graphitisation, the improvement in the mechanical properties being attributed to the formation of mixed crystals of iron and tungsten, giving rise to a new structural constituent of tungsten-ferrite. The addition of 0.2 per cent. of vanadium, in addition to the tungsten, produced no material effects. Adding 0.475 per cent. tungsten to a cylinder iron, the author raised the tensile strength from 16.6 to 17.6 tons per sq. in.

Molybdenum.

The addition of molybdenum to cast iron was first investigated by Campion who found that 1 per cent. of molybdenum increased the strength and reduced the hardness. Smalley's preliminary experiments showed that 0.1 per cent. of molybdenum closed the grain of grey cast iron without appreciably affecting the hardness, and led to further experiments. The addition of 0.15 per cent. of molybdenum to an ordinary grey iron containing 2.0 per cent. silicon, reduced the tensile and compressive strengths and the chilling power, exerted little effect on the Brinell hardness, and increased slightly the transverse strength and deflection. Increasing the quantity to 0.25 per cent. slightly reduced the chilling power, increased the transverse strength and deflection, but did not affect the other properties. In the presence of 0.5 per cent. of molybdenum, apart from the chilling power which is slightly reduced, all the other properties are improved, especially the compressive and transverse strengths. The effect of small quantities of molybdenum was more marked in cylinder iron containing 1.25 per cent. silicon, 0.12 per cent. improving the mechanical properties, but reducing the chilling power. The addition of 0.24 per cent. molybdenum further improved the tensile strength without affecting the hardness, compressive and transverse strengths. In all the irons neither the fluidity nor total shrinkage was affected by the molybdenum additions. Further tests were carried out adding 1.5 per cent. of molybdenum to a special cylinder iron when the tensile, compressive and transverse strengths were increased by 25, 22 and 9 per cent. respectively. On common grey iron 1.5 per cent. of molybdenum exerted a similar all-round improvement although to a lesser extent. As regards the carbon, the tendency of molybdenum is to reduce rather than increase the amount of carbide. Machining properties are affected by over 0.5 per cent. molybdenum, the iron becoming exceedingly difficult to cut. Piwowarsky's tests show that molybdenum produces practically the same effect on grey cast iron as does tungsten on a similar iron and confirms those of Smalley with up to 0.5 per cent. molybdenum. A further increase to 1.0 per cent. molybdenum, however, produces no further increase. The addition of 0.2 per cent. vanadium as well as molybdenum does not produce any better results.

Vanadium.

It has been shown that vanadium in small quantity in conjunction with tungsten or molybdenum does not produce any material benefits in grey cast iron. Investigations carried out on the influence of vanadium alone have been extensive, but contradictory results have been obtained. Moldenke's experiments with vanadium additions up to 0.36 per cent. give inconclusive results. Kent Smith showed that with 0.15 per cent. of vanadium there was an improvement in the tensile, transverse and compressive strengths. He states that the principal action of vanadium is as a scavenging agent for removing oxygen and nitrogen. Norris agrees, generally, with Kent Smith's conclusions, and states that vanadium exerts a strong influence in refining the grain, eliminating porosity, and promoting soundness, increased strength, resistance to wear and rigidity. Hatfield's experiments on the heat treatment of white cast iron containing vanadium, show that vanadium tends to maintain the carbon in the combined condition, and to prevent the precipitation of graphite. Campion found that 0.15 per cent. and 0.25 per cent. of vanadium increased the strength but diminished the hardness of cast iron. Smalley's experiments with 0.1 per cent. vanadium additions do not confirm the hardening effect of this element. Unlike the previous investigator, Piwowarsky shows that this element produces the formation of carbide. The effect of vanadium appears only with additions over 0.5 per cent., and then very suddenly, and is most marked in the lower silicon irons. The transverse and compressive strengths increase, also the hardness which is increased to such an extent that the irons can no longer be regarded as commercial irons. The author's own experiment with 0.125 per cent. of vanadium produced a slight increase in tensile and transverse strengths and also in hardness.

Copper.

Investigating the influence of copper on cast iron, Lupin concluded that while the addition of the element was not beneficial, its presence had no detrimental effect. There was a slight graphitisation effect on the carbon and the tensile strength increased from 19 to 22 tons per sq. in. with 4.9 per cent. of copper. Smalley found that the addition of 0.5 per cent. of copper tended slightly to increase the hardness although there was a slight decrease in the combined carbon. Hamasumi found that with copper additions up to 4.0 per cent. there was a steady increase in the tensile strength and Brinell hardness, and the alloys appeared to be tough. As regards the effect on the carbide erratic results were obtained.

Tin.

Guillet investigated the influence of tin on grey cast iron, and found this element to considerably increase the hardness, and that the hardness was maintained at high temperatures. Hamasumi's tests with up to 6 per cent. of tin show that up to 2 per cent. it increases the strength and hardness slightly, but with over 2 per cent. the irons become hard and brittle.

Aluminium.

Investigations by Melland and Waldron show that the influence of aluminium up to 0.5 per cent.

on cast iron is similar to that of silicon. The total carbon is reduced, and the graphite precipitated. Addition of aluminium over 0.5 per cent. produced a reversion, the carbide becoming more stable, and it was suggested that this was due to the formation of a double carbide of iron and aluminium. Recent tests by Piwowarsky do not confirm this, additions of aluminium up to 0.8 per cent. producing graphitisation. In the presence of low silicon there is an increase in the transverse strength and shock-resisting properties, but a considerable decrease in the hardness and compressive strength.

Titanium.

Early investigations by Moldenke show that a small addition 0.05 per cent. of this element increases the transverse strength but that larger additions produce no further advantage. Piwowarsky's recent experiments confirm this, 0.1 per cent. of titanium producing maximum graphitisation.

Heat Treatment of Alloy Cast Irons.

To ascertain how alloy cast iron would behave when subjected to temperatures such as would be experienced in internal combustion engines, a series of heat treatment experiments were carried out by the author. The irons tested were a plain cylinder iron and irons of similar composition containing manganese, chromium, nickel, vanadium, tungsten and chrome-nickel. These alloy irons were selected, as the elements contained in them had produced the most satisfactory results on grey cast iron in its cast condition. It has since been regretted that a molybdenum iron was not included in the series.

The heat-treatment experiments were carried out under three sections:—(1) Prolonged heating tests for 200 hours at 450 deg. C. and 550 deg. C. respectively; (2) elevated temperature tests as cast and after the above prolonged heat treatment; (3) growth tests.

The results obtained from the first series of tests indicated that in all the irons low-temperature heat-treatment decomposed the carbide with a corresponding decrease in the strength and hardness of the material. The increasing of the manganese from 0.97 to 2.43 per cent., or the addition of 0.392 per cent. of chromium or 0.475 per cent. of tungsten had a stabilising effect on the carbide; whereas an addition of 0.746 per cent. of nickel or 0.124 per cent. of vanadium accelerated graphitisation. The chromium produced the most satisfactory result, the manganese and tungsten, while increasing the stability of the carbide over that of the plain iron, did not produce the same stability as the smaller amount of chromium. In the iron containing both chromium and nickel, chromium exerted the predominating influence, the nickel, however, allowing of the introduction of a larger percentage of chromium.

The second series of tests carried out on the plain, the chromium, the tungsten, and the chrome-nickel irons indicated that if either of those irons is subjected to prolonged heat treatment at temperatures ranging from 450 deg. C. to 550 deg. C. the elevated temperature tests obtained in their cast condition cannot be taken as representative. In the cast condition the tendency is for the strength of iron to diminish slightly as the temperature rises and then to increase again with a further rise in temperature, attaining a maximum in the neighbourhood of 400 deg. C., after which the strength rapidly diminished with increasing temperature. After prolonged heat treatment there is a diminution in strength which falls off uniformly and regularly. This decrease in strength is fairly large, showing in the case of the plain iron, when tested at 400 deg. C., decreases of 21 and 27 per cent. after heat treatment at 450 deg. C. and 550 deg. C. respectively, and in the case of the chromium iron decreases of 4 per cent. and 15 per cent. after similar treatment and when tested at the same temperature. The relative increases in tensile strength for the chromium, tungsten and chrome-nickel irons, over the ordinary cylinder iron, when tested at 400 deg. C. after prolonged heat treatment at 450 deg. C., are 32, 13 and 17 per cent. Breaking at 400 deg. C. after a 500 deg. C. treatment the corresponding increases are 38, 30 and 25.5 per cent.

The amount of growth which takes place in all the irons at 550 deg. C., as determined in the third series of experiments, was small when compared with an ordinary foundry iron. In the cylinder iron growth attained a maximum after 10 heatings of 8 hours duration, when the volume increased by 0.13 per cent. The manganese and vanadium irons showed the most growth to take place during the first 10 heatings and then slowly to 25 heatings with a slight tendency to rise; change of volume after 25 heatings amounting to 0.17 per cent. Growth in nickel iron takes place slowly at first but increases with the number of heatings yielding a volume change of 0.25 per cent. after 25 heatings and still increasing. There was little change with the tungsten iron, a maximum of 0.04 per cent. being obtained after 10 heatings. With chromium there was a contraction in place of growth. The contraction takes place slowly for 10 heatings, then more rapidly to 20 heatings, then slowly again to 25 heatings, where the volume has decreased by 0.27 per cent. The chrome-nickel iron did not show contraction, although the chromium content was higher than in the chromium iron, the effect of chromium in producing contraction evidently being prevented by the presence of nickel. The growth attained was a maximum of 0.08 per cent after 20 heatings.

Conclusions.

Considering the various investigations that have been carried out and summing up the results so obtained, one or two definite conclusions may be arrived at.

(1) The special elements which exert the most influence on the properties of grey cast iron are chromium, manganese, tungsten, molybdenum and chrome-nickel. These elements not only improve the properties of cast iron in its cast condition, but in all cases, assuming that the molybdenum behaves similarly to tungsten, the stability of the irons is increased under low temperature (450 to 550 deg. C.) conditions. Chromium to the extent of 0.4 per cent. gives better results than slightly larger amounts of tungsten or molybdenum or than 2.5 per cent. of manganese. The last three elements in the proportions stated give somewhat similar results so that it is doubtful if any material advantage would be gained by using the more costly and more difficult alloying tungsten or molybdenum in preference to manganese.

The combined effect of chromium and nickel is that the nickel allows of the addition of a larger percentage of chromium although the benefits derived from the increased chromium are more than diminished by the accompanying nickel. Better results would no doubt be obtained by omitting the nickel and increasing the chromium either in the presence of additional silicon or by casting in heated moulds.

(2) Nickel, vanadium, copper, and tin produce slightly better properties in grey cast iron in its cast condition. The first two elements, however, accelerate graphitisation under heat treatment and it is possible a similar result would be produced by copper. The effect of tin on the stability of the carbide under heat treatment has not been investigated, but there are indications that it might have a stabilising effect.

(3) Addition of aluminium or titanium produce no beneficial results, but rather tend to promote rapid graphitisation.

DISCUSSION.

Mr. J. Shaw, after congratulating the author on the excellence of the Paper, stated that Mr. Donaldson had put before them such a mass of data from various sources that he (Mr. Shaw) would require some time to read and digest it, before attempting to offer any criticism. He therefore, confined his remarks to Mr. Donaldson's own figures. He was pleased that the author had used as his base material a pig-iron of uniform composition, but one also that contained all the elements in proportions found in a good commercial pig-iron, and that his base was not a washed iron, but one where all effects of ordinary amounts of Si, S, P, C and Mn come into play. The results were such that any foundry with control could duplicate. Taking the table giving additions of Mn, Cr, Ni, one found that the tensile strength simply followed the increase of C.C., and it was open to the construction that if the original iron had had its C.C. increased only similar results would have followed without the alloy additions. If they took the effect of Ni, a recent Paper by Wickenden proved fairly conclusively that small additions of Ni, such as Mr. Donaldson used, were harmful instead of strengthening, if the Si was much above 1 per cent. The Ni acted simply as silicon in cases where the latter was about 2 per cent and reduced the combined carbon and strength. The same author had also pointed out that the increased hardness due to fairly high percentages of Ni was due to the closer uniform harder sorbite formed, which at the same time machined easier.

During their experiments on chilled rolls they found that a difference of 4 points in the total carbon content of an iron acted exactly in the same manner as an increase or decrease of 3 points of silicon on the same material, so that in all deductions the difference in total carbon must be taken into account. While they had done a little work on the effect of annealing certain castings at high temperatures, the work under actual service conditions had not been at work long enough to draw clear conclusions. Some dies containing 0.703 per cent. Cr, and 0.445 per cent. Ni were taken up to 950 deg. C., and had given good service. The Brinell number was reduced from 512 to 269, yet there was no appearance of graphite. Other rings of this type after being annnealed twice at 950 deg. C., were then taken again up to this temperature and quenched in water. The Brinell number was then 713. Yet these castings were quite strong and not brittle, but, of course, not machinable. A similar ring was placed in a pan with malleable castings, and after five days and nights at 950 deg. C. was allowed to cool in the furnace. There was still little or no appearance of graphite. Quite half a dozen of these rings were tested for growth, but with two heatings to 950 deg. C. for six hours no increase of size was shown. Whether that would continue with further annealing he was not prepared to say.

Mr. J. Ferdinand Kayser said he was very disappointed to notice that the author had expressed his results to three places of decimals, and yet had apparently only made one series of each particular range of composition. It was highly improbable that the analysis was correct to the first place of decimals, and it certainly would not be correct to the second. That might seem a rather startling statement, but after seeing the analysis made by different chemists of repute, on one and the same metal, he (Mr. Kayser) never ventured to express analysis to more than one place of decimals, and then always with considerable mental reservation. He thought that manufacturers of iron castings were far too nervous in adopting alloy additions in order to improve their metal. Roughly speaking, one could say that the addition of 1 per cent. of molybdenum would increase the cost by approximately 7s. 6d. per cwt.; 1 per cent. chromium, 2d. per cwt.; 1 per cent. vanadium, approximately 15s. per cwt. Such increases of prices were, however, by no means just cause for alarm, and, given the results sufficiently high, there was no need for a maker hesitating to put on the market a casting costing five or even ten times as much as a similar casting made from ordinary grey iron. It appeared to be generally agreed that chromium was one of the most beneficial metals that could be added to grey cast iron. Approximately 3 to 4 per cent. of chromium gave, of course, a white iron, and one very easily susceptible to heat treatment. It could be softened suitable for machining, and, if necessary, could then be re-treated and hardened.

An Uncommon Cast Iron.

It did not seem to be known in the cast iron world that for some years now a metal has been on the market containing approximately 3 per cent. of carbon and 14 to 15 per cent. of chromium, together with approximately 0.7 per cent. silicon and the usual other impurities found in hematite iron. That metal could be forged without much difficulty, and could be given any Brinell hardness from approximately 250 up to 600 by a suitable heat treatment.

Mr. E. Adamson said it occurred to him that there was possibly a difficulty in regard to the open iron and the close iron. They could add manganese to iron, but on melting in the crucible they would get a hardening effect. The effect if manganese was added in the blast furnace would be to open the grain, with resultant higher carbon. That meant that in the open iron they had low combined carbon and higher manganese. The results of practical work were of much interest, as they showed the practical difficulties under which the furnaces worked, and were of more importance than those derived in the laboratory.

Many of the results shown that night were not commercial irons, but were laboratory results, and therefore could not be relied upon to give any strict guidance in the foundry. Referring to titanium, the speaker said it was not generally known how useful it could be as a cleanser. This was particularly the case in regard to iron in blast furnaces.

Mr. Hyde referred to early experiments which he had with Professor Arnold with pure Swedish iron, and went on to say that one interesting thing he had noticed was that with nickel steel containing 1 per cent. of carbon the nickel threw carbon out in the form of graphite. The nickel behaved almost exactly like silicon.

The Author's Reply.

Mr. J. W. Donaldson, in reply, said that while he agreed with Mr. Shaw that the increase in tensile strength followed the increase in combined carbon which was produced by the manganese, chromium and tungsten additions, he thought that the strengths so obtained were more stable under heat treatment due to the increased stability of the special carbides than would be the case in a plain iron of similar carbon content. With reference to Wickenden's Paper, he had not seen it, but he was pleased to know that the results obtained with nickel were somewhat similar to his own. Mr. Shaw's annealing experiments with chrome-nickel cast-iron dies and rings were of considerable interest. The falling off in hardness after annealing at 950 deg. C. was to be expected, but why that decrease should have taken place without precipitation of graphite he could not understand. The increase in hardness after quenching from 950 deg. C. was also to be expected, being no doubt due to the formation of martensite and troostite. The fact that no growth occurred after heating to 950 deg. C. clearly demonstrated the beneficial effect which chromium had on this property.

In reply to Mr. Kayser's remarks regarding the analysis, he would say that, where three places of decimals were given, these were simply the average of two results determined to two places of decimals and differing by 0.01 per cent. He was glad to hear Mr. Kayser's views regarding the addition of special elements to castings, and especially that he agreed with him (Mr. Donaldson) in the beneficial effects produced by chromium. The fact that an iron containing 3.0 per cent. carbon and 14 to 15 per cent. chromium was on the market was quite new to him, and also that such an iron could be machined, forged, and subjected to heat-treatment. In his own experiments he found that an iron containing 0.9 per cent. chromium, 1.5 per cent. silicon, could not be machined. The iron he referred to was cast in a cold sand mould, and possibly the one mentioned by Mr. Kayser was cast and cooled under different conditions.

Mr. Adamson's remarks regarding the production of iron in the blast furnace were very interesting, particularly with reference to the effect of manganese on the production of close and open irons, and also with regard to the cleansing effect of titanium. With reference to some of the results dealt with in the Paper, they were derived from irons produced in the laboratory, and although they could be used as a comparison among themselves, he agreed that they could not be used as a guidance in foundry practice.

Mr. Hyde had referred to his early experiments with Professor Arnold on irons prepared from pure Swedish iron where only one constituent was varied. He (Mr. Donaldson) knew of experiments in progress at present on irons prepared in a similar manner, where the phosphorus content varied in one series and the chromium content in the other.

Birmingham, Coventry and West Midlands Branch.*

THE TRAINING OF FOUNDRYMEN.

By E. Ronceray, Honorary Member.

In introducing the lecturer for the evening, Mr. C. Retallack, who presided, said that for many years he had been impressed with the need for something to be done for the education of the young moulder. It was not a craft that appealed to most boys. Already something had been done at Sheffield, and very good work had also been done at the Technical School at Wednesbury. He had paid a number of visits to Paris to see the provision that was made there for the technical training of the foundryman, and each time he was more impressed with the genius of Mons. Ronceray and the success which was attending his labours. The present meeting was the outcome of the impetus which he derived from an inspection of what was being done. It was often said that the foundry industry was not making progress at the same rate as the engineering industry. It was suggested that in their craft they still belonged to the Queen Anne period and that they had a venerable attachment to the methods practised by their grandfathers; that in the foundry all was rule of thumb, and that it was the last place to introduce modern economic practice and conditions. Whatever they might have to say about the lethargy of the last fifty years—and he admitted that we had been lethargic in this country—there had now come a vital awakening in their craft. There was now a spirit of inquiry and a determination to explore every avenue which would result in eradicating what was erroneous and applying the methods of research to design, patterns, gating, moulding, refractories, temperatures, and especially to the material used. The British Cast Iron Research Association had become a great and living force. Ably led by its director, Mr. Pearce, and by Mr. Fletcher, research to that body was not merely

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* Joint Meeting in conjunction with British Cast Iron Research Association.

a question of papers and essays. Every defective casting submitted was microscopically analysed and reported upon, and the whole *modus operandi* of foundry practice and material was under review for the benefit of the members. Mr. Retallack expressed his appreciation of the work of THE FOUNDRY TRADE JOURNAL. No trade paper had made more rapid progress, he said, and the information published was of the greatest value both to the students and the workers in the foundry craft. He referred to the difficulty of obtaining skilled moulders, many of whom, he said, went to the U.S.A., where they got increased remuneration. Boys as a rule did not like foundry work, which was laborious and dirty. It was a trade, however, that required skill, and never were the requirements so exacting as they were to-day. What they needed to do was to link up the technical schools with practical work in the foundry, to connect the boy at the technical school who promised well in his metallurgical studies with practice in a model or other foundry. For this development they had to go to Mons. Ronceray, the living embodiment of ironfoundry in all its multitudinous branches and details. The outstanding feature of Mons. Ronceray as a founder was that he was bringing into daily practice in the foundry his extensive knowledge of metallurgical technique and kindred investigations. Whether it was the pencil downgate or the syphon triplicate pouring brick, he had a faculty possessed by few scientists, who were too much confined to the laboratories, and never got down to the foundry floor.

The training of the juniors merited careful attention, and they ought to give the greatest attention to boys who had a passion for foundry work, and there were some. He mentioned that the French Government had recognised the splendid work which Mons. Ronceray was doing by making him a Chevalier of the Legion of Honour.

MONS. RONCERAY, who was very warmly received, said it was always with renewed pleasure that he came to lecture in Birmingham, where everything relating to the foundry trade was so much appreciated. Some time ago he received a visit from his friend Mr. Retallack, who came to consult with him on the subject of foundry education. "Whether he came to me," Mons. Ronceray added, "with reference to elementary training of apprentices or for higher educational purposes I really do not know, because I have been accused of spreading my efforts over the whole field of foundry education."

FOUNDRY TRAINING FROM APPRENTICESHIP TO THE FOUNDRY TECHNICAL HIGH SCHOOL.

The war had shattered all French organisations, most of the skilled men had been killed or were disabled, whilst requirements were enormous, and, as a leading politician said, France had to become a nation of "cadres" (staffmen) if they intended to keep their position amongst the nations. They had in consequence to frame a complete organisation of their industries. It was with the object of promoting a general plan for the foundry industry that the Author presented a paper at the first post-war conference of the A.T.F. of Paris, held in Liège in 1921.

This paper dealt more with the ascertaining of the disorganisation of foundry training and the submission of a plan than the showing of results. The hopes and purposes of the Committees appointed to improve the conditions were expounded, and the desire that a Foundry High School should be opened to raise the scientific and technical level of foundry engineers and managers was put forward. How these ends were attained will be shown.

The three stages of foundry education are:—(*a*) The training of artisans; (*b*) the education of charge hands and foremen, and (*c*) training of foundry specialists and managers.

The Training of Artisans.

The greatest obstacle to foundry apprenticeship is the reluctance of boys to enter the trade. Whilst engineering or electrical trades find as many apprentices as they like, it is a practical impossibility to convince boys to become moulders. They notice that engineers or electricians are invariably well-dressed, superior men, whose function it is to move handles or levers, to drive automobiles, ships, aeroplanes, or something of this description. Their choice is governed by the romantic appearance of the profession, and it is a disappointment for them to discover later on that, very often, their work is dirty and obscure, unemployment frequent and wages modest. The foundry world realises that moulding is not the dirty, stupid job that some people think it is. The foundry is the basis of all engineering trades. It presents a vast number of interesting jobs; possible improvements are enormous, and the prospects are very promising for good men. The foundries become every day more comfortable, cleaner and better equipped, and the best men can get very high pay in this form of employment. It is thought that in Britain also efforts are being made to attract intelligent young men; whilst it is certain that at the present time much difficulty exists in France.

It is hoped that "professional orientations," which is to be attempted in France in the years to come during the last term of elementary schools, will bring some improvement, though it has still to be proved.

Another great obstacle to apprenticeship is the lack of enthusiasm of foundry owners. It is said that apprentices are troublesome, that they cost a good deal of money, and that they leave before the end of their time. From personal experience it can be stated that there is nothing in such fears. When apprenticeship is properly organised it is a source of satisfaction. It must not be feared that the apprentices will leave the firm when their time is served; on the contrary, this is to be desired. Lack of moulders is not due to exchange of trained men, but the lack of a general training policy. In Britain it is thought that there are difficulties arising from moulders' unions. There are no difficulties of that kind in France.

Apprenticeship Pamphlet.

To help apprenticeship, the Syndicat des Fondeurs de France has thought useful to publish a pamphlet giving general information and advice. This pamphlet contains information to help recruiting of apprentices, a contract form, legal tests relating to apprenticeship and a programme of foundry courses, which is to be developed in a text book to help teachers and boys. This can be consulted on application to the B.C.I.R.A.

Apprenticeship in the Foundry or at a School.

The general opinion in France is that the bulk of moulders must be trained in shops, where the work is more normal and the atmosphere more businesslike than in schools where work cannot be conducted on a sufficient scale. But proper training in the foundry requires the strict use of adequate methods; otherwise, training in school may be preferable.

The Syndicat pamphlet recommends to group the boys under the supervision of a capable instructor, and to avoid at all costs putting them under the journeymen in the foundry, who are liable to use them as labourers.

It is recommended to give them at once simple, but useful work by increasing steadily the difficulties. Every morning the castings are examined by the instructor. The wasters are carefully broken in presence of the boys. These previous examinations generally disclose the causes of the defects and their remedies. Those remedies are immediately applied and their results inspected at the next melt. If especially interesting cases are met, apprentices are gathered to inspect them, and are questioned on the causes of wasters and remedies.

Choice of Instructor.

The choice of instructor has a great bearing on the results. He must be a very competent man, capable of working himself, fond of boys, having sufficient pedagogical qualities to teach and interest his pupils. No labourer's work must be imposed on boys, otherwise they lose interest in their trade. It is wonderful to visualise the results of such methods. The boys make considerable progress, and they work with zest and enthusiasm.

Apportioning of Period.

The total time served is three years. It is recommended to use the first year to teach the general basis of the trade, exacting from the boys good and well-finished work, rather than speed, but not to hesitate to undertake more and more difficult work as soon as knowledge and experience are acquired, at the risk of making a few wasters, which, after all, are not fruitless. The enthusiasm of boys is raised in direct proportion to the confidence which is shown in them. They get quickly discouraged if they are treated like labourers or low grade workmen, who are supposed to be only good for low and tedious work.

After one year, speed can be developed by offering boys premium or piece work, but quality must be insisted upon. The difficulty of the work is increased as time goes, but after about 18 months the average boy is capable of making most of the ordinary work given to moulders, though at a slower speed. He must be given indifferently all work usually made in the shop: sweeping, gears, cylinders, engine bases, etc. If necessary the instructor should help him and try to raise his interest by comparing his work with similar work accomplished by skilled workmen. Drawings of castings in progress must always be in the boy's hands.

From his entrance into the shop the boy must have his own tools and a cupboard in which to keep them. He must be trained to take care of his tools, and not wander in the shop to look for a shovel, a rammer or bellows.

Foundry Instruction Courses.

The general custom is to have foundry instruction courses twice a week, that is, 4 hours per week. Some foundries arrange them during shop time, others after. The first year is generally employed to teach elementary drawing and mathematics, while the second and third years are devoted entirely to trade matters, as referred to in programmes A and B of the pamphlet. The instructor should seize every opportunity, and, if necessary, provoke it, to refer to the drawing of the casting in progress. This is an excellent method of raising the boy's interest.

Sometimes the instructor is the teacher of the foundry courses, sometimes it is another man. In this latter case, the two men must work in close co-operation to avoid differences of opinion. The lessons of the teacher on sands, melting, lifting pressures, etc., must be confirmed by actual tests or observations.

Influence of Staff.

The influence of staff on the final results may be considerable. The first conditions of success are a complete faith in the utility of apprenticeship and the possibility of success. If the chief is convinced, he will be in a position to obtain the hearty co-operation of his assistants, the influence of which is of considerable weight in the course of time.

But his personal action may be very great. He must himself see the boys and their parents, tell them the advantages and interest of the trade and the future of it for educated people. He must induce the educated boys to enter the foundry, even if necessary by increasing their pay. Those boys generally learn quicker than the less educated ones, and are the recruits for the future staff.

Later on, the principal must exert a continuous action, keep his staff on the watch, see the boys often, adroitly praise or blame them, organise competitions, gives prizes, in short, make clear the interest he bears to his boys.

Actual State of Apprenticeship in France.

The regions which have best succeeded in the training of foundry apprentices are: Nord, Ardennes, Haute-Marne, Creusot district, and Paris region. In the last region 150 apprentices for iron, steel and aluminium and 60 for brass have passed examinations last year. The Prefecture de la Seine has awarded 15 certificates of "*aptitude professionelle*" after examination passed by a jury named by the Prefect de la Seine. The report of jury mentioned "The whole of the members consider that, from the professional point of view, the average level of candidates was excellent. Their skill was considered either as finish of work or speed, corresponding to that of good workmen of full age."

Apprentice Schools.

Apprentice training at schools has only recently been started in France at the Institut Colbert at Tourcoing, Institut Turgot at Roubaix, Ecole de Métiers at Lyons, and is in process of organisation in various "*écoles pratiques*" and in the "*Ecoles Nationales professionnelles*" of Armentières, Nantes, Voiron and Tarbes.

The apprentices trained in these schools, so long as they do not leave the trade, which may be feared, are probably better fit to enter the lower staff of foundries than to make pure workmen. Their general education will enable them to join the staff, but their manual training will be inferior to that of apprentices trained under proper shop conditions. The latter conditions may, however, be imperfect, in which case the school apprentices show superiority over the shop-trained ones. Whether the boys trained at school intend to become workmen or rise to foremanship, it is strongly recommended that they should improve their knowledge by spending a few years of their youth in various foundries doing actual work before finally settling down. Those desirous of advancement must not seek clerical work, but they must be anxious to complete their knowledge by assimilating industrial methods, costing, organisation, and observation of human factors.

The Training of Foremen.

It is to be regretted that no systematic formation of foundry foreman has been undertaken either by the Government or private organisations. There is only a Sunday course in Paris, providing 20 lectures, which can hardly pass for such. The author is very sorry about this, and one of his ambitions has been to fill that gap. Circumstances have not permitted it up to now, but he hopes to be able to contribute to it in the near future on similar lines to those followed for the higher form of teaching.

In the author's opinion, the foremen's training is a very important thing comparatively easy to organise. The recruiting should be made amongst the ambitious and intelligent young men who have entered the trade either from the sand heap or through a professional school. Even the foremen in existence at present, who suffer from the lack of technical knowledge, would be eager to follow such courses. It seems, therefore, that no difficulty would be met to have students anxious to learn. The only difficulty seems to find teachers and to pay them. The foundry high school, to be dealt with later, will in a short time have widely distributed sufficient men able to teach foundry topics in a capable way. The foundrymen, their regional organisations, and the Technical Education Board, which has now special resources for this purpose, will not fail in their duty. So that everything points to a recrudescence of regional courses specially organised for foundry foreman training.

The Training of Foundry Executives.

Up to now, the training of foundry executives has been carried on in a certain number of technical colleges. Except for the Ecoles d'Arts and Métiers, this training was not in direct relation to foundry needs, but referred more particularly to metallurgy. The Ecoles des Mines, Ecole Centrale des Arts and Manufactures, Instituts Industriels devote a few lectures to foundry topics. However, the Ecole Centrale has an important shop laboratory and well-considered courses, but short.

The Ecoles Nationales d'Arts and Métiers have for a long time been the source of foundry managers outside of theoretical courses. Practical foundry profession was taught there during three consecutive years for seven hours a day, which have been first reduced to two years at five hours per day, and finally to one year. The actual tendency is to train there non-specialised engineers, all students passing in the various shops during their first and third year of scholarship. During the second year only a certain number of students follow foundry or pattern-making courses, and very likely they will form a good part of future foundry managers when they have gained sufficient experience and knowledge. They are expected to form an important part of the students of high school.

Ecole Superieure de Fonderie.

In his Paper presented on behalf of the I.B.F. to the conference recently held in Liège, Mr. J. G. Pearce mentions that "on foundry subjects, the scientific man can hardly start researches of value for lack of practical knowledge, while the practical man is not in possession of sufficient scientific knowledge to draw the full conclusions of his observations."

It is to fill this gap and to unite in one man scientific and technical knowledge and experience that the Paris Foundry High School has been created. It is the first of its kind in the world, to the author's knowledge.

It has been created on the proposal of the author by the Syndicat Général des Fondeurs de France with the help and collaboration of the Technical Education Board.

Mr. Ch. Dufour, Chairman of the Syndicat des Fondeurs de France, put it to the general meeting on July 30, 1923, the funds were immediately raised, and the first meeting of directors of the new school took place at the Board of Education early in October under the chairmanship of the Minister, Mr. Gaston Vidal, assisted by Mr. Dufour and Mr. Labbé, Directeur de l'Enseignement Technique. The decree organising the school appeared on October 23, and the courses were opened in January.

It must be understood that the school is not intended exclusively to form foundry specialists, but to complete the knowledge of foundrymen, having already a general scientific training, by teaching them the special topics of the profession which are at present disseminated in technical books or Press or even not published.

The students may be either graduates from special schools or men who have risen from the bottom. As far as possible, half of the vacancies are reserved for each category. An entrance examination is to be passed by both categories, and all of them have to justify good foundry practice.

Standard of Courses.

The standard of courses is scientifically as high as possible, consistent with the scientific training of students. It is thoroughly practical at the same time, for the object is above all to produce foundry executives or managers with a scientific training.

The method followed to reach such a result is to select for each course the best specialist known. A library, with a bibliographical organisation, is being placed at the disposal of professors and students. The following *resumé* will give an idea of the topics studied with the names of teachers. The latest works published in the world have to be investigated and eventually taught.

FOUNDRY HIGH SCHOOL.

Course of Lectures.

Metallurgy.—General metallurgy (Cournot), 3 lectures Metallurgy of non-ferrous metals, study of principal alloys (Cournot), 4 lectures. Classification of pig-irons, steels, malleable; Study of blast furnaces; Theory of air-furnace converter, open-hearth furnace (Brull), 15 lectures, 3 laboratories.

Physical and Chemical Study of Materials used in Foundry.—Metallography; Study of constitution and structure, properties and treatment of metals and alloys used in foundry (Portevin), 20 lectures, 9 practical. Dilatometric study of alloys (Chevenard), 2 lectures. Investigation through X-rays of defective castings; Application of Debye method to study of alloys (Delauney), 2 lectures.

Industrial Heating. — Study of combustibles, combustion and furnaces (Roszak), 11 lectures.

Geology, Mineralogy and Refractories.—Study of principal minerals and natural substances used in foundry and industry (Bertrand), 11 lectures. Refractories used in foundry (Bodin), 4 lectures.

Electricity.—General notions and principal laws of electricity: Application to the foundry needs (Nugues), 12 lectures.

Analytical Chemistry. — Sampling; Chemical analysis and tests; Laboratory organisation (Fournel), 14 lectures, 30 practical. Industrial methods of rapid analysis (Levi), 2 lectures.

Introduction to Foundry Work.—General theory of moulding and pouring; Determination of acting forces in moulds (Pillon), 6 lectures. Generalities; Industrial status of foundry; General internal and technical organisation (Ronceray), 2 lectures. Materials used in foundry (Ronceray), 6 lectures. Pattern making (Masviel), 10 lectures. Scientific and experimental study of sands (Lemoine), 5 lectures; Study of foundry defects and general rules resulting (Ronceray), 2 lectures.

General Moulding Study. — Sand and loam moulding. Study of different processes (Debar), 2 lectures. Moulding boxes; Moulding tools (Debar), 3 lectures. Preparation of sands; Apparatus used (Lemoine), 2 lectures. Evacuation of gas in sand; Ramming (Ronceray), 3 lectures. Core making (Ronceray), 3 lectures. Pattern drawing, finishing (Debar), 1 lecture. Drying; General theory of stoves (Debar), 3 lectures. Handling of molten metal (Debar), 1 lecture. Pouring (Debar), 1 lecture. Sorting, fettling, repairing, inspection of castings (Ronceray), 1 lecture.

Melting and Treatment of Metals.—Blowing apparatus and its control (Bouzy), 3 lectures.

Ferrous Alloys.—Treatment of cast iron in the foundry; Properties of cast iron; Special irons (Lemoine), 4 lectures. Cast-iron melting, in cupola (Ronceray), 5 lectures. Cast-iron melting, in air furnace (Ramas), 1 lecture. Semi-steel (Levi), 2 lectures. High-strength cast irons (Le Thomas), 1 lecture. Malleable iron (theoretical study) (Lemoine), 2 lectures. Malleable iron (practical study) (Levasseur), 4 lectures. Steel (theoretical and metallurgical study) (Vanzetti), 3 lectures. Practical study of the steel foundry with converter. Siemens-Martin furnaces and electric furnace (Vanzetti), 5 lectures. Theoretical study of electric furnace (Remy), 4 lectures.

Non-ferrous Alloys.—Study of copper alloys and other non-ferrous alloys (Lemoine) 5 lectures. Melting and refining. High-strength brasses (Le Thomas), 1 lecture. Light alloys; theoretical study (Lemoine), 3 lectures. Light alloys: practical study (de Fleury), 4 lectures.

Different Kinds of Moulding; Specialities.—Pattern plates and machine moulding (Billon and Debar), 6 lectures, 3 practical. Sweeping gear moulding and turbines (Masson), 2 lectures, 2 laboratories. Loam moulding (Fabre), 2 lectures.

Special moulding of light work: stove plates, sanitary castings, radiators (Ronceray), 1 lecture. Chilled castings; Rolling mill rolls; Chilled wheels, etc. (Ramas), 1 lecture. Railway castings (Dewee), 1 lecture. Welding of cast iron (Dewee), 1 lecture. Automobile castings (Thivot), 1 lecture. Cireperdue, medals, art work, imitation bronze (Derdinger), 2 lectures. Large brass castings, propellers, high-strength brasses, bells (Gauger), 4 lectures. Pipe making, permanent moulds, centrifugal castings; Electrolytic and non-electrolytic coverings; Inoxydation, enameling (Levasseur), 4 lectures.

General Organisation of Foundries.—The *rôle* of foundry manager (Dufour), 1 lecture. Lifting apparatus in the foundry (Pillon), 3 lectures. General organisation; Equipment; Handling; Description of a few types of foundries (Ronceray), 2 lectures. Scientific management of foundries (Nusbaumer), 3 lectures. Cost prices; Their organisation (Feron), 2 lectures. Influence of fire losses on cost prices (Brizon), 1 lecture. Selling; Its organisation (Feron), 1 lecture.

Graphic Work and Applications.—Moulding studies and discussions (Ronceray and Debar), 24 lectures. Reports on visits of foundries and discussions (Ronceray, Debar, Lemoine), 24 lectures. General design of foundries; Shop planning; Study of defects (Ronceray, Debar, Lemoine).

Graphic Work.

It must be remembered that all students have a knowledge of foundry practice, so it is no use to have practical moulding taught. It must be known before coming to the school. The students must also have a thorough practice of engineering drawing, so as to be able to express their conceptions and views.

Every 10 days they have to make the complete study of the moulding of a casting, starting with a very simple work, and finishing at the end of their work with automobile or locomotive cylinders or similar work.

The studies comprise: Approximate weight of castings; weight of metal; machining allowances; contraction allowances; methods of moulding, reasons of the choice; construction of patterns;

construction of core boxes; design of moulding boxes, detail of moulding; special precautions to take to ensure a sound casting; quality of sand used; core making, composition of sand used; mould closing; method of pouring, precautions to take; composition of metal recommended, its manufacture; heat treatment if required; estimation of time for pattern, core boxes, mould, cores; cleaning and fettling; and criticism of the design to improve the casting or speed up the work.

The object is to provide men capable of conducting the work from the beginning to the end, and to promote the organisation of studying foundry work before starting the work. There is bound to be in the future a "ways and means department" in the foundry as in the machine shop.

Every week the students, accompanied by one or two of their lecturers, pay a visit to one of the numerous foundries around Paris. Those visits are made in a quite different way from ordinary school visits. The students would have little to learn from a superficial visit, as most of them have seen numerous foundries. They are given a certain part to study, such as the melting plant, ovens, general arrangements of the foundry, lifting apparatus, core making, sand-preparing plant, etc. Some of them in rotation have to present a report with their criticisms and proposals of improvements. These reports are discussed with the teachers and these discussions are most instructive. In a very short time the students learn "how to see," to express an opinion for themselves, and eventually to become able to avoid making the faults that they have encountered.

They also have to design parts of foundries, such as the core room, melting plant, sand-mixing plant, raw material, handling, etc., so that step by step they become able at the end of the year to design a complete foundry.

During the Easter holidays a week's trip is undertaken in an industrial district, not only to visit foundries of special character which could hardly be found around Paris, but also blast furnaces, coke ovens, rolling mills, steel works, etc., so as to give the students a general view of metallurgical industries.

In addition to the periodical examinations during the year, the final classification is made by two special examinations—one at the end of the year and a second a few months later.

The first one refers to the study of the moulding of an important casting on the same lines as during the year. Last year it was a Diesel engine cylinder. The time allowed to make the whole work was 10 hours, and remarkable solutions were presented.

The second is a paper to be presented on a subject selected by the student himself. It is a kind of simple research, affording an excellent means of appreciating the personal value of each man and the profit he has drawn from the teaching. In future these papers will be presented at the end of the year, *i.e.*, about four or five months after the end of the courses. They will have to be made in private shops where the students have been absorbed.

Last year very interesting papers were submitted, and amongst others there were: "On a chilling test for high-silicon cast irons"; "Chaplet-welding in iron castings"; "Silicon-aluminium alloys"; and "The 'life' of metals."

At the moment no buildings have been acquired, but use is made of lecture rooms at the Ecole Nationale d'Arts and Metiers of Paris. It is expected that, with the help of all those interested, the students will be allowed to use a part of the buildings now used for other purposes. If so, there will be available a splendid lecture and work room, a library and sample room, a general laboratory, a balance room, a metallography laboratory, a sand laboratory, a research laboratory, some offices, and, in the cellar, some space for heavy machinery.

DISCUSSION.

MR. JOHN CAMERON, J.P. (President of the Institute of British Foundrymen), said his first feeling was one of envy that France had got so far ahead of us. The scheme which had been described was very complete, beginning with the apprentice and passing on to courses of technical training, in which students were encouraged to do independent research. We were not coordinated in so complete a manner in this country, though the education of the moulder and of the apprentice had always been of tremendous interest to the Institute of British Foundrymen. That interest, he believed, began with the first President, the late Mr. Robert Buchanan. He was glad to notice that the Birmingham Branch was taking a keen interest in the apprentices, and he urged employers to give the work every support in their power. He admitted that the foundry industry was asleep for many years, but some ten years ago it wakened up. The world war came along, and foundrymen were asked to do things that they had never done before. They were asked to make iron to special tests, and they rose to the occasion. He believed that they were on the eve of improvements, and that the castings for internal combustion engines, locomotives, warship engines, etc., would require to be made to higher tests than had ever before been required. For that reason, if for no other, he considered that the work being done by the Institute of Britsh Foundrymen and the Cast Iron Research Association was invaluable. Theirs was a splendid craft, calling for skill and resource and the facing of difficulties.

Junior Technical Schools.

Mr. A. S. Barnes (Senior Inspector of the Board of Education) said there must be co-operation between the trade itself and the schools if there was to be a worthy system of education for the foundry trade. We had in this country a type of school which, so far as he knew, did not exist in France, and that was the junior technical school. The junior technical schools took boys at thirteen years of age from the elementary schools. and for two, and in some cases for three, years gave them a full-time day training in mathematics, drawing, mechanics, science, and in manual instruction in the wood working and metal working shop. Such boys were very efficiently trained, and when they got into the works would develop into charge hands, foremen, etc.

If they wanted the services of a higher grade of boy than they were getting at present they would have to show parents and the boys themselves that there was some sort of a career open to them. They must show that as the reward of ability and hard work there was a chance of attaining a good position. Some modest levy in a centre such as Birmingham would enable them to establish a model foundry or to establish in some existing foundry a day on which apprentices could go for training. In the Birmingham Municipal Technical School and in the Technical Schools at Handsworth, Aston and Wolverhampton, there were foundries and facilities for training in foundry work, although unfortunately they were not fully taken advantage of by the industry. Birmingham seemed to be a very excellent centre for initiating an experiment, both on account of the number of foundries and because of the progressive character of the people.

Mr. John D. Goodwin (Vice-President of the I.B.F.) said the engineering profession was overstocked at the moment, while in the foundry trade there promised to be good openings for professional foundrymen—he did not mean purely academic people, but men who combined both practical and theoretical qualifications. Everything pointed to a greater scope for cast iron in the future. Experts had quite recently visited the Continent to see what progress had been made, and they had brought back a great deal of information. Generally speaking, he did not think this country had much to fear. He believed France was a little bit ahead of them in the work that had been described, though in this country there were certain technical schools which were nearly covering the ground, although they were not specialising solely in foundry work. So far as cast iron research was concerned the Continent had not gone far beyond what was known here, except in isolated cases. He advocated the encouragement of better work by the payment of bonuses. It did not follow that the best teacher was a good workman. The best workman was a man whose whole mind was concentrated on his job, and he very often had neither the ability nor the patience to talk about it. Referring to the fear of losing lads after a great deal of time and trouble had been expended on instructing them, he said his experience during the past 25 years was that they would not leave if they could be made to appreciate what they were doing and why they were doing it.

Mr. J. E. Fletcher expressed the opinion that Mr. Ronceray had outlined a scheme which might be very well regarded as a pattern. It was quite true in this country that we had technical schools and junior technical schools, but they were not doing for the foundryman exactly what was wanted. They were not doing all that might be done to secure that fusion between the scientific and the practical side which ought to exist. They seemed to imagine that the foundry lad was incapable of learning the elementary principles of science. That was not true. He had had to deal with hundreds of them, and many of them had made themselves proficient in science. It was encouragement that the lads needed. Those who employed them must believe in them, and there must exist a personal contact. He had been impressed with the personal relations existing between the heads of firms and their men in America. When once a young fellow got thoroughly enthusiastic about foundry matters he had entered upon a new era. He thought Mr. Ronceray's address would make all of them ask themselves: " Where do I stand; do I know as much as I ought to know as foreman, manager, or as the owner of a foundry? " They could not expect to see the advancement of the craftsman unless they themselves took the intelligent interest in the work which made them themselves experts. He hoped we should soon see in this country evidence that better educational facilities were capable of producing clever moulders as well as clever craftsmen.

Dr. R. S. Hutton (Director of the Non-Ferrous Research Association) said he felt that the unique higher education described by Mr. Ronceray deserved all the emphasis that could be given to it. It was in that direction, he was sure, that we wanted to keep our eyes very clearly fixed. One of our weaknesses lay in the fact that, compared with some other nations, we had not been absorbing men of higher education in our industry. If we had an opportunity of establishing in this country some such scheme of higher education in foundry work as Mr. Ronceray had described, he felt sure it would go a long way towards helping us in the other problem of the apprentices' education. Fortunately science and education had no national frontiers, and we were free to extend our experience as much as possible, but he felt that many in the past had failed to appreciate the enormous fund of experience and knowledge which was available in France.

Dr. F. Johnson said that he welcomed Mr. Ronceray's address as an event which gave every promise of being epoch-making. There had been too great a tendency in Great Britain to let things drift, in matters concerning the education of foundry workers, in the hope that (to use the lecturer's native tongue) "la chose d'elle-même se fera."

So far as he could see, there was no lack of interest on the part of educational authorities. For his own department he could speak emphatically, and say that considerable and earnest attention had been given to the special requirements of foundry students. Classes for ironfounders had been successful in the past, but had perforce to be discontinued because of the lack of students. He had this session started a class in Foundry Metallurgy, under the able control of Mr. Arthur Marks, A.R.S.M., and, although there was little response at first, the class had steadily grown in numbers as it became more widely known.

He fully realised that this was only a first step, but such a class could be very helpful to students whose education was of a suitable standard to enable them to take advantage of the instruction given. He looked hopefully for a lead from foundry owners, and he thought that a scheme which enabled a foundry learner to attend part-time day classes would prove to be the most advantageous and efficient.

The training of hand and eye in the works foundry would go on side by side with the scientific training of the mind in the class-room, the two forms of learning being complementary, conducive to efficiency and contributory to the acquisition of an experience of enduring usefulness.

The fusion of the practical and scientific outlook in one brain seemed to be the ideal state at which we should aim. Moreover, the occasional relief afforded by day-time instruction at the school would have an exhilarating effect.

It would not be possible for every learner to pass on to the highest forms of instruction. Examinations and tests would sort out the brighter intellects from the others, but none of the work of training need be abortive.

The speaker expressed the hope that foundry owners would extend every possible encouragement to their young employees to take advantage of any scheme of training which might, with their approval and co-operation, be arranged.

A scheme for granting certificates in metallurgy had already been approved and put into operation in his department. There would be no difficulty in providing, as alternatives to some of the courses in the curriculum of that scheme, classes in foundry subjects.

He expressed regret that, owing to a very pressing engagement, Dr. Sumpner had been unable to stay for the discussion.

Mr. F. J. Cook (Chairman of the Research Committee, British Cast Iron Research Association) thought the outline which Mr. Ronceray had given of a syllabus for the training of apprentices would be most useful. One feature of Mr. Ronceray's scheme which had contributed to its success was the fact that they had not attempted to teach everything in connection with the foundry by one man. In his opinion one of the weaknesses of schemes in this country was that the reverse was the case. He was not saying anything derogatory of the teachers in the technical schools, but it was obvious to anyone who had had to deal with technical matters as applied to everyday work that it was impossible to find any one man who could teach everything in the way of applying science to practical work. There were plenty of foundrymen in the county perfectly willing free of cost to undertake a few lessons or lectures in some special subject in which they had specialised. With regard to the junior section which they had started in Birmingham, it had been hoped that the section would have been in the hands of one of the best men in the world, he thought, the late Robert Buchanan. He (Mr. Cook) was trying to step into the breach, and he hoped that everyone with youths under their control would send them along.

Mr. V. C. Faulkner (Sr. Vice-President I.B.F.) expressed the belief that in spite of the excellent system which had been organised in France by Mr. Ronceray more money had been spent in Great Britain on foundry education than in France. What was mainly required here was co-ordination. Many efforts were being made throughout Great Britain, and probably what would meet the immediate needs of the industry was the institution of a national examination. With sufficient enthusiasm for the object such an examination could easily be established, and he was of opinion that the necessary enthusiasm would be forthcoming from the whole of the foundry districts of the country. For instance, he believed that either Sheffield or Birmingham University, or the City and Guilds, could organise and supervise a national examination to be held in all the various centres. That, he was convinced, would meet immediate needs, because, after all, we had in Great Britain a very large number of eminent foundrymen, and it would be well to ask ourselves how they attained that position. If they had a National Examination Board it would greatly enhance the status of the foundryman.

Mr. J. G. Pearce (Director of the British Cast Iron Research Association) said there was no doubt as to the magnitude of the problem before them. It was agreed that there was a shortage of skilled men and an equal shortage of men who could take important managerial positions. It would be possible to get boys into the foundry trade if schemes were developed for teaching the trade thoroughly to all comers and to make it easy for the more ambitious boys to reach the highest positions in the industry. Apprenticeship and shop instruction must go hand in hand with part-time teaching in the technical schools. He wanted quite unofficially to make a rather revolutionary suggestion. It was that conditionally on part-time attendance at the technical school the State should make a grant to properly trained apprentices. To his mind an important feature of the school in Paris was that it brought together under one roof and compelled them to rub shoulders, the ambitious artisan who had come up from the bottom and had been through the shops and the University and technical high school graduate whose practical training had been limited. The industry needed both classes of men, and he thought the formation of a school in this country would be justified on that ground alone. Such a school would have to be provided jointly by the Board of Education and the employers. The latter must find the money jointly with the State and the school must be conducted, so far as the actual teaching was concerned, by men from the industry itself. There would be a Foundry Exhibition in London next June, in connection with which there should be a competition of a practical character for moulders, core makers and pattern makers. He suggested that the six men who did best in those competitions should be permitted to compete among themselves for a scholarship which would entitle the best man, the star young foundryman of Great Britain for the year, to a period of training at the French Foundry High School. He suggested that it should cover a period of eighteen months and probably £150 would cover the expense. Six months would be necessary to learn the language, there would be six months' training at the school and six months to complete the practical training for the Foundry High School diploma. The money should be jointly found by the Research Association, the Institute of British Foundrymen and the Foundry Equipment and Supplies Association.

Mr. D. H. Wood thought the best thanks that could be tendered to Mr. Ronceray would be to put a similar scheme into operation in this country. He moved a resolution to the effect that the meeting, having heard with great interest and satisfaction Mr. Ronceray's description of the training of apprentices and foundry operatives, approved of the formation of a Committee to be constituted to prepare a scheme for similar training in this country and promising full support for the project.

The motion was seconded by Mr. Beech and carried.

Replying to some of the points raised in the discussion, Mr. Ronceray said he did not agree that the training of apprentices could not be properly carried out in small shops. His experience was that in many cases the best apprentices came from small shops where adequate methods had been employed. He welcomed the suggestion made by Mr. Pearce that a boy should be sent over to Paris. They were not selfish, he said; they were anxious to have representatives of other nations. During the first year they had a Spaniard, in the second year a Spaniard and a Czecho-Slovakian, and they were very anxious to have a Britisher.

Newcastle Branch.

THE PATTERNMAKER AND SOME OF HIS WORK.

By S. Carr, Associate Member.

An observer of the various classes of workmen entering and leaving the workshops of our engineering factories will doubtless have noticed the change, in comparatively recent years, in the size of the tool-box which shadows the patternmaker from one place of employment to another. His box is smaller and contains less of the tools carried by his forbears, also those he does carry are lighter in weight and are often in combination form. An old-time patternmaker's tool-chest, with its skew and skipjack planes, thumb planes and ploughs, bow and keyhole saws, handscrews, etc., would be a chest of curios to many. In the old days he carried everything with him, except the workshop, and no doubt his tool-chest would have made a good substitute even for that.

It must not be thought that only the modern development of hand tools accounts for the change, but rather the greater development and use of machinery in the patternshops of to-day. There still are shops, however, where men are expected to provide all, and are expected to give a good account of themselves in semi-darkness and a dust-laden atmosphere. If efficiency is to be expected then a man must be given good conditions, plenty of light, and a good supply of clean air must be maintained at a reasonable temperature. It is impossible to work with edged tools and numb fingers, or if one has to perform a series of physical jerks to stimulate circulation. A patternshop should be well lighted, and not too low, efficiently heated, and should contain apparatus for removing the shavings and dust from the machines. Cleanliness is essential.

The machinery should be such as to eliminate as many hand operations as possible, such as planing, sawing, sandpapering and turning. There are other operations, such as are involved in corebox construction, that can now be performed by machinery, examples of which will be referred to later. It is necessary that patternshop machinery should be at least in as good a condition as the best used in the fitting shop, and too much emphasis cannot be laid on this point.

All wood-cutting machines are dangerous, and if not kept in first-class condition the danger is materially increased and the full advantage of the machine is lost; for example, when the glass paper on the sander is worn extra pressure must be applied and the result is a scored and burnt surface on the wood. Again, if the cutters on the planing machine are not ground and set true the wood comes off tapered and so requires hand-dressing. With a sharp bandsaw one can cut very close to the line, and only a light contact with the sander disc, or bobbin, is required for finishing, but when the saw is not in good condition a good margin must be left and the work ground down to size on the sander.

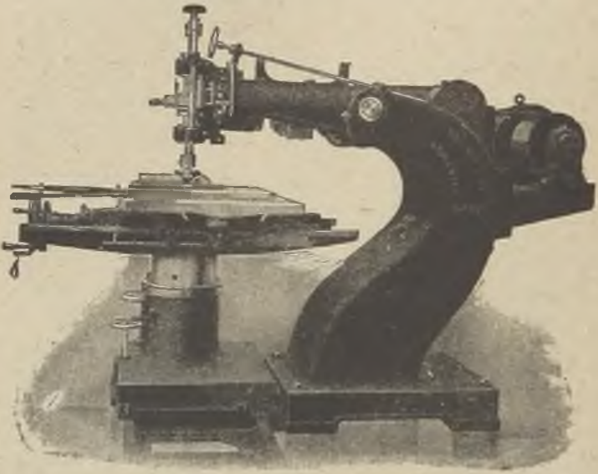

FIG. 1.—MECHANICAL WOODWORKER.

Necessity for Broad Knowledge.

Assuming that there is the desired shop and machinery, what of the patternmaker? A good patternmaker is not one who is skilled only in the use of hand tools, but one who is also skilled in the use of machines, and who is able so to construct his work as to get the best results from machinery. His calling also demands that he should have a good knowledge of woodcraft, coupled with ability to read working drawings of both the orthodox and unorthodox types; he must possess a good knowledge of geometry and machine construction, and, most important of all, he must possess the ability to visualise the pattern from a drawing. To this may be added a quotation from a recent publication: "A good patternmaker must be a good moulder." It is possible, by concentration of mind, actually to see the pattern and casting if the elementary rules of machine drawing are thoroughly mastered, and all classes of apprentices should be encouraged in this direction. Both the patternmaker and moulder require higher practical and technical training, particularly in each other's sphere of work; they are interdependent, so that it is insufficient for the patternmaker to understand moulding, but it is necessary for the moulder to understand patternmaking.

A patternmaker who understands patternmaking alone is analogous to the moulder who understands just one type of moulding. Both, if they wish to succeed, must get out of their watertight compartments and increase their knowledge of the modern developments in each other's work, and in engineering generally. If it is accepted as a fact that the pattern is indispensable to the moulder it follows that the patternmaker is essential to the production of castings, and, consequently, his knowledge of foundry work is most necessary. He should understand more than moulding operations alone. He should interest himself in the various types of moulding, the composition of the various sands and the effect of heat upon them; the metal put into the mould, the cupola; in short, in "metal founding."

The degree of accuracy now demanded from the patternmaker and moulder and the intricacy of castings used in modern engineering make it imperative that at least a general knowledge of the function of any particular casting should be known, for such information will assist in deciding the method and type of moulding, machining allowances and certain tolerances. Not only is this knowledge helpful in production, but it is both interesting and instructive, and relieves the monotony of factory life. This knowledge may be readily obtained, for it is difficult to conceive of any branch of engineering upon which it is not possible to get cheap instructive literature written in such a manner as to be interesting and easily understood.

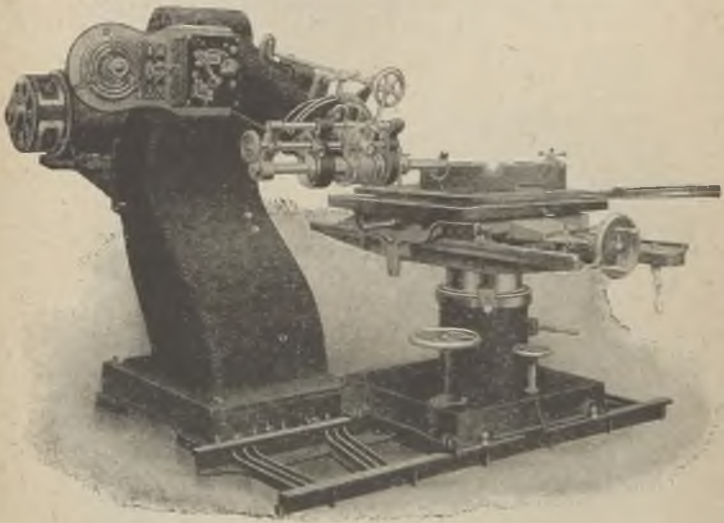

FIG. 2.—MECHANICAL WOODWORKER WORKING WITH THE SPINDLE HORIZONTALLY.

High-class Patterns Necessary.

Turning now to the work of the patternmaker, some men have spent their lives on one class of work only, large or small, or in a particular branch of engineering, while others have had a good general experience, but if a man has a thorough knowledge of the subjects that have been enumerated then he can very quickly adapt himself to any class of patternmaking.

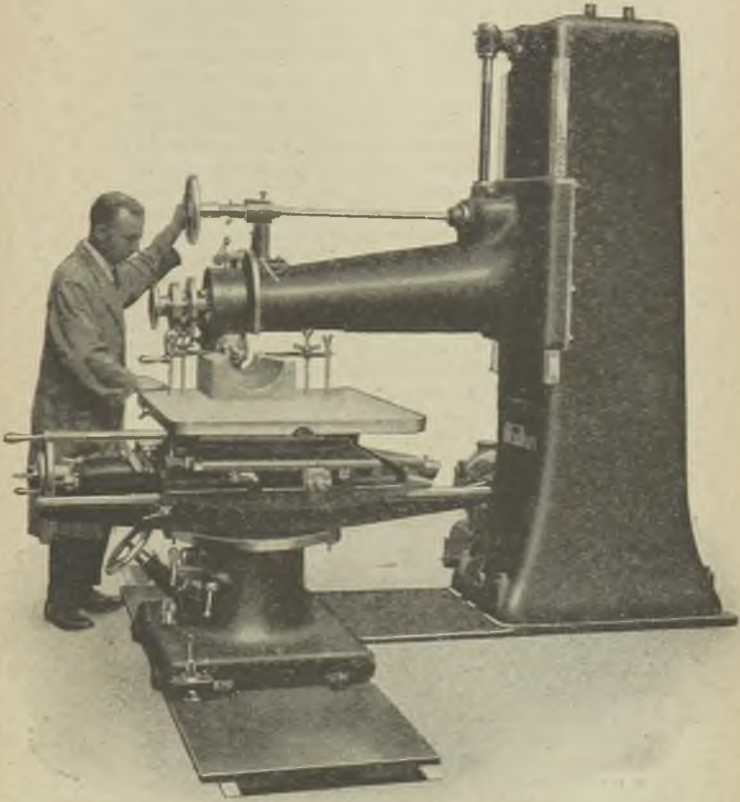

FIG. 3.—SEMI-AUTOMATIC UNIVERSAL WOOD MILLER.

Being the era of modern labour-saving devices, brought to a high state of efficiency, the demand for "apology patterns" should no longer exist. Skeleton or template patterns, except in very exceptional cases, should be committed without ceremony to the cupola, and without the option of resuscitation. Indeed, if the greatest possible advantage is to be taken of the modern moulding machines little short of the perfect pattern will suffice, and with modern patternshop equipment the majority of old-time arguments for a "makeshift job" no longer exist. Time unnecessarily spent on finishing and mending a mould due to a shoddy pattern is lost time, and is a direct charge against the patternshop, and this is only too often overlooked. Surely the final cost of a casting is of more importance than the particular departmental cost.

Where scantlings are reduced to the minimum, and only a small margin is allowed for casting weights over estimated weights, it is essential for the moulder to have an *accurate* pattern, no parts being left for him to carve out of the mess which usually remains after withdrawing certain types of patterns with which he is painfully familiar.

Use of Modern Machinery.

Until quite recently much of the work in the patternshop has been in the nature of handwork, and with the object of reducing this, core frames, strickles, sweeping boards for sand-moulding, loam patterns, thicknessing the mould, loam core boxes, and other methods were introduced, thus transferring a large amount of pattern and corebox making to the foundry. These methods, while doubtless effective in their object of providing castings, do not permit of a very high degree of accuracy, and liberal machining allowances become necessary, while one has not to be too critical of the appearance of the casting, nor too exacting during calibration. Such castings would not be tolerated in many classes of work to-day, and the patternmaking has to be done in the patternshop.

The ever-increasing demand to do work mechanically caused woodworking machinery engineers to make a special study of patternshop requirements, and the result is that to-day there are many first-class machines which reduce hand labour in the patternshop to a minimum. The circular saw, bandsaw, planing machine and wood grinders are all very efficient machines, but the variety of work produced is very limited, and it is owing to this limitation that the mechanical woodworkers have been evolved.

The Mechanical Woodworker.

Fig. 1 shows one of these machines, which is adapted to cut either patterns or core boxes. The cutter is shown in the vertical position, while on the table of the machine is a bend pipe pattern. As the cutter revolves the table is moved so as to cut the straight portion of the pipe; but on reaching the centre of the radius the table is locked and is then ready for turning, thus enabling the bend portion to be cut. On reaching the straight portion again the locking gear is released and the table moved, thus enabling the inside half of the pattern to be completed. The outer or convex half of the bend is completed in a similar manner. The corebox is treated in the same way, only the shape of the cutter is reversed. The great feature of the machine is the number of operations that can be performed by simple movements. The base of the table can be easily moved along the runway and the table is so constructed that additional movement may be had in the same direction, also in a transverse direction. It can also be turned completely round, so enabling circular work to be completed at one setting, while the height of the table may be altered to suit the work in progress. The cutter spindle can be raised or lowered as desired, while the fine adjustments permit of the highest degree of accuracy. The spindle may be turned through an angle of 90 degrees, and can be locked at any intermediate angle, so enabling taper to be cut on a pattern at one operation. Fig. 2 shows the spindle in a horizontal position. When it is desired to cut long boxes of large diameter a boring bar is used, which has one end attached to the spindle, the other end being supported by means of a suitable standard.

An Improved Woodworker.

A recent development on the preceding machine is shown in Fig. 3. It is known as the

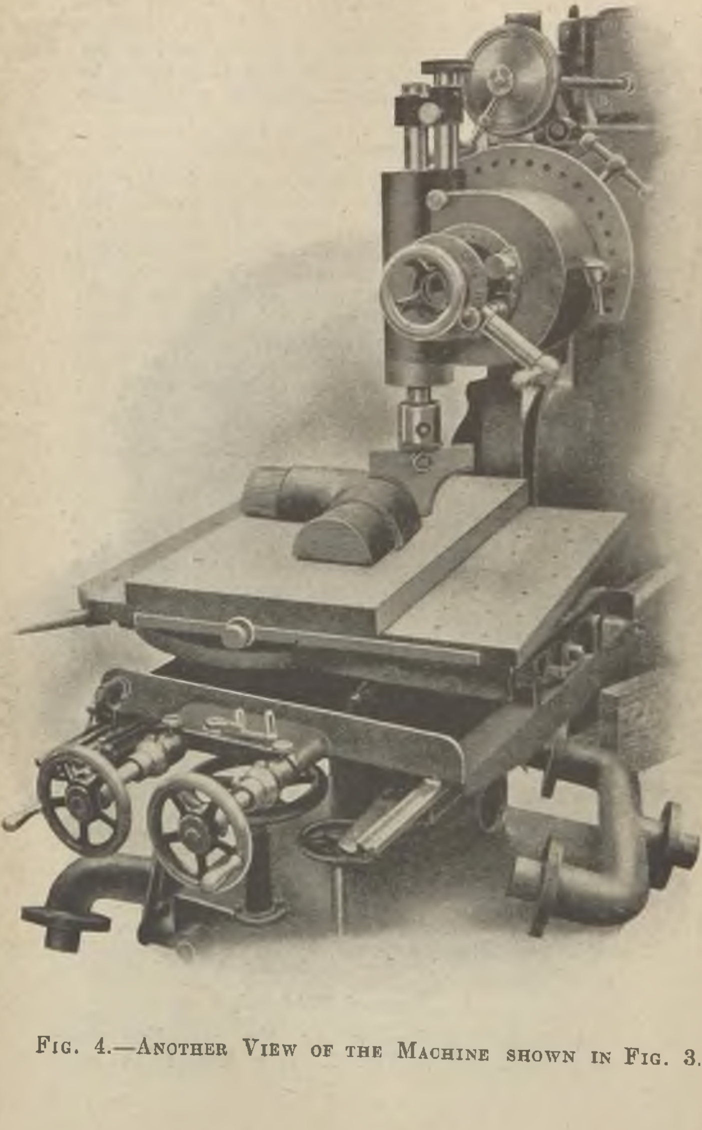

FIG. 4.—ANOTHER VIEW OF THE MACHINE SHOWN IN FIG. 3.

"Semi-Auto Universal Wood Miller," and is adapted for larger and heavier classes of work. While possessing the same features as the "Mechanical Woodworker" there are additional advantages. All operations can be controlled from the front of the machine; it will also be noticed that the spindle is below the level of the overhung arm, which obviates the necessity of using a boring bar when cutting long-core boxes. The cutter spindle is gear-driven, and can be reversed or stopped at will, while the speed is controlled to suit the size of cutter used.

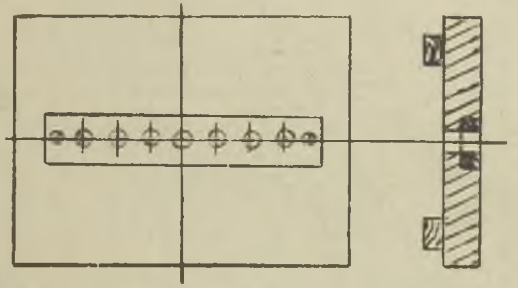

FIG. 5.—WOOD TURNOVER BOARD WITH METAL DOWEL PLATE.

Another feature of importance is the "Patent Revoluble Cutter Head" (not shown in the illustration). This permits of a cutter to be operated with its axis at right angles or parallel to the surface of the work, which is a great advantage when cutting pipe coreboxes of large diameter. Another view of the same machine is shown in Fig. 4. A half-corebox for a globe valve, having a maximum diameter of 1 ft., can be finished on a good machine in about one hour, while bend patterns and coreboxes, valve coreboxes, eccentric sheaves, liners, bushes, etc., can be completed in a matter of minutes if in the hands of a skilled operator.

There are several additions provided with these machines for cutting spur and bevel-wheel patterns, mitre wheels, and also worms and worm gears. The feed and timing gear for cutting such wheels is most accurate, while they can be cut in a fraction of the time taken by hand. Much time can also be saved by considering the construction of a corebox or pattern so that the greatest benefit can be derived from the machine.

If the cutters are kept in perfect condition the products of these machines require very little finishing at the bench, while the time saved easily disposes of the crude foundry-made pattern, and makes a woodworking machine almost indispensable in the patternshop.

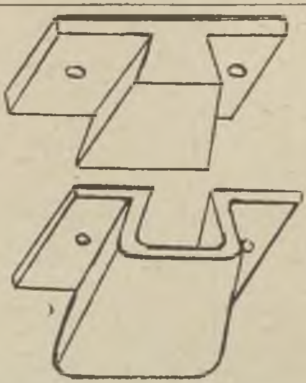

FIG. 6.—BRASS DOVETAILS.

A Modern Method of Construction.

Having seen something of what can be accomplished by the use of machinery in the patternshop, the "Building Method" of tee pieces, bends, etc., may be illustrated in a practical manner. (The author here illustrated this section of the Paper by working models.)

As the tendency of present-day practice is to standardise, many parts of pipes and pipe connections are of standard section. Up to certain pressures the metal is of a constant thickness, for a certain bore, while the flange thickness, diameter, number and diameter of bolts are also constant; consequently, if a tee piece of any given diameter is required for a certain pressure a standard pattern and corebox is made.

In pipe lines such as boiler-feed, bilge, oil and lubricating systems it is frequently found necessary to vary the diameters of the pipes, and so there may be a 3 in. × 3 in. × 2 in. tee piece or 5 in. × 4½ in. × 3 in., and so on. It is then that a great multiplicity of patterns accumulates and there is also the tendency for the use of the skeleton type of pattern to be persisted in.

In the 3 in. × 3 in. × 2 in. tee piece there are parts of a 3-in. standard and a part of a 2-in. standard, and when a new pattern 3 in. × 3 in. × 2 in. is made there is overlapping of pattern and corebox construction, extra storage is required, and in the larger sizes of pipes this must be of no small consideration. If instead of making complete new standard patterns they are made in sections as illustrated (Figs. 7 and 8), it will readily be seen that by assembling the parts required from each set any desired combination can be arrived at.

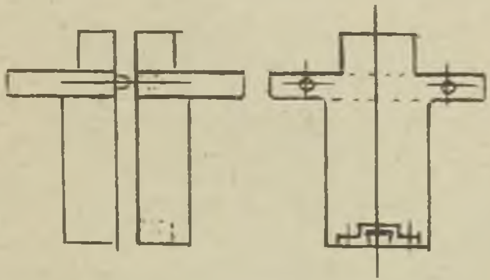

FIG. 7.—STANDARD FLANGED END SHOWING DOVETAIL.

As will be seen from the illustrations, the flanged portions are held in position by brass dovetails (Fig. 6), while the centre portion is dowelled on to the turnover board. The board, if of wood, has a metal plate inserted, the plate being drilled with holes from a jig; the holes are evenly pitched and of such a diameter as to suit the dowels (Fig. 5). When fixing the dowels on to the pattern the drilling jig should be used, and any uncertainty of the pattern fitting into its place is eliminated. Moreover, if several turnover boards are in use the patterns will be interchangeable, and any change of formation of the pattern can be carried out in very short time.

The system can very conveniently be applied to the moulding machine, only it is advisable to use a metal pattern plate. The modification required for the pattern is the use of another dovetailed piece in the end flanges, as shown in sketch No. 10. This additional dovetail is kept sufficiently long to cover at least two dowel holes so that after placing the special bolt in position it is sure to suit a dowel hole. The special bolt and wing nut are shown in Figs. 11 and 12. It is possible by this means to reconstruct or remove a pattern from the machine in about one minute. Where special pipe connections are required, such as Y pieces, direction pieces, etc., only the centre portion requires to be constructed, the flanged ends being used as before.

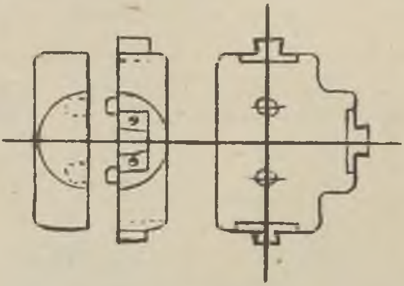

FIG. 8.—CENTRE PORTION OF TEE PIECE SHOWING DOVETAILS AND DOWELS.

The coreboxes are a very simple proposition, and when making, say, the 3-in. tee piece the box should be made of a cross formation, as this proves very convenient when cross connections are required. The boxes can be quickly cut on the woodworking machine, and in the case of the 3 in. × 3 in. × 2 in. connection a reducing piece can be turned in the lathe, screwed into the corebox and the machine can cut out the new 2-in.

end (Fig. 13). Figs. 14 and 15 show various combinations possible with the system.

Bend Pipe Patterns.

Applying the "Building Method" to bend pipes use is made of the standard flange pieces, while the bend or centre portion is built up from a number of sections of a varying number of degrees. The number of sections for a complete set of a certain size of pipe is seven, made up of 1, 2, 4, 8, 16, 32 and 64 deg., so that it is possible to get any combination of angles from 1 to 127 deg. Each section has a spigot on one half and a faucet on the other (Fig. 16). The turnover boards have a recess cut, following the radius of the bend into which the spigot half of the pattern is fitted (Fig. 16).

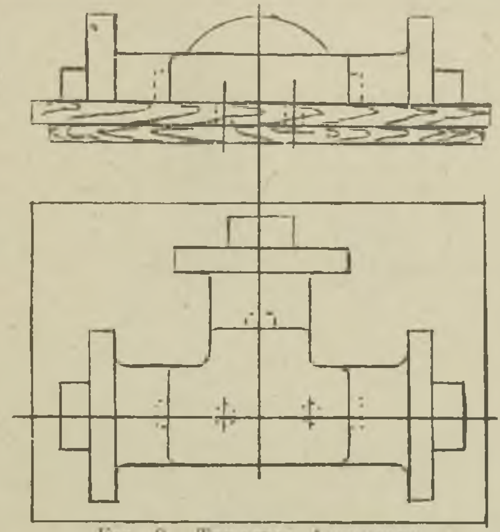

Fig. 9.—Tee-piece Assembled.

The coreboxes are constructed in degrees similar to the patterns, and are mounted on boards having a recess as in the pattern plate. Each section of the corebox has a spigot so that the whole can be assembled exactly as the pattern. In many cases half-coreboxes will prove sufficient, both for bends and branch pieces. Where machine moulding is adopted, it should be pointed out that, by having the holes arranged in the pattern plate so as to be symmetrical, and by using the drilling jig and standard dowels, half-patterns only may be employed, or by using two half patterns together two complete castings can be produced.

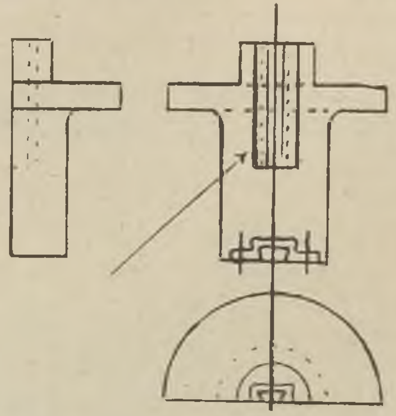

Fig. 10.—Showing Additional Dovetail for Machine Moulding.

The author has endeavoured to show something of what can be produced in a modern patternshop by modern methods of production, and also to draw attention to a system of pattern construction, the principle of which it may be possible to adapt to other classes of work.

In conclusion, the author wishes to thank the Wadkin Woodwork Machinery Company, who so kindly furnished the slides specially for the Paper, and also to Mr. H. Bonner, of Messrs. Grey's, of West Hartlepool, who gave him permission to make use of the " Building Method " of tee pieces and bends.

DISCUSSION.

Mr. J. W. Frier said he had seen something which he had not seen before, namely, the construction of patterns by the "Building-up Method," although, of course, it might not be new to some people. There were certain things Mr. Carr mentioned in his Paper which touched upon the question of the co-operation of the patternmaker and the foundryman, and the desirability of a better understanding and better working fellowship between them. He had heard it said that the patternmaker was *the* man and that the moulder only came next, but there were also cases where the patternmaker was said to be unnecessary. In such a foundry the moulders worked from drawings, and he had often seen them constructing parts of, say, a cylinder pattern out of a block of loam. The body of the cylinder was swept out with strickles, but the other parts of the coreboxes, he did not see, and, therefore, whether they were part skeleton or otherwise he would not like to say.

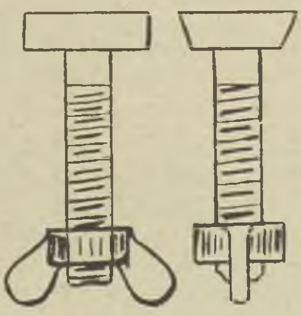

Fig. 11.—Showing Special Bolt for Machine Moulding.

Speaking from the foundrymen's point of view, he thought that Mr. Carr's method would be valuable and would save much time in the case of a firm which dealt with standard work, but that it could not very well be adopted in a place where jobbing work was done and where patterns were not kept as a general rule. He presumed that the method in question was designed for machine moulding. In his opinion it would have to be changed slightly for certain work. In conclusion he wished to congratulate Mr. Carr upon his very instructive Paper.

Mr. **Herbst** remarked that one point was not very clear to him, namely, how the pattern was fixed to the pattern plate for the machine, because it appeared to him that the nuts would get in the way.

Mr. **J. M. Smith** said he thought that from the remarks which had been made it was important, especially for the younger members of the craft, that, as a Branch, they should endeavour to pay a visit to one of the more modern foundries of the district, *i.e.*, one which specialised in machine moulding.

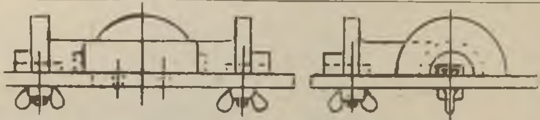

Fig. 12.—Pattern Assembled for Moulding Machine.

As the lecturer had explained, with machine moulding it was only necessary to use half the pattern. In the foundry the moulding box had to be made of uniform type so that top and bottom could be rammed off one half of the pattern. This applied not only to the particular kind of pattern shown that night, but to all kinds of present-day repeat moulding. It was a most interesting subject, and, to the younger men who had been brought up in a big jobbing foundry, where there was no repetition work, a visit of that nature would be an education in itself.

Mr. **G. W. Scott** said the "Building-up Method," which the lecturer had demonstrated, was a very ingenious one, but, of course, would only be useful where the firm had a good system of standardisation. Without that standardisation it would be very difficult to work it with effect.

Unfortunately, there were a good many firms which had not yet reached that degree of standardisation, but he quite saw that where this existed the method would be of great value and would solve some of the more difficult questions in the patternshop.

The Chairman said he thought that there was a standard system nowadays for the making of pipes generally. There was also a British standard for flanges, and this ought to reduce the amount of patterns, which had to be kept in stock.

Mr. C. Gresty said that there were one or two small points which appealed to him in connection with Mr. Carr's Paper.

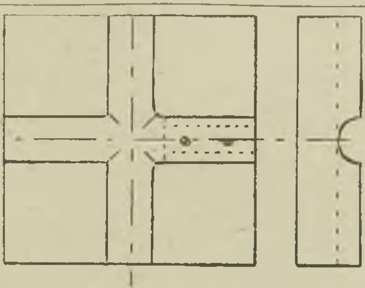

Fig. 13.—Core Box: The Reduced End is Shown by Dotted Lines.

He believed he was right in saying that a great many patterns for repetition work were nowadays made in metal, and he would like the lecturer's opinion as to how long a metal pattern would last as compared with one made of wood. Further, did the castings themselves show any improvement when a highly-polished metal pattern was used? He was also wondering who made these metal patterns and whether there was such a person as a "metal patternmaker."

Another question he wished to ask was whether the patternmaker could help the foundryman out of the difficulty of having to eliminate the use of chaplets? A foundryman was nowadays often ordered to make cast-iron castings without chaplets, and it struck him (the speaker) as being rather a tall order in some cases. Had Mr. Carr had any experience in that respect? Could the shape, size or length of the core prints be altered to help in this matter? Take, for instance, the ordinary globe valve, which contained one or two chaplets to support the core. Such castings, he believed, could be made without chaplets. Could the lecturer tell him whether, by altering the core prints, anything could be done to give the cores sufficient strength to do without chaplets?

In conclusion, he said that in common with the other speakers he had been very interested in the Paper, and it was the first one he had heard on pattern-making at any meeting of the Institute.

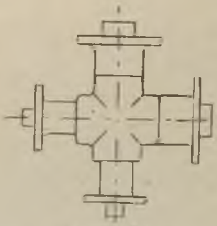

Fig. 14.

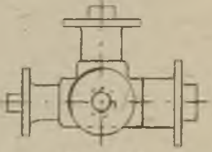

Fig. 15.

Author's Reply.

In reply to Mr. Frier, with regard to making cylinder patterns out of blocks of loam, Mr. Carr said he had heard of many foundry methods and what was possible in the foundry, but it was the first time he had heard of this being done. Other foundries claimed that they could make pipes out of pieces of sticks. Well, all he could say was that he had seen some of the pipes.

In reply to Mr. Herbst, the degree of accuracy which a patternmaker could attain now was a little higher at least than that of the prehistoric millwright. The patterns could be made on the pattern-plate so as to get the two halves definitely identical. This could be done quite easily with a turnover board, and, personally, he thought that the foundry did not exploit the latter to the extent that they might.

In answer to the Chairman's remarks with regard to the fixing of the pattern to the pattern-plate, the lecturer said that, with a suitable pattern-plate, the nuts did not get in the way as they were arranged so as to be clear of the machine table. Where the casting was symmetrical, one half-pattern only would be required, the top and bottom of the mould being made from the one half-pattern. Where the pattern was not symmetrical, however, it was necessary to use two pattern-plates, each having half of the pattern attached, or to use the two sides of the pattern-plate.

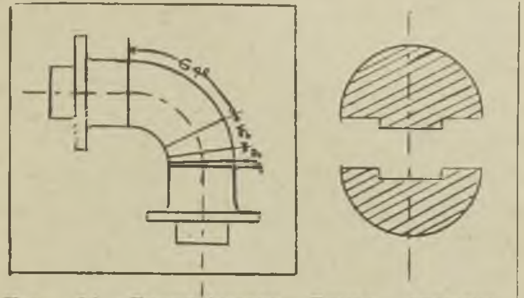

FIG. 16.—RIGHT-ANGLED BENDS SHOWING SECTIONS ASSEMBLED WITH STANDARD ENDS.

In reply to Mr. Gresty's first question, metal patterns would last a lifetime, whereas, of course, wood ones would not, but, with ordinary care in handling a wood pattern, it would last any amount of castings. He thought that one could get just as clean a mould from a hard wood as from a metal pattern, and did not think there was any difference in the castings produced.

In answer to Mr. Gresty's question as to who made the metal pattern, he said it depended upon the district in which one lived. In some districts there were men who did nothing else but make metal patterns. In a place where these patterns were not made as a general rule, however, the patternmaker did the job if he could get it, but if the authorities said that it could not be made in the pattern shop, then it had to go to the fitting shop. It all depended upon which was the stronger department.

With regard to the elimination of chaplets, whilst the patternmaker could assist the foundryman in that direction, the engineer could assist to a greater extent by designing the casting so that chaplets were not required. The lecturer then illustrated on the board how this could be done in the case of the globe valve.

Vote of Thanks.

A hearty vote of thanks was proposed to the lecturer by MR. C. GRESTY. MR. FRIER seconded, and said it was the first Paper of that type which they had had, and he was only sorry that there were not more patternmakers present to take part in the discussion.

Wales and Monmouth Branch.

MAKING A MOTOR ROAD ROLLER.

By Ben Hird, Member.

Fig. 1 illustrates a casting for the hind roller of a Barford Perkins motor road roller. It is 4 ft. 6 in. long by 4 ft. dia., whilst the thickness of the perifery and ends is 2¼ in. This casting weighs 3 tons, but larger sizes weighing 5 to 6 tons are made. The weights often are required to vary in the same size of rollers. This is effected by adding extra thickness to the perifery walls, by making the diameter of the core smaller. There is a 12½-in. diameter hole at each end, and also a facing ring at the end, as is shown in Fig. 1. These are machined to a definite length-gauge to receive the gudgeon-pin castings. This is the only

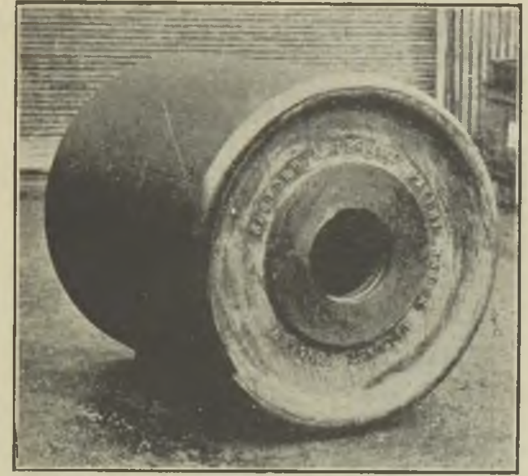

Fig. 1.—Roller for Motor Road Roller.

machining done to the rolls. The face of the perifery must be perfectly smooth and free from marks or swells. Therefore, the whole mould has

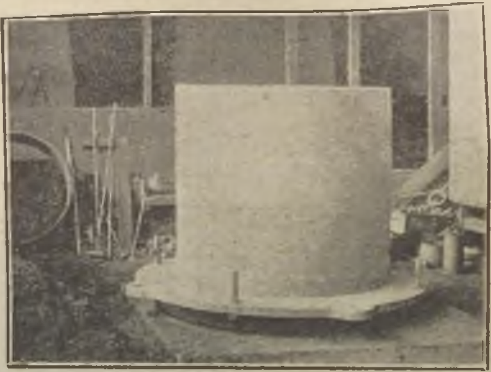

Fig. 2.—C.I. Cylinder used as Pattern for Middle Part.

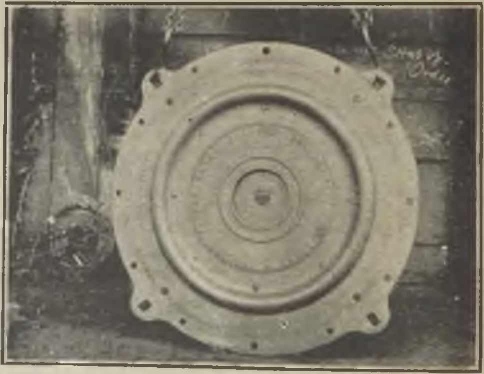

Fig. 3.—Pattern Plate for the Ends of the Roller.

to be wet blacked and thoroughly dried in a stove. The whole of the mould and core are rammed on a Mumford plain jolt ramming machine having a

6-ft. table and a lifting capacity of over 6 tons. They are finished and blacked by skilled moulders. At the opposite end to the one shown on the illustration a $1\frac{1}{2}$ in. diameter thimble or union with internal thread is cast in at the inside edge of the beading. This is used for filling the roll with water, which is used as ballast when heavier weight is required; it is plugged with an ordinary gas plug.

Fig. 2 shows the cast-iron cylinder which is used as a pattern for moulding the middle part of the mould; it is about 2 in. thick, and machined inside and out with a very slight taper on the outside. The four small holes in the top edge of the pattern are for inserting hooks to draw the pattern from the mould; this is done with the aid of a crane, the pattern being well rapped on the inside with wooden mallets before and during the operation.

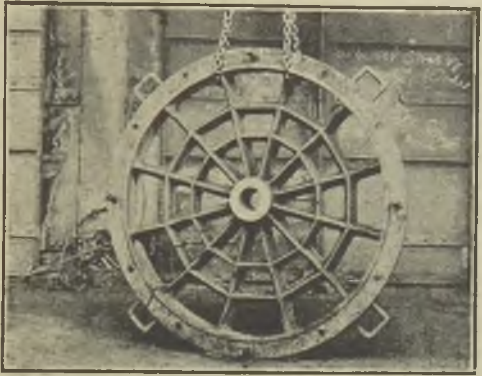

FIG. 4.—BOTTOM-PART BOX.

The table of the jolting machine is seen projecting about 2 in. above the floor level. On the table of the machine a cast-iron ring 5 in. deep and $2\frac{1}{2}$ in. thick, machined true on both edges, is placed. This is designed to take the pattern plate, which has lugs cast on and machined accurately with the centre, which engage the cylinder and hold it in position. On the other side is the pattern for moulding the top and bottom ends. The projecting round edge of the pattern fits easily inside the ring and helps to prevent any

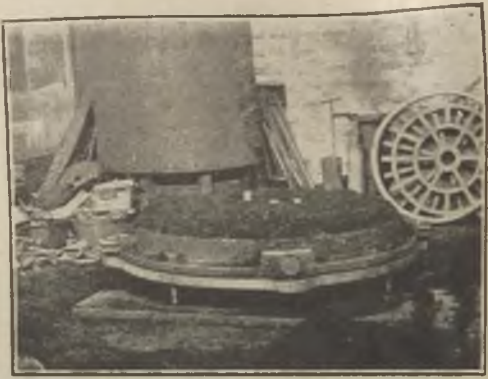

FIG. 5.—TOP PART FILLED WITH SAND READY FOR JOLTING.

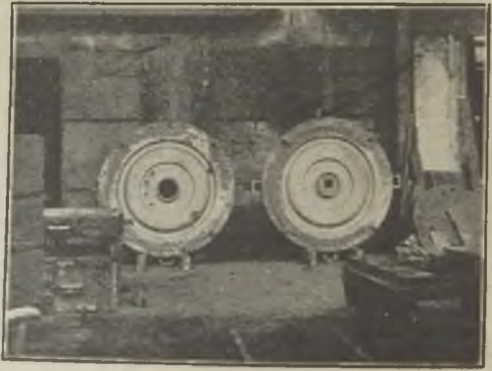

FIG. 6.—TOP AND BOTTOM PARTS READY FOR STOVING.

tendency of the pattern plate to slide off the ring. The four pins for setting the middle part of the box are drilled radially with the centre of the plate, and slotted for cotters, which are used for holding the box to the plate.

A 5-ton electric crane operates over the machine. There is also a 10-ton crane in this moulding bay. The two cranes co-operate to handle this job, and any others that happen to be under construction in the bay.

Arrangement of the Bay.

The jolt ramming machine is at the bottom end of the bay, quite close to the sand-mixing plant.

FIG. 7.—JOLTING UP THE MIDDLE SECTION.

In the centre of the moulding bay, finishing and casting of the moulds is carried out Near the top end are two large core stoves, and next to these at the very top end are the cupolas—one small one of about 24 in. inside diameter, and a larger one 36 in. diameter next to it. The large roll moulds are finished and blacked opposite to the stoves, and assembled and cast opposite the cupolas.

In Fig. 3 is shown the other side of the pattern plate, which is used for making the top and bottom parts of the roller. The part forming the round edge is detachable, so that it can be changed when square edge or slightly different sizes are required. The recess in the centre takes the centring boss of the bottom-part box. When making the top part, a centre pin about 10 in. dia. is located in the centre hole (as is shown in Fig. 4), and through which the core is held down and the gases escape. The facing piece is a loose wood ring located in the centre of the raised beading.

FIG. 8. C.I. CENTRING BOSS AND LONG EYE-BOLT FOR CARRYING THE CORE.

Moulding Box for the Bottom Part.

In the centre of Fig. 4 is shown the boss, which is bored with a good taper and faced true for receiving the centring pin of the core, when the job is being cored up. The bars are wedge-shaped in section, the thin edge being nearest the pattern, to allow the sand freedom to pack under the bars when being jolted. The top-part box is very similar, with the exception of the centre, which is a plain ring bar about 12 in. dia. The boxes are split through the edge and bars to allow for expansion and save them splitting in a more inconvenient place. As will be seen, the stout box handle acts as a cramp at this place. The pins are cotter-pins, and the holes round the edge for extra bolts for securing up before casting.

The top part is shown in Fig. 5 filled up with sand ready for jolting. The same ring that is used to support the middle-part plate is placed on the jolt table, the pattern plate put on this. The runner pegs are set on the loose facing ring, and the guide pin put in the centre. About 1½ in. of sand is riddled on over the face, the edges of the plate, where the box takes a bearing, swept clean, and the box bedded on and firmly cottered down through the pins. A few lifters are put in here and there to help to hold up the top during casting, and sand is filled in to 4 or 5 in. above the top of the bars, to allow surplus sand for jolting. The mould is then jolted about sixty to seventy jolts, the loose sand left on top is gone over with a flat rammer to tighten it, and then shovelled off level with the bars. The mould is then lifted off with the crane and taken away down the shop for finishing and blacking. The bottom part is made in almost the same manner. After the facing sand has been riddled on, the centre is cleared to allow the machined boss to take an iron to iron bearing on the plate.

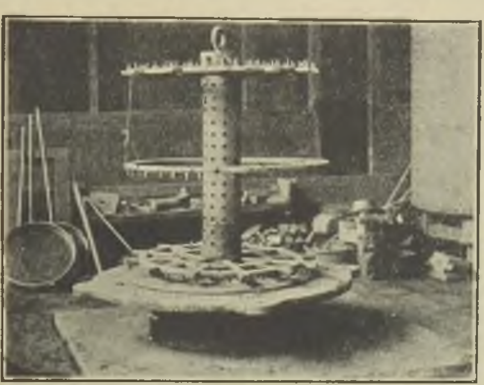

Fig. 9.—Skeleton for Constructing the Core.

In Fig. 6 is shown the top and bottom parts finished and blacked ready for putting into the stove. The left hand is the top and the right hand the bottom. On the top part in the facing piece are four runners and the riser off the top of the rounding edge. At the bottom left-hand corner is the threaded thimble, through which the roll can be filled with water for ballast. The projecting ring of sand round the centre hole takes a bearing on the core, which takes a bearing on a similar ridge on the bottom part, but the weight of the core is taken on the metal boss in the centre.

FIG. 10.—WITHDRAWING THE CENTRE CYLINDER.

The middle part, shown in Fig. 2, as has already been explained, is the cast-iron cylinder pattern in position on the plate. Before putting on the middle-part moulding-box, the outside pattern is well wiped over with a piece of waste soaked in paraffin.

The middle part is shown in position in Fig. 7, filled with sand and almost ready for jolting. The box part is built up of three separate sections. This was done for the purpose of adapting the boxes to suit various lengths of rollers. Small holes were drilled in the boxes for vent and to allow steam to escape during drying. There are four stout equally-spaced trunions for handling purposes, The conical arrangement surmounting the mould is made of sheet iron, and is placed on the top of the cylinder pattern to prevent the sand falling inside, and to provide a feeding head of sand while the mould is being jolted. The sheet-iron ring in front is placed on the top edge of the box to further assist in making this head of sand. When the sand has been piled up as high as possible and jolted, a second filling and jolting is necessary to ram the mould to the top. The first ramming settles the sand to about the top of the first joint; about sixty jolts are given to each ramming. The cone and ring are then removed, and the top edge finished off with a flat rammer. The mould and plate are removed down the shop for drawing the pattern and finishing the mould. So tightly is the sand packed, that one instance is recalled where the pattern, for some cause or other, had been left in the sand overnight; it clung to the pattern, and came out with it, stripping away from the sides of the box almost clean.

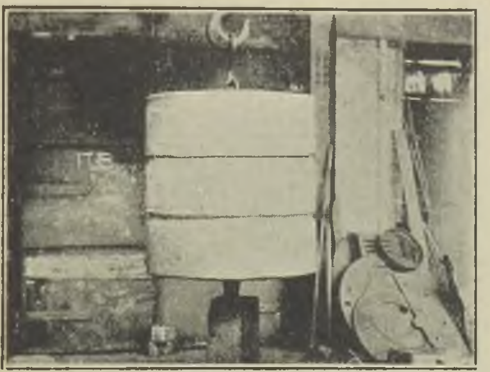

FIG. 11.—THE DRIED CORE READY FOR ASSEMBLING.

Core-making.

The making of the core is carried out on the jolt machine. For some months after the moulds had been successfully made, the cores were still rammed by hand. It was thought, if the outside could be rammed, so could the inside, and after trial it was found to be quite successful. Fig. 8 shows the cast-iron centring boss and the long eye-bolt for carrying the core. The iron boss is machined with taper on the small part, and faced true on the underside of the large part, it is tapped to take the small eye-bolt at the bottom and the long eye-bolt at the top. The tapered part is made an easy fit in the hole in the centre of the bottom part shown in Fig. 7. The curved sheet-iron plates are placed inside the cast-iron cylinder pattern to form the outside diameter of the core; these are made to various diameters to suit the thickness and weight of the roller as required.

Fig. 12.—The Assembled Core ready for Casting.

The skeleton of the core is shown in Fig. 9, and, like some other skeletons, part of it has been wired up, which explains the apparent suspension in mid-air of the centre ring. On the jolting table a ring about 11 in. deep is placed to allow for centring pin and small eye-bolt, which projects through the core plate; the centring pin is placed in a hole in the core plate just large enough to admit the small part, and securely fastened underneath with the small eye-bolt and washer. The hole for the long eye-bolt is plugged with waste. The cylinder pattern is now placed on the plate, and located by the raised pieces projecting above the plate. The two semi-circular sheet-iron plates for forming the thickness are placed inside, and sufficient sand shovelled in to allow for well bedding down the bottom core iron. The loose sand is cleared of the top of the centring pin, the waste taken out of the screw hole. A washer sufficiently large to engage the core iron is placed on the centre, and the large eye-bolt screwed down until its collar tightens on to the washer. More sand is thrown in and rammed by hand to about 2½ in. above the core iron. A smaller iron cylinder pattern is now placed in position in the centre, allowing space for about 3 in. of sand all round, which is now filled in level to the top, and the centre-core ring placed on this. When the core is jolted the ring settles with the sand to about a central position. More sand is filled in, and the core jolted solid to the top. The centre cylinder is then withdrawn (Fig. 10).

The vent barrel is now set in position and the centre space filled up with coke, which is given a few jolts to pack it. The coke and sand are now levelled off to just below the top of the vent barrel, and the top core iron bedded on.

The small cup or ring is set centrally on the core iron for packing to hold the core down, when closing the mould. Sand is now thrown on, and the ramming of the top face of the core is finished by hand, and strickled out to allow for the 2½ in. of thickness at the top end of the cylinder. The plate shown below the bottom core-iron forms the thickness at the bottom end (Fig. 9). The whole is now carried down the shop on the core plate by the crane, the cylinder pattern withdrawn, and the two half-circular sheet-iron pieces taken away. The core is finished and blacked by the moulders and put into the stove on the plate to dry. Two ribs for extra strength are cut by hand round the core.

Fig. 11 shows the dried core removed from the core plate and ready for lowering into the mould. The centring pin can be seen resting on the block.

The assembled mould is shown in Fig. 12, ready for pouring. The bridge across the top is holding down the core, which is packed on to the iron ring set into the top of the core by similar rings and wedged to the bridge.

Lancashire Branch.

SOME METALLURGICAL POINTS IN ELECTRIC STEEL CASTINGS AND NOTES ON DEFECTS.

By F. A. Melmoth (Mappin Medallist), Member.

The normal metallurgical procedure in the production of electric steels has been dealt with quite fully in many Papers submitted to members, and needs no further discussion at the moment. The writer feels, however, that there must be many users of electric furnaces, who, like himself, are occasionally thrown into contact with cases of abnormal behaviour—occasions when the usual metallurgical explanations fail to meet the case, and where known and demonstrated facts offer no acceptable elucidation of the trouble. With a view principally to stimulating discussion, the present Paper attempts to deal with one or two of these questions, and offers tentative theories, none of which is given with any degree of dogmatism.

Fluidity.

In previous Papers dealing with steel castings the writer has mentioned briefly the matter of the comparative fluidity of these steels. He has suggested that fluidity may not be a direct function of temperature and orthodox composition. The well-known difference in fluidity, or " life " as it is often called, existing between electric steels and converter steels of similar composition, has been explained theoretically in several ways. It has been stated in fact that the difference does not exist, and that given temperatures in either type will produce equal fluidity. The writer cannot, however, accept this, and he believes that most practical steel makers who have had the opportunity of working the two processes, side by side, on the same material, will agree that a marked difference does exist.

The suggestion has been put forward in explanation of this, that in the case of the converter metal, its method of production almost ensures the presence of dissolved oxides, which continue to react with the deoxidising elements added, with consequent production of heat during the period of casting. One would expect in this case to find an appreciable loss of such elements during this period, which is not borne out to any serious extent in practice.

As a contrast to this theory there is the possibility of the direct solution of oxygen, or oxides, which by their presence lower the solidification point of the steel, thus giving a longer liquid range and consequently increasing the "life" of the molten metal. The writer prefers to keep an open mind on this question, and would merely state a few observations carried out over a period of some years.

Method of Production.

Electric mild steels can be produced either by the single or double slag process, the choice depending on the quality of the scrap material to hand, or the degree of purity demanded in the product. In the double slag process the melting slag, high in oxides, is removed after melting is complete, and with it the bulk of the original phosphorus content of the charge. A new slag is then made on the metal by the addition of lime, and a small amount of spar, which slag after fusing, is kept decidedly reducing in action by the periodic addition of small quantities of anthracite coal dust or similar material. Such a slag rapidly removes oxidising conditions, and there is little doubt but that the bulk of the oxides are removed thus from the bath of liquid metal. Finishing alloys are added and, given sufficient heat, the material is cast in the ordinary way.

In the single slag process, however, all the operations are carried out under the one slag. This slag contains quite appreciable percentages of oxides, even up to the time of tapping the steel, and strongly reducing conditions are not present.

It has been the writer's experience that the single slag method of production produces a material more capable of running light sections, and easier to manipulate in hand shanks for small work, owing to its apparent greater degree of fluidity. He would reiterate that differences in composition from the orthodox standpoint are certainly not the reason, and as the difference is noticeable almost consistently over a great number of charges. it is unlikely that variations in temperature should always react in the one direction.

Effect of Strongly Reducing Slags.

It has been the experience of most producers of electric steels using two slags, and strongly reducing conditions, to come up against an occasional charge of an unusually viscous nature. The writer has experienced several such charges, and has been unable to associate the peculiarity with temperature. In conjunction with his colleague Mr. George Batty, Works Manager of the National Steel Foundry, he arranged for a close observation in this works, and the one with which he himself is connected. Electric furnaces of three different makes could by this means be observed, together with converter produced steels of the same general analysis.

The same conditions were found in both works. Certain charges, fortunately of infrequent occurrence, were found to be of such a sluggish nature, although extremely hot, that it was impossible to handle the material in shanks at all.

In order to ascertain whether this was in any way due to the strongly reducing conditions, steps were taken to remove promptly such conditions on each occasion that a charge behaved in this manner. By the addition of a small quantity of iron ore to the slag, or of rusty steel scrap to the bath, the slag was made slightly oxidising. The viscous condition was removed, and there is no doubt in the writer's opinion, therefore, that this sluggish condition is in some way connected with the strongly reducing conditions of the double slag process.

A point strongly noticeable about such charges when being cast was that in appearance they were very much hotter than converter metal of similar composition. They were glowing white, and invariably set over in a skin on the surface of the metal immediately it was in the shank.

This lead to the consideration of the possibility that the condition was one in which the material had the peculiarity of dissipating large amounts of its heat energy in the form of light. A singular point bearing on this, is that many of these charges could be satisfactorily cast from the bottom pouring ladle direct into the moulds although skimming over immediately if they exposed any appreciable surface, such as in a hand shank.

Mr. Victor Stobie's contribution to the discussion on the writer's Paper given at the Manchester Conference two years ago contained a striking point which can be taken as some confirmation of the above suggestion. In order to fill up some feeder heads, Mr. Stobie took wild highly oxidised electric furnace metal which had been subjected to no reducing slags. Ferro-silicon, etc., was added to quieten it, and much to Mr. Stobie's surprise the material ran perfectly and left the ladle quite clean. The interesting point in view of the writer's present remarks is that Mr. Stobie remarked on the *cold appearance* of the material as it was cast, in fact, the writer believes he likened it in colour to cast iron.

Effect of High Temperature and High Silicon Combined.

A second very uncomfortable type of happening which is also fortunately infrequent, is that of a charge which is hot and wild, and cannot be quietened by ferro-silicon additions except in very unusual quantities. Several of these have come under the writer's personal notice, and in almost every case, although a final sample taken from the furnace has been dead and apparently quite in order, the steel has risen badly in the moulds, and any castings made have been scrapped.

Returning the remaining liquid steel to the furnace and treating it for a further period under a reducing lime slag, although resulting in a sound furnace sample exactly as before, was only followed by the same result. If the steel were allowed to solidify, and the resulting metal then remelted and dealt with normally, no trouble was experienced. The most surprising fact was that silicon was invariably very high, often from 0.7 to 0.9 per cent., and the material hot.

Careful observation revealed that in most cases, either owing to poor bricks, or careless workmanship in control of the furnace, the roof and walls has been badly run, and the slag become consequently somewhat siliceous. Additions of ground anthracite coal to the slag obviously accounted for the high silicon content by the reduction of the silicon so obtained from the slag; but, why did the steel rise, and why was it necessary completely to solidify it and remelt before it could be made sound? Also, why were the furnace samples sound before tapping?

With all reserve, the writer suggests that in some manner, probably related to the silicon content, the steel possessed a greatly increased capacity for absorbing gases, and retaining them only in the fluid condition. These gases were thrown out of solution during solidification, and caused the steel to rise. The samples from the furnace taken in a slag-covered spoon were not subjected to the mould gases, and were therefore sound. The evidence still suggests, however, that it is possible the condition of the silicon content was different from that of a normal steel, and a little thought will show that quite a moderate form of the same trouble might account for many of the cases all steel founders come across, of apparently inexplicable unsoundness. There are undoubtedly many such cases, as where analysis is apparently correct, mould and cores in every way identical as nearly as is humanly possible, and yet there is the occurrence of most aggravating patches of trouble from unsoundness.

Contraction: Effect of Process.

A point of unusual interest is that of contraction when considered in the light of the above points. The normal contraction allowance for mild steels of the converter type is $\frac{3}{16}$ in. to the foot. For electric furnace steels, of the double slag type, which have been subjected to what the writer would call "over reducing" conditions, the common allowance is $\frac{1}{4}$ in. to the foot. As these steels are of practically the same composition, the question at once arises why should their degree of linear contraction vary? The writer can offer not the slightest feasible suggestion on the point, but careful measurements being made at the present time in the works with which he is connected, suggest that single slagged electric furnace charges, which have not been "over reduced," have a linear contraction practically identical with converter steels of similar composition. This does not seem to make it reasonable to associate the phenomenon with casting temperature, but it does appear to add substance to the writer's suggestion that steels of identical orthodox composition can behave in different manners, according to the conditions to which it is subjected during manufacture.

Behaviour in the Mould of Steels made by Different Processes.

Carrying the comparison of converter steels and electric steels, or single slagged and double-slagged electric steels, into the realms of practical behaviour in the mould, the writer has found some remarkable impressions in the minds of the moulders handling the various kinds of steels. He is not prepared to explain these away as the results of prejudice, in fact he feels that only the worst form of prejudice can cause one to ignore the intelligent observations of the moulders concerned. The writer is carrying on his efforts to check and prove or disprove many of the ideas put to him by such people, and is not prepared at the moment to offer more than mere comment. He would, however, assure members that even in the present stage of his inquiries he is convinced that the majority of these observations are founded on something more than fancy, and also that they are all in some way interconnected; comparative fluidity, linear contraction, behaviour to mould gases, etc.

It is a common impression that smaller risers are needed to produce soundness in a given section of converter steel than is the case with "over reduced" electric steel. The writer's own experience goes rather to prove this, and in connection with it would mention one point brought to his notice some time ago.

The chemist of the National Steel Foundry, Mr. Windsor, by which firm the writer was engaged at the time in a consulting capacity, stated most definitely that two tons of electric steel of the "over reduced" kind, occupied more ladle space than an equivalent weight of converter steel. As, in the solid form, the two steels are almost identical in weight for a given bulk, the writer would like to know whether this can be in any way interpreted as a reason for first the excessive contraction of such over reduced material, and secondly for the moulders' contention that such material requires larger feeding heads.

Absorption of Mould Gases.

Susceptibility to the effects of mould gases is another charge laid by the practical man against the "over reduced" electric steel. Regarding this, the writer asserts most emphatically that the most difficult steel in his experience from which to make a really sound casting is one which has been subjected for a too prolonged period to strongly reducing conditions. No obvious explanation occurs to the writer for such behaviour, but he would quite tentatively suggest the following as a theory which at any rate supplies a point for discussion, however incorrect it may ultimately be proved to be. In the molten superheated-condition, all these mild steels must possess a capacity for gas solution. This solution may be of temporary nature, the gases being evolved on solidification, or it may quite possibly be that in some cases the solution is permanent, and the gases are held in solution even in the solid condition. Is it possible that steels made in the conditions existing in the converter have used up their available capacity, in other words, are they in some fashion, saturated? And, is the material with which they are saturated, capable of being held in solution through solidification?

An affirmative reply to these questions would suggest that on coming into contact with mould gases, such steels, being incapable of taking them into solution, will drive them forward and merely displace them without absorption.

The atmosphere in which electric steels are made is very different, however; in fact, great claims are made for these furnaces on account of their atmosphere and degasifying conditions. Then, is it not conceivable to suppose that such steels arrive in the mould with a great capacity for absorbing, unfortunately often in an only temporary manner, large quantities of such gases as they encounter during pouring?

The writer feels that such a theory is difficult to substantiate by actual proof, but he believes that this temporary absorption of mould gases and their liberation on solidification is at the bottom of many steel foundry troubles. Many foundries add small quantities of aluminium actually to the stream of metal as the mould is being cast, and some founders state most emphatically that added thus it is much more effective in promoting soundness than when added to the ladle during pouring from the furnace. The writer is definitely inclined to agree with this, and would suggest that this belief might possibly be taken to have some connection with the theories above mentioned, on absorption of mould gases. Aluminium is believed to possess the capability not only of removing dissolved oxides but of conferring upon steel the capability of retaining gases in solid solution. If, therefore, it be added almost at the precise moment at which the steel absorbs such gases, and is actually present in the metallic form, it appears probable that such action will then take place with the greatest efficiency. The writer holds that aluminium added to rising steel in an endeavour to make it sound when cast is grossly bad practice, and the steel suffers in consequence, but he believes that small quantities added to well made, and deoxidised steels, tend to confer on the steel the capacity of dealing more satisfactorily with any gases with which the steel may come into contact during casting.

The foregoing would suggest that in order to obtain the most satisfactory results, silicon content should be no higher than is called for to ensure initial soundness in the steel, whilst it would be of benefit to keep manganese on the high side, say, from 0.7 to 0.9 per cent. This is found to be in accordance with actual practice. A high silicon, particularly if thin sections, calling for abnormally high temperature, are the order of the day, does not favour the production of sound castings but rather the reverse.

The metallurgical consideration of electric steel castings is closely bound to the question of sands, in fact, it is extremely difficult to deal usefully with one without the other. The writer would emphasise that it is not by any means a difficult matter to make perfectly sound mild steels electrically. To produce from such steel perfectly sound sand castings is altogether another question. Every practical foundry man attaches due importance to the effects of sand, variations in its physical and chemical condition, its moisture, and the degree of ramming to which it is subjected. He takes it as an accepted fact that all these points can materially affect the successful production of a casting, even given well-made metal.

Suggested Research.

Whilst realising this, it appears to the writer that the line of progress from the purely metallurgical side, is in the direction of the study of mould effects upon liquid metal, and the subsequent attempt to produce steels less affected by such actions. Accepting the fact that highly superheated steels may and probably do, dissolve large amounts of gas when cast, then fairly obviously a profitable line of investigation exists in two directions. The first, can any conditions be induced in the steel in which it shows this solvent action to a lessened degree, and second, can the steel's chemical constitution be made of such a type as to favour the permanent solution of these gases in the solidified condition?

Assuming there to be any foundation of fact in the suggestions previously made in this paper, then the assumption would be that the first condition is affected by the silicon content. In other words, excess silicon with high temperature, has a tendency to increase the temporary solution of gases, and their partial evolution on solidification. The second condition, again assuming the general accuracy of the observations, would be affected by both aluminium and manganese, each of which appear to favour the retention of dissolved gases in the solidified metal.

DEFECTS IN STEEL CASTINGS.

In a Paper of this type, it would appear that only defects of a metallurgical kind should be dealt with, but as previously stated, defects due to metal and defects due to other factors affecting the metal are too closely related to be usefully discussed separately.

Porosity.

The most common defect is porosity, and this may be of several kinds. When directly attributable to metal, it is due to an oxidised condition of the steel, and denotes incorrect furnace manipulation. Fortunately, analysis will almost always explain the trouble, and no ambiguity exists in allocating the blame.

There are, however, many cases of porosity, or sponginess, which cannot be so easily dealt with. The association of porosity with the condition of the metal as handed to the moulder, in all cases, is not unknown to the writer, and whilst this constitutes a very convenient attitude for the moulder, it ignores some of the most important factors in the production of steel castings. Badly-vented moulds or cores, a more or less impermeable sand, an excess of moisture, or the existence of steam in a partially dried alleged *dry* mould, can all cause sponginess, sometimes locally in the casting, and sometimes general.

In connection with porosity an interesting point is the consideration of the comparative liability of steels made by different processes, to this defect.

Contributing to the discussion on Mr. Bradley's Paper on Light Steel Castings given at the Birmingham Conference a few years ago, Mr. D. Wilkinson, whose experience of light steel castings is extensive, emphasised the necessity for the highest attainable temperature of casting to ensure soundness. Mr. Wilkinson is, of course, at present producing his metal by the converter process. The writer having some experience of this metal is inclined to agree, but does not consider it advisable to classify this and the behaviour of electrically-produced steel in the same category.

It does most certainly appear that porosity is a decided possibility in electric steel, cast into sand moulds, as a direct outcome of too high a casting temperature. Many cases of abnormally-hot charges showing porosity in the first castings made, whilst the metal was at its hottest, have come to the writer's notice. Analyses was identical in both porous and sound castings, the only difference being that the sound castings were poured from metal which had lost its first extreme heat. Close observation has confirmed the opinion that whilst hot metal is an absolute necessity, yet a point exists beyond which the liability to unsoundness is markedly increased. If the suggestions made earlier in this Paper can be applied, an explanation is forthcoming. The gas solubility capacity of the steel, and the writer refers to temporary solubility, is increased by the high degree of superheat, with the consequence that quantities of gases, in solution at high temperatures, are thrown out on approaching solidification, with consequent unsoundness in the casting. The suggestion previously made that converter-produced steels have a less available gas-dissolving capacity would offer an explanation of the difference in behaviour of the steels referred to by Mr. Wilkinson, and those being now discussed.

Another possible cause of porosity which is intimately connected with steel production is possible slag action in the ladle. Should the slag be allowed to become in any degree oxidizing just before pouring, its churning up with the steel during pouring from the furnace is liable to produce reaction between its contained iron oxide and the deoxidizing elements of the steel. This may result in their being reduced to a point at which they are incapable of ensuring soundness, and porosity in the castings will result.

Obviously in cases definitely associated with faults in the metal, such as have been mentioned, evidence exists which allocates the blame comparatively easily. Analysis, where silicon is too low for safety, prevents any possible argument. In the latter case, where slag action in the ladle is involved, an inspection of the slag will immediately suggest the cause of the trouble. Even in the case of an excessive temperature of casting, the fact that only the first castings poured are affected, tends to the assumption that excessive temperature has been the culprit. It is therefore an easier matter to deal with such cases of porosity than others which may be due to one or more of a number of reasons connected with the mould itself. Defective venting, wet sand, close impermeable moulds due to too fine a grade of sand, or an excessive amount of a clayey bond, are all serious contributive factors to porosity. In almost all cases where castings suffer from porosity directly due to metal, such porosity is general, and all castings from the particular charge are affected. Odd cases of porosity or local porosity in a casting are naturally much more likely to come under the category of moulding defects than metallurgical manipulation.

Contraction Cracks.

Unless special precautions are taken in the mould, mild steel castings, particularly if of a fragile light-sectioned nature, are very liable to crack on cooling. Metallurgical error can undoubtedly contribute to this.

Mild steels, high in sulphur, are notably tender when cooling from the liquid condition. To some extent this can be counteracted by working with a fairly high manganese content. By the formation of manganese sulphide in such a manner, which exists as minute dots throughout the steel, the alternative formation of iron sulphide is prevented. Iron sulphide having a low fusion point, exists between the iron crystals in a more or less filmy form, thus partially destroying their cohesion. After the crystals are formed and the material solidified, such sulphide can still remain fluid, causing the material to be excessively weak at a red heat, and to offer little resistance to the strains to which it is subjected during cooling and contraction.

Here again, analysis points out the cause, which should never be existent in basic electric steel. One of the most valuable properties of the basic electric furnace is its ability to produce with ease very low-sulphur material.

Badly made steel, tapped in a rising condition. is sometimes corrected and made apparently sound by overdoses of aluminium. The writer has previously condemned this as very bad practice, but would add that such material is also very liable to crack in the castings. This is no doubt due to the inclusion of quantities of non-metallic material, such as alumina.

Given a good steel, and normally careful methods of moulding to prevent cracks, the writer is of the opinion that faulty designing is responsible for more trouble with cracked castings than any other cause. Designs are often submitted to the steel founder which have been evolved quite obviously with only one object in view, namely, to fit into the place desired by the designer. The writer believes most strongly that a short course of steel foundry instruction should be a component part of the training of all designers engaged on parts for production as steel castings. Indiscriminate variation of section, the existence of large bosses demanded solid on otherwise thin sectioned castings, are often a perfect bugbear to the steel foundryman, and his failure to give satisfaction is no doubt attributed to his ignorance. Whilst intelligence properly applied when making the moulds will assist materially in preventing such cracks, no skill of the moulder will reverse the natural laws governing the solidification and cooling of steel. Its comparatively high degree of contraction, its high melting-point, and weakness at high temperatures are all definite laws over which the founder can exert no control. He can only take all possible precautions to prevent their causing an excessive degree of trouble. In the writer's opinion such points should also receive the careful consideration of the designer. Granting the engineering demand as regards general design, he should as far as possible bear in mind the following points:—(*a*) Section of metal should be as even as practicable; (*b*) sharp changes of section and sharp corners avoided wherever possible; and (*c*) the minimum number of heavy bosses, which latter should be cored out if in an inaccessible position for feeding, a state of affairs which often exists. A consideration of these simple points would most decidedly minimise the tendency to crack exhibited by many castings, particularly of the automobile type.

Contraction Cavities or "Draws."

The liquid contraction of steel being considerable, steel castings are somewhat prone to this trouble. Heavy risers are often necessary, and careful attention to their point of application and shape is one of the vital points in the production of sound castings. Design will not always permit of correct methods being applied, and here again the consideration of the designer is called for. In order to mitigate the ill-effects of contraction where feeding is rendered difficult by design, various methods are resorted to. The insertion of nails, the application of internal and external chills are common methods applied.

Although these methods are often successful in degree, it must be admitted, however, that they carry with them the possibility of introducing other troubles. Design of chills and their comparative thickness must be carefully studied in relation to the job being made, or very often the latter state of the casting is worse than its first. External chills, for instance, if too severe in their effect, are very liable to cause serious cracks. The object of chills being to induce comparatively even temperature conditions throughout a cooling casting by the abstraction of heat from the thicker portions, it follows that an excessive chill effect will defeat this object, and merely remove the position of the trouble from one part of the casting to another. Soundness may be improved from the drawing standpoint, but cracking troubles encouraged.

Internal chills, say in heavy bosses, are very useful to the steel foundryman when design will not permit of satisfactory feeding arrangements, but here again great caution is necessary if trouble is not to result. In green-sand moulds moisture is very apt to deposit itself on chills or nails, and if moulds are left closed too long before casting almost certain blowing can be expected.

It has appeared to the writer that many defects described by the practical moulder as draws are in fact blows, or in some cases a combination of the two. Some years of observation have convinced him that could gas occlusion, caused either by blowing in its many forms or by the turbulence of the steel during the pouring operation, be entirely prevented, much of the trouble attributed to "drawing" would not be present. This will be considered further in the next section of the Paper referring to blown castings.

Blown Castings.

This defect will be considered as altogether a separate one from blowholes, which previously have been discussed under the heading of porosity. Whereas the former occur as numerous small holes either general or in some local part, the type now being dealt with generally exhibits itself as a large cavity, existing in one or more parts of a casting.

In almost all cases it can definitely be assigned a cause without difficulty. Ineffective or non-existent venting of cores or moulds, the use of wet or dirty chills, are the usual causes. Design in this instance can once again contribute materially. Comparatively small, deep recesses in the vicinity of heavy sections of metal will almost without fail cause a blow, which will usually pass into the heavy section. Very often this can be seen immediately the casting is cleaned, as the hole caused by the blow comes right to the surface, but often the metal closes behind the gases penetrating the steel, and the hole caused is not discovered until machining operations are well advanced.

DISCUSSION.

In the absence of the Author, this Paper was read by Mr. G. Batty, Technical Director of the National Steel Foundry (1914), Limited.

The discussion was opened by the Chairman (Mr. J. Masters), who asked for information as to the effect of the higher casting temperature of basic electric steel. This might be the cause of the additional contraction which was experienced.

Mr. Batty agreed that high-casting temperature was a contributory factor to additional contraction, but the higher casting temperature of basic electric steel, as compared with converter metal, by no means covered the whole difference. It did not seem logical that casting temperature should affect the actual freezing temperature of the metal, but experience appeared to indicate that this was the case.

Contraction was covered by the difference between mould dimensions and the ultimate dimensions of the cold casting. Steel, whether cast into sand moulds or chill moulds, solidified on a system which might be described as a continuously thickening envelope. One must visualise an initial solid envelope formed within a very short space of time after the metal touched the mould. This initial envelope was maintained in tight contact with the faces of the mould for a certain length of time by the ferro-static pressure exerted by the liquid steel within the initial envelope. As the envelope thickened and was able to exert a force greater than the ferrostatic pressure of the liquid interior of the casting, the component began to contract consonantly with decreasing temperature. In the case of both hot-cast and cool-cast metal, the initial envelope is maintained for a certain length of time in contact with the mould, but it is fairly certain that the metal which is cool-cast has a greater rapidity of thickening of the initial envelope than has the hot-cast component. It seems reasonable to assume that hot-cast metal will bake the mould more extensively than will the cool-cast metal, and, therefore, the hot-cast metal should create a greater mould-resistance to contraction. He was speaking of metal cast into green-sand moulds, and he thought the members would agree that it was somewhat contradictory that hot-cast metal, having a tendency to increase the resistance offered by the mould to contraction, should actually contract to a greater extent than metal which was cast at a lower temperature, and, therefore, produced a less degree of mould resistance to contraction. It might be that he was attaching undue importance to the baking effect of the metal upon a green-sand mould, but, even if the baking effect was non-significant, it must be remembered that the additional contraction experienced with hot-cast metal indicated that a high casting temperature resulted in a higher freezing temperature. Such a point appeared to be incapable of proof, but general observations tended to indicate that the solidification temperature was definitely affected by casting temperature. What they were discussing at the moment was contraction in the solid condition as distinct from the liquid or fluid contraction. The point was proved very definitely by one incident in his experience.

Contraction in Wheel Castings.

Two wheels from the same pattern were cast from one heat of basic electric steel, one being cast whilst the metal was very hot, the other being cast from practically the last metal in the ladle. The moulds were, as nearly as possible, identical in degree of ramming, and they were of practically identical dimensions; yet the hot-cast metal had a contraction appreciably greater than that of the cool-cast wheel. It would, therefore, seem that for practical purposes they must assume that a high casting temperature involved the raising of the solidification temperature.

Liquid Contraction.

As to liquid contraction, he could give some definite information obtained by casting ingots which were subsequently split and carefully measured to determine the volume of fluid contraction cavity. Certain ingots of basic electric steel, cast at a temperature which formerly pertained in the works he was visiting, showed a liquid contraction of 4.1 per cent. A very hot-cast example showed a liquid contraction of 4.5 per cent.; the cool-cast ingots had a liquid contraction of approximately 3 per cent. These ingots were cast at a speed somewhat in excess of the casting speed which pertained in most British works; therefore the "auto-feeding" of the lower levels of the ingots was not accomplished to anything like the normal extent. When considering steel castings, however, it should be remembered that the quenching effect of a sand mould was very much less than that of an ingot mould unless the section of metal being cast in a sand mould was very thin. It was fairly certain that the liquid contraction of basic electric steel was appreciably greater than that of converter steel of the same chemical composition, as indicated by a statement of the contents of carbon, silicon, manganese, sulphur, and phosphorus. This necessitated, provided identical methods of running were used, the imposition of larger risers or sink heads on castings produced from basic electric steel.

Mr. T. Makemson said it occurred to him that very high contraction would introduce fresh moulding troubles with steel castings, or complicate those which existed. Mr. Melmoth himself had pointed out that the moulders had noticed this, and insisted on a larger feeding head than was usually necessary. Perhaps Mr. Batty would tell them whether this excessive contraction had any other noticeable effect upon moulding troubles. They knew that in steel castings generally contraction did introduce all sorts of complications that did not occur in cast iron, and it occurred to him that the complications might be intensified by the excessive contraction with this particular type of electric steel castings.

He had always been under the impression that with the electric furnace one obtained castings of the highest quality, but at a corresponding price, largely owing to the very high cost of electric current. He therefore wished to ask how the cost of these castings compared with that of steel castings made by the converter process or the open-hearth process. He had an impression that the cost was higher. At the same time it was a practical fact that many firms, including Mr. Melmoth's and Mr. Batty's, who produced electric steel castings, were successfully competing with the producers of other types.

Actual Contraction Determined.

Mr. Batty said he had determined what he believed to be a true normal contraction of basic electric steel for the conditions which pertained in the foundry he controlled. Straight bars were moulded 12 in. long, 1 in. square, in cross-section. At each end of the mould a small metal stop was placed—being located contacting with the pattern—and the distance between these stops was carefully measured before the mould was closed. The resultant bars were measured in the cold condition at the points indicated by the metal stops, and at their normal casting temperatures they had a solid contraction of 2.406 per cent.

Cost of Electric Steel Castings.

With regard to cost, it must be admitted that the electric furnace product was likely to be more expensive, because of the extra precautions which had to be taken to ensure mould collapse under the stress of the contracting casting. This did not refer necessarily to cores, but to relieving the mould. Provision for eliminating almost entirely mould resistance might be achieved, in the case of many castings, by adjusting the composition of the moulding sand when green-sand production prevails, but with dry-sand moulds it was frequently necessary to take extra precautions to relieve the moulds. This involved extra expenditure, which affected the ultimate cost of the casting. Then again the provision of larger risers increased the proportion of discard and consequently reduced the proportionate yield of saleable castings in relation to weight of metal in ladle. He earnestly recommended a study of the methods which might be adopted in running castings; as a guide-post he would say that it was illogical to expect cool metal in a riser efficiently to feed hot metal in the body of a casting. Converter metal, he believed, was cheaper in the ladle than a high-grade basic electric steel; therefore, with the cost increments indicated, there could be no doubt that basic electric steel castings were a more expensive proposition. But it must not be forgotten that the castings in commerce, produced by the two methods under discussion, were by no means identical in composition. The basic electric steel was much purer, much freer from the deleterious constituents, sulphur and phosphorus. He felt that he was stating a fact in saying that basic electric steel castings were superior to those made by the converter process. He had in mind comparative destruction tests made by certain of their customers, such tests being amplified by observations on the properties of components throughout extended service.

The comparison with the cost of open-hearth steel castings could be made in the same way, taking the fundamental factor of the cost of metal in ladle, plus the cost increments indicated as being potentially applicable to electric steels.

Mr. Melmoth's Paper indicated, and he was able to support the statement, that steel must be carefully made in the basic electric furnace if losses from spongy castings were to be avoided. He quite agreed that a heat, high in silicon, cast at a high temperature, was likely to produce that form of unsoundness which was generally known as sponginess.

Then there was the liability to over-reduced steel in the electric furnace. That feature must be covered fully in its significance in relation to lack of fluidity and to its abnormal contraction, in addition to the liability, on certain occasions, to sponginess.

Fluidity.

Observations on a large number of heats of basic electric steel pointed to the conclusion that fluidity was related to the presence of a dissolved oxide or sub-oxide of iron in the liquid steel. One instance which occurred at Braintree was very significant, and pointed definitely to an association of dissolved oxide of iron with fluidity. A heat of electric furnace metal was tested for fluidity by taking a spoon sample from the bath, the sample being free from slag on the surface, and, counting in seconds, the time taken for the metal in the spoon to film over on the surface. This spoon time-test, as it was termed, was usually a fair indication of the way in which the metal would behave. In the specific case he was referring to a heat of 50 cwts. of metal, obviously very hot, would not give a spoon time-test of more than 22 seconds. Slag samples showed white, and were evidence of perfect reducing conditions. He would go further, and say that a perfectly white slag was evidence of over-reducing conditions. To this charge of 50 cwts. was added 1 cwt. of rusty plate scrap, the plates being approximately $\frac{1}{8}$ in. thick. This scrap was rabbled into the bath, being very rapidly melted. A spoon sample taken within two minutes of adding the rusty scrap to the bath gave a time-test of 48 seconds. The "finishings," consisting of ferro-silicon and ferro-manganese, were added, and a spoon time-test taken four minutes thereafter gave a reading of 38 seconds. Here they would note the effect of the addition of silicon upon the fluidity or fluid life of the metal. This 50 cwts. heat was tapped into the ladle, 40 cwts. was subsequently distributed to the moulds on the casting floor by hand shanks, and the remaining half ton of metal was cast direct from the ladle into moulds. The whole of the metal ran cleanly from the ladle, and he was quite certain that very little of the heat could have been distributed by means of hand shank if it had been tapped before the addition of the oxide of iron on the scrap. It must be remembered that the addition of cold scrap must reduce materially the temperature of the bath, yet the fluidity increased enormously. The conclusion that fluidity was related to the presence, in an unknown quantity, of dissolved oxide of iron, had been supported in many subsequent instances, oxide being added either in the form of ore or in the form of mill scale. The use of rusty scrap applied when the bath was obviously very hot as well as sluggish.

Fluidity and Light Emission.

The peculiar behaviour of over-reduced electric steel in the hand-shank was a very serious thing in a foundry producing a large number of small castings which might not safely be produced by casting direct from the bottom-pour ladle; and it was imperative that the over-reduced condition be readily recognised and eliminated before the metal was tapped from the furnace. It was very easy to obtain, in the basic electric furnace, excessively strongly reducing conditions which caused the phenomenal behaviour of filming over in the hand-shank mentioned by Mr. Melmoth in the Paper. Some years ago Dr. McCance, in discussing the difficulties of bottom-pouring ingots of certain steels, especially chromium steels and high silicon steels, suggested that these steels gave up a great deal of their surface heat as light, and hence lost very rapidly their fluidity. It seemed to him that the steels of which Dr. McCance was speaking were, because of their composition, likely to be free from dissolved oxides, and that perfect reducing conditions, which were so readily obtainable in the electric furnace, served, in a mild steel, to eliminate such dissolved oxides as were assumed to be a normal constituent of converter or open-hearth steels.

Mr. Batty said a steel was considered to be reduced when free oxide of iron, such as would cause sponginess, was eliminated. The term "over-reduced" was possibly the shortest definition which indicated the elimination of dissolved oxide or sub-oxide of iron, which he assumed to be present in mild steels of the plain carbon type produced by the converter or open-hearth processes. In the basic electric furnace reducing conditions were brought about by a combination of ferro-silicon and powdered anthracite or other carbon medium. The general practice, after the oxidising slag had been removed, was to add sufficient silicon to deoxidise the bath, and to leave remaining approximately 0.10 per cent. silicon in the steel. Additions of carbon were made to the slag so that a smaller amount of silicon might efficiently deoxidise the steel, the silicon being the vehicle of the reaction. Briefly, "reduced" referred to a steel from which free oxide of iron has been eliminated, and "over-reduced" indicated a steel from which dissolved oxides, in addition to free oxides, have been eliminated. It was not claimed that the incidence of dissolved oxides was a fact, but it was claimed that a great deal of strong evidence could be adduced in support of the contention that fluidity in mild steels was related to the presence of an undetermined quantity of dissolved oxide of iron.

Spongy castings contained blowholes filled with gas which had been evolved by the steel. Mr. Melmoth had indicated in his Paper that analysis would show whether or not the steel was of a composition likely to be uncontaminated by free oxide of iron. A steel which contained in the liquid condition any appreciable amount of free oxide of iron was almost certain to produce spongy castings, and he suggested that this was due to an extraordinary capacity for gas solution by a mild steel, at a high temperature, containing appreciably more than the customary content of silicon. It was possible that a mild steel of a high-silicon content was, at high temperatures, involved in an encyclic reaction productive of free oxide of iron but such a theory was difficult of proof; probably a careful series of analyses covering the composition of the gases in the blowholes might throw a good deal more light on the subject. It was probable that a very minute quantity of free oxide of iron might cause sponginess of a serious degree as a result of an initial reaction, probably in the range of temperature where the metal was just solidifying between oxide of iron and carbide of iron. Expressed simply this reaction read:—$FeO + Fe_3C = 4Fe + CO$.

This initial gas bubble might actually induce from solution in the metal a considerable volume of gas which would otherwise have been retained in solid solution.

Blows from cores or from corners of a mould were due to an entirely different set of circumstances, and should not be confused with any deficiency of the metal such as results in spongy castings. Mr. Melmoth made this point perfectly plain in his Paper.

Usually it was a matter of no difficulty to secure collaboration between a foundry and the designers employed by the foundry's customers, and his own experience was that such collaboration had made for him a number of friends. But there had been cases where the designer had refused to abate, in any particular whatsoever, his demands upon the foundry, with the result that the foundry had been involved in serious losses before the weight of fact compelled the designer to admit reluctantly that his proposition was impracticable. However, they must thank the designer for keeping them moving forward; in many cases the difficulties propounded by him had brought about a higher skill in moulding and the evolution of certain foundry expedients which otherwise might håve remained undiscovered for a considerable time.

In the production of steel castings, chills, either external or internal, were used to promote uniformity in the temperature gradient of the casting. Another purpose for which they were used was to eliminate risers on certain parts of castings, such as bosses, the bosses being subsequently drilled or bared and the chill totally removed. If neither chill nor riser were applied there would be a contraction cavity in the boss which would create considerable difficulty in drilling the requisite hole. Of course certain internal chills were never removed by any subsequent machining operation on the casting, their function being to produce a uniformity of temperature in the casting and to maintain as nearly as practicable a uniformity in the temperature gradient of the casting, so as to avoid any undue stressing of the component.

Shape of Risers.

The shape of risers depended somewhat upon the method of running. One must never lose sight of the fact that steel freezes as a continuously thickening envelope, therefore risers should not be "necked." Otherwise there was a danger of feeding the neck sound but leaving the casting below the neck unsound.

The art of steel-making consisted very largely of a knowledge of a number of small details, and although one detail, by itself, might not appear to have great significance, its inter-relationship with other details demanded most careful scrutiny.

He regretted that he was not able to deal with the more abstruse scientific considerations involved so fully as Mr. Melmoth would have done. Some of the theories he had put forward might sound somewhat extravagant, but the application of them had led to definite valuable commercial results. Those responsible for the production of wealth in commerce might be content with an incomplete theory or definition, provided they were able to focus facts to the extent of securing reductions in costs of production. If they functioned as producers or conservors of wealth they must be content to be known by their works rather than by their words.

Super-Reduced Steels Loose Fluidity.

Mr. G. C. Grant stated that rustless steel castings were being successfully produced in Manchester, and it was found that the successful casting of this material was dependent upon the heat of the metal in the ladle and the method of running.

He substantiated Mr. Batty's remarks regarding the elements silicon, manganese and chromium in mild steel, and stated that a small percentage of titanium had a similar effect of turning what was obviously a hot heat and which normally would have run through a $\frac{3}{4}$-in. nozzle without difficulty, into a condition in which it was only got out of the ladle with difficulty. Although he was unable to ascribe the reason, the fact remained that super-reduced steels were less fluid.

Mr. Batty replied that he quite agreed that titanium, in common with certain other elements, was competent to eliminate dissolved oxide of iron and would therefore be likely to produce the sluggish over-reduced condition.

Vote of Thanks.

Mr. J. S. G. Primrose said it gave him great pleasure to move a vote of thanks to Mr. Melmoth and Mr. Batty for having put before the members an admirable Paper which covered a great deal of ground, the value of which they would be able to appreciate when they were able to study it in printed form. It was an interesting historical fact which not many people knew, that Messrs. Laske and Elliott of Braintree was the first firm in this country at whose works the electric furnace was used commercially for producing steel. Sheffield might have a claim to priority in respect to experimental work in that direction, but actual commercial production began at Braintree. There also the first electric non-ferrous metal furnace was started.

He would like Mr. Batty to give them a more precise explanation of what was meant by "over-reduced" steel.

Mr. S. G. Smith, in seconding the vote of thanks, said the troubles of the steel founder appeared to be very much akin to those experienced in the iron foundry, but probably in some phases they were intensified, due to the increase in liquid and solid contraction. He was in full agreement with Mr. Melmoth's suggestion that the designer of steel castings should serve a term in the steel foundry. It applied equally to the iron foundry, and he had advocated it for many years.

Mr. Melmoth did not appear to be entirely in favour of using chills, applied internally or externally, because troubles might arise from them. That was the impression made on his mind after listening to the Paper. What method could be substituted where it was desired to equalise solidifying conditions? It was assumed, of course, that the design of the pattern could not be altered.

Mr. Batty had stated that the utmost importance should be attached to the locality of the risers. This, again, applied equally to the iron foundry. Wherever it was possible the runners should be located at the parts that would cool first, thereby making the cooling of the casting more uniform and avoiding irregularities in shrinkage, both liquid and solid. To put the runners in the thick section of the casting was a mistake often made in the iron foundry.

The vote of thanks was passed unanimously.

Lancashire Branch
(BURNLEY SECTION).

OIL-SAND CORES AND PRODUCTION.

By W. West, Member.

The application of oil sand as a means to foundry production has been by this time definitely confirmed in everyday practice. The ease with which the sand mixtures can be made, and the subsequent baking, are factors admirably suited to foundry work in general, and of which no foundryman need have any doubts as to success. It is, however, of the utmost importance among the practical details of oil-sand preparation that a suitable mixing vessel be used, to ensure an even distribution of the oil over the sand grains. The ordinary paddle mixer to be had on the market to-day is well adapted for the mixing process, but in some cases where the addition of certain gums are made, which are necessary for intricate and overhanging types of cores, the maximum amount of green bond will be obtained by passing the mixture through mullers of medium weight. It is generally recognised that ordinary shore sand is of excellent quality to meet the necessary requirements, the grain size being of a finer mesh than that of a river sand, a better finish is obtained on the surface of the casting, at, incidentally, a very much lower cost. Little or no serious disadvantage is experienced from the presence of salt, nor yet from the small pieces of sea shell that are distributed among the mass. Where cores are required to take positions in which they are more or less surrounded by liquid metal, it is advisable to make small additions of an open-grained sand to ensure permeability.

Much discussion has arisen from time to time concerning the condition of the sand, whether such should be dry or damp. The answer depends very much upon the facilities to hand, the layout of the plant, and the object to which efforts are being made. If the work to be executed is not of a repetition character and of only limited quantity, when the laying down of the necessary drying plant would not be warranted, then the use of damp sand is not of any great moment, but may, if wisely handled, prove to be a factor of economy and a means of making the core more permeable to gas, through the evaporation of the water vapour.

Production of repetition castings, however, calls for dried sand, the degree of dampness is an indefinite and variable factor which tends to cause irregularities in the resultant cores. In addition to this, the accompanying prolongation of the drying time, owing to the amount of water present is a definite impediment to output, the loss of which may possibly amount in actual cost to more than that entailed by the initial drying.

Essential Properties.

Most of the required properties of an oil-sand mixture are well defined, and successful results from the use of it depends upon the character of the individual items constituting the mixture. Perhaps the most important of these items is the type of core oil used, for success or failure is chiefly governed by its character and behaviour. The oil should possess a composition calculated to give the maximum of bonding power between the grains of sand; after drying the film thus formed should be capable of resisting the effects of moisture, when the core is allowed to stand in the open during a protracted period. One other salient property required is the rapid disintegration of the core after solidification of the metal, to allow the casting the greatest freedom in contraction, while from a production point of view, the shorter the time necessary for drying, the more suitable will be the core mixture. No part of the making of oil-sand cores is more important than, after selection of the oil, to give the mixture a suitable heat treatment, for upon this depends the correct functioning of the various constituents.

It is proposed, therefore, to deal more specifically than usual with the character of the core oil and its subsequent drying in order further to explain some of the basic principles which are involved in the process.

The choice of an oil is generally decided upon by the evidence of its physical properties, for it is of first importance that it should be of such a fluid character that a perfect covering of the sand grains is obtained with the minimum mixing. Apart from this factor, the remaining properties of a sand mixture are bound up with the chemical composition of its constituents, and, from a study of the many types of oils and their respective compositions, it is evident that every oil is not suitable nor capable of producing oil-sand for foundry use.

Classification of Core Oils.

Broadly speaking, the better-known oils, and those whose prices bring them within the scope of foundry interest, can be divided into three distinct groups according to their respective source of supply:—(1) Animal oils; (2) mineral oils; and (3) vegetable oils.

Animal Oils are well represented by such examples as whale oil, cod-liver, and sperm oil, etc. They are of interest only, for while they have the necessary qualifications for core making, the offensive smell of the fumes emitted during the drying process make their use distinctly objectionable.

Mineral Oils are found free in nature as petroleum or distilled commercially from oil shale. Certain members of this group have very low flash points, and are exemplified by petrol and benzoline, while others with higher flash points are paraffin, lubricating and machine oils. These are useless as binders because of the form of their constitutions, which have no power to dry under the effect of time or temperature.

Vegetable Oils, however, are of the utmost importance, for they include many of those oils which are of the greatest service to foundry practice. The members of this group are composed of triglycerides of unsaturated organic acids, and it is upon the saturation of these by the absorption of oxygen of the air that they possess the peculiar property of drying under the influence of temperature and time. The group is generally divided further in three classes, according to their drying power, when left exposed to the air in thin films at ordinary temperature:—(1) Drying oils, *i.e.*, linseed, hempseed, and poppyseed oils; (2) semi-drying oils, *i.e.*, cottonseed, soya bean oils, etc,; and (3) non-drying oils, *i.e.*, rape, castor, and olive oils. Thus a non-drying oil like rape oil will remain fluid under atmospheric conditions for an indefinite period; linseed oil, belonging to the drying class, will set to a tough elastic film within a few days; while semi-drying oils like cottonseed are between the two classes.

This distinction in drying properties, there is reason to believe, is entirely one of degree, for Livache (Compt. Rend. 1895) points out that all fixed oils, vegetable or animal, are capable of setting to an elastic filament, similar to those yielded by the drying oils, if left sufficiently long at higher temperatures than atmospheric.

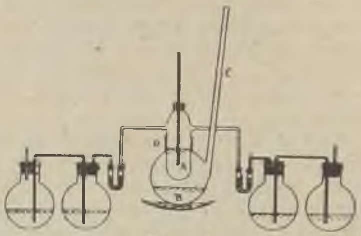

FIG. 1.

It will be evident, therefore, that a core oil may consist of one particular oil, or perhaps several, which may or may not be entirely vegetable, but, if so, may originate from different classes of the same group. It is of distinct advantage when production is one of the main features that the oil or oils in use should be entirely of the drying class of vegetable oils, which will produce, other things being equal, the maximum number of cores in the minimum time.

The Properties and Character of Linseed Oil.

When exposed to the air linseed oil gradually absorbs oxygen from the air, and assumes finally a dry or gelatinous mass known at linoxyn; the reaction is accelerated under increase of temperature within defined limits. It is on account of this peculiarity that it exhibits the binding together of sand grains in an oil-sand core during drying. It is therefore important to notice that the drying property of an oil is clearly indicated by its power to absorb oxygen; so that if it were possible to determine the amount of oxygen which any oil was capable of absorbing in a given time, we should be able to enumerate the various kinds according to their respective drying powers. A direct method for this measurement is not yet possible, but valuable assistance is rendered by the fact that the unsaturated acids in the vegetable oils which take up oxygen, also absorb iodine to a similar degree in the presence of a third substance like carbon tetrachloride, so that an estimation of the iodine absorbed by any oil is an indication of its drying power. To this end the amount of iodine absorbed by a definite weight of oil, fixed at 100 grammes, is expressed as the iodine value.

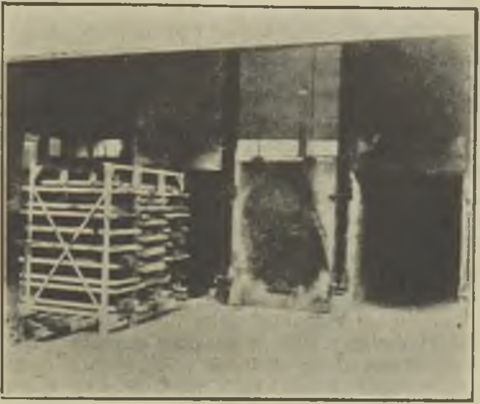

FIG. 2.—CORE STOVE AND RACK.

Of these more common vegetable oils the first four exhibit marked drying properties; the next four are semi-dryers; while the remaining three are of the non-drying type. In each case there is a definite decrease in the iodine value as we pass from the drying to the non-drying oils.

It was Hazima (Zeitsch Angen, 1888) who first pointed out that the iodine value of an oil rises with its drying power.

TABLE I.—*Iodine Values of Various Oils.*

	Iodine Value.		Iodine Value.
Linseed oil ...	185	Sunflower oil ...	125
Chinese tung oil	171	Maize oil	120
Hempseed oil ...	153	Cotton seed oil ...	105
Poppyseed oil ...	136	Olive oil	95
(Slide No. 1)		Rape oil	95
Soya bean oil ...	125	Castor oil ...	85

It would appear, therefore, that the use of an oil having a high iodine value in the untreated sample will give the quickest drying results. It is significant from the position which linseed oil occupies in the foregoing list, that its great popularity as a core oil and a core oil base is not by any means misplaced.

Changes During Drying.

Additional reactions take place during the process of drying, and it becomes necessary to have an understanding of these.

Krumbaar (Chem. Zeit, 1916, 40, 937) has shown in his results of experiments that when linseed oil is heated to definite temperatures in an atmosphere of carbon dioxide the figures shown in Table II were obtained.

TABLE II.—*Krumbaar's Experiments on Linseed Oil.*

Temperature in deg. C.	Duration of heating in hours.	Relative viscosity.	Iodine value.
		Std. 1.00	Std. 175.0
200	20	1.13	168.7
200	40	1.35	160.1
260	15	2.35	145.6
260	30	7.96	108.0
300	10	115.0	120.4
300	20	not flow	76.3

The direct fall in the iodine value suggests that some action takes place in which oxidation has no part, but as the temperature increases with a prolongation of time the oil thickens up to the degree that it will not run, as indicated by the relative viscosity.

Fahrion (Zeitsch Angen Chem. 1892.5.17) suggests that this action was one of polymerisation, that is, inter-molecular changes take place whereby the number of atoms in the molecule of the oil increases to some multiple of their original number.

In this direction the experiments of Dr. J. N. Friend (S. O. & C. Chemists, Vol. 7, No. 49), in which the author had the privilege of assisting, are of great interest, showing as they do that polymerisation of linseed oil is at first quite definitely marked at 250 deg. C.

TABLE III.—*Heat Treatment of Baltic Oil Four Years Old.*

Temp. in deg. C.	Duration of heating in hours.	Density at 20 C.	Iodine value.	Relative viscosity.	Mol. weight.
Original	sample	943.9	167	100	829
50	100	943.8	164	86.6	833
50	250	945.5	166	122.8	833
80	100	944.5	161	128	868
134	50	949.6	157	156	875
218	50	946.9	153	190	950
250	25	951.4	120	1,050	1,174

In these experiments the pure raw linseed oil was heated in glass vessels at temperatures ranging from 50 to 250 deg. C. To maintain the temperatures below 100 deg. C. the vessels were immersed in a water thermostat, maintained at a constant temperature. For higher temperatures the apparatus as shown in Fig. 1 was designed, and proved entirely successful. The whole apparatus is made of glass, the oil being placed in A and an air condenser fixed directly on to B, whilst D is a ground-glass joint to avoid trouble with cocks and rubber connections. Heat was applied through the medium of a sand bath over a Bunsen burner. To exclude the possibility of oxidation, the vessels were filled with nitrogen by drawing air first through flasks containing

Fig. 3.

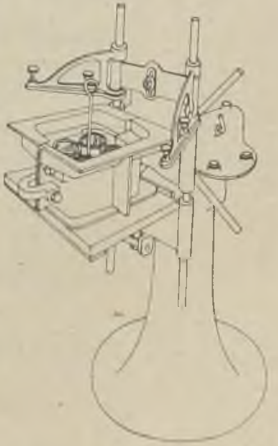

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

The Making of a Motor Cylinder Jacket Core.

alkaline pyrogallol, which liquid absorbs the oxygen, allowing the nitrogen to pass through. Table III gives a few of those obtained from the experiments.

Any attempt at a detailed discussion of these results would be entirely outside the scope of this Paper, but it is distinctly interesting, from a practical point of view, to notice that a definite change in all the factors begins at 250 deg. C., and this point therefore provides a definite index as to the changes during the drying process.

To recapitulate, it has been found that the bond of an oil-sand core is a tough elastic compound formed by the oxidation of certain unsaturated acids which compose the constitution of the oil, together with its subsequent polymerisation under the influence of temperature and time. A measure of the presence of these constituents which are responsible for the formation of the film bond can be obtained from the respective iodine value of the oil. The present degree of published knowledge points to the high value of linseed oil as a binder, from the point of its drying properties; also from the high value of the film bond which it produces.

It has been indicated from results of experiments given that a temperature of 250 deg. C. brings about changes in the core oven which must have some bearing upon the ultimate result. In practice this has been amply confirmed by the writer, for with one of the drying of the vegetable class, *i.e.*, linseed oil, successful results are being now obtained quicker and better, the ovens being kept at a temperature not below 250 deg. C. and not exceeding 300 deg. C.

These temperatures are in accord with many figures which have been published as indicating general practice, and it would therefore appear to be confirmed that polymerisation which takes place at this temperature has a definite bearing upon the subsequent results.

Drying Process.

On the subject of drying or baking of oil sand the variety of arrangements for handling and the types of ovens in use are innumerable, both factors being determined by the nature of the work in hand principally and the circumstances under which this is executed. From a production point of view, however, it becomes necessary that the amount of handling should be reduced to a minimum, the type of furnace be such that an even temperature can be steadily maintained, and that access in and out the oven should be of the simplest character. Fig. 2 shows a battery of ovens having these conditions in a foundry producing repetition work on medium production. The battery as shown is heated directly from a coke

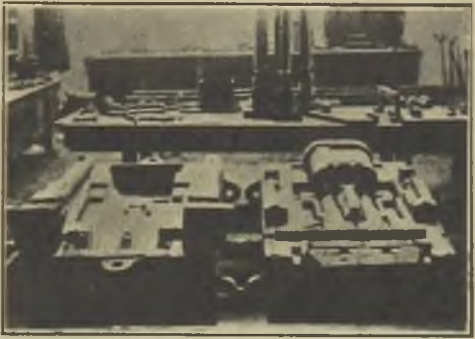

FIG. 8.—COMPLETE MOULD FOR A TROJAN CYLINDER.

fire, the products of combustion being boosted from the firebox to the furthest extremity of the ovens by a well-regulated air supply proceeding from a 2 h.p. electrically-driven fan. The ovens themselves are separate and independent, the closing of two small dampers being sufficient to isolate any oven individually from the live flue which connects directly to the fire grate.

The opening of the flues allow the hot gases to rise and pass through the entire breadth and length of the oven, and out again into the outlet flue which is common to all, but from which each can be individually isolated. The charges of oil-sand cores are carried on special racks made suitable to accommodate the various sizes of plates upon which the cores rest and the differing heights of the cores themselves. These racks are of the utmost convenience, insomuch that they are of light construction, easy to handle and, like the ovens, are strong and durable. The system of working is to have one of these steel racks within turning reach of two or three core-makers, according to the class of work, so that as each core is made and turned out on to a suitable metal plate which is at once and without double handling placed in the precise position for drying. From a production point of view this is ideal, and definitely means a saving of labour, greater satisfaction to the core-makers, for their will-to-work is thereby greatly increased by an apparently small convenience.

Two of these racks are required to make a charge for any one oven, so that when this number are fitted with cores, a small portable transveyor is wheeled into position, and by the action of a few pumps of the handle the rack is lifted from the ground and run into position in the oven. To lower the rack it is merely necessary to press a release lever with the foot, the oil passes from the pump cylinder and the descent is accomplished.

Each rack will accommodate approximately 25 cwts. of sand cores, and with a good regular temperature of 260 to 280 deg. C. the two racks are ready to withdraw in 1½ hours from the time of insertion.

Methods of Application for Production.

When the extreme conditions are visualised under which castings, ferrous and non-ferrous, are produced, together with the innumerable number of shapes and sizes, it seemingly becomes impossible to deal with the subject of oil sand and its application to these manifold practices. The range of application, however, cannot be limited, for as it is of universal service to the foundryman, each in his sphere of activity, so will methods be devised differing according to the ideas and initiative of the individual, and the character of the work to be undertaken. It will, therefore, occur to the thinking mind that any attempt to outline individual shop practice, as in the following illustrations, is merely an additional expression of opinion.

Production, therefore, can be equally accelerated by methods of application, as well as the use of oil sand, and in Fig. 3 is illustrated one method of making a motor cylinder jacket core. For this it is necessary to have a core mixture having sufficient strength in the green condition to maintain the required shape unassisted, and further, being entirely surrounded by molten metal during the process of casting, it is necessary that it should possess the maximum degree of permeability consistent with the required bond. The cores are produced by one man at the rate of 18 per day. To the cast-iron pillar of the machine the entire core box is pivoted, and is free to revolve a complete circle if required. The centre carries two stout rods upon which slide the top and bottom tables, both of which are operated by the movement of the four-handed lever on the pivot centre, and become automatically locked in the open or closed position. Fig. 3 shows the machine in the normal position stripped of its loose pieces to show the metal cylinders which form the barrel cores.

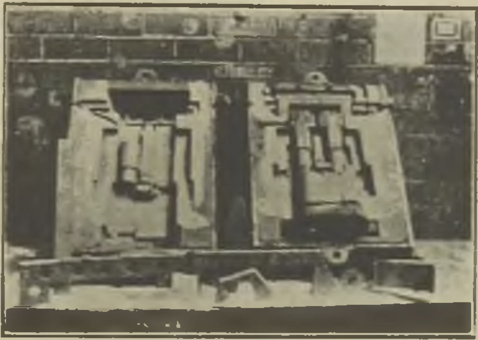

FIG. 9.—TROJAN CYLINDER MOULD AND JIGS FOR CHECKING DIMENSIONS.

Fig. 4 is the completed core box ready to receive the oil-sand mixture; the outer shell is easily removed by an outward movement after releasing the clamp. After placing four small wooden plugs into the tops of the small barrels, the oil-sand mixture is rammed into the box to the half-way line, when four curved $\frac{1}{8}$ in. dia. wires are placed around the centre-piece to strengthen and take the weight of the jacket walls. Ramming is then continued until the top of the bore-formers is reached, when the wooden plugs are withdrawn and metal plugs substituted, so that their flat sides are coincident. Two additional iron loose-pieces are now put into position to form the core print necessary for fixing in the mould. The ramming is afterwards completed and four small vents inserted in the barrels.

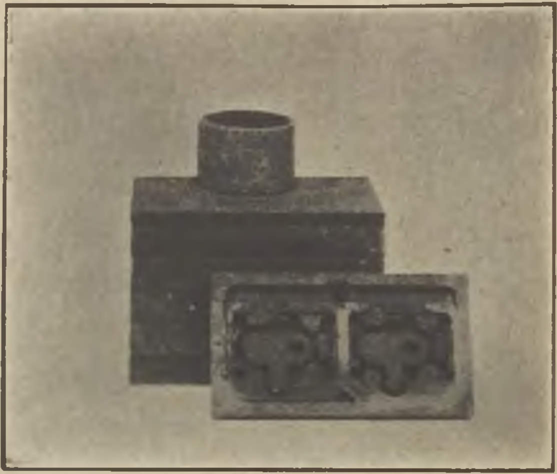

FIG. 10.—MAKING AN OIL PUMP IN STACK CORES.

Fig. 5 illustrates the completed operation of covering the core box with the necessary turning-out plate, and the arms swung into position preparatory to inversion. By means of four thumb screws the box and plate are securely clamped, and at the same time a perfect level is made to ensure a good draw.

The entire core box is now inverted on the unlocked pivot, and requires steady handling to balance around the dead centre. Fig. 6 shows this operation accomplished—and the new position is securely held by the automatic locking device. This latter arrangement consists briefly of a centre plate which carries the ends of two levers, the further extremities are attached to the top and bottom tables respectively, the shape of the levers being curved in such a manner at the point of attachment to the centre plate, that they pass over the dead centre. Fig. 7 shows the core stripped ready for removal. It will be noticed at this stage that the two cast-iron pieces remain at the base of the core; these are not removed, nor yet the metal plugs, which were inserted to form the top portions of the barrels in the position as shown, but are left throughout the drying period.

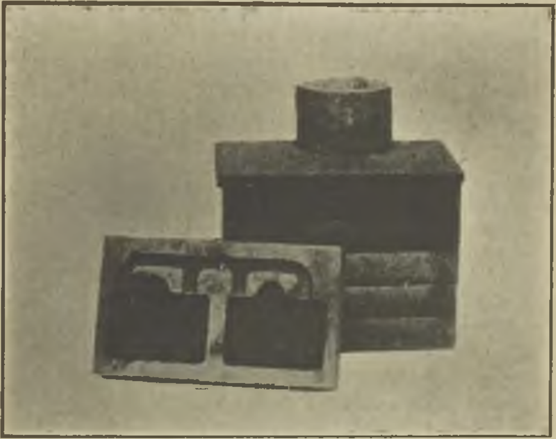

Fig. 11.—Same as Fig. 10.

Fig. 8 illustrates the assembling of the complete Trojan cylinder with the jacket core in position, all the cores being made from various mixtures of oil sand according to their respective positions and functions. Each core, as it is fixed in position, is checked for dimensional correctness by the metal jigs shown in Fig. 9.

Stack Cores.

The question of production of small castings calls for special initiative from the foundryman, more especially when such depart from the plain, cubic or rectangular design, having undercut or hollow portions wherein hang various shapes of additional projections. The diminutive sizes add to the complication of the difficulties, for such types of castings under immediate discussion do not lend themselves to the suggested moulding machine. To make this possible, however, it would be necessary to block out the pattern extensively, and production to any extent worthy of the name could only be obtained by the use of several such patterns on the one plate. It is at this juncture that oil sand stack cores come as of very practical assistance to the foundryman.

Fig. 12.—Same as Fig. 10.

Figs. 10, 11 and 12 show the method of making an oil pump consisting of three different parts. The entire cores are made in oil sand, each section of the stack when placed one upon another provides a complete mould with one common runner communicating by small sprues to two castings in each section, thus from only one stack twelve castings are obtained.

If a closer examination is made the open views will show that the middle and bottom portions of the pump are far from being simple castings, and, from the machine shop point of view, the few thousandths allowance for surface grinding is the only error allowance. Production when working on this principle is well maintained, for one core-maker alone is allowed for one stack of twelve castings a matter of two hours for the making and fitting together ready for casting, and is well able to produce his piece-work earnings.

Such examples as those which have been given do not by any means exhaust the potentialities of oil sand, and whether individual interests are centred upon large or small, steel, iron or brass castings, its unfailing qualities are found to be precisely the same.

It is by means of its application to the making of larger castings that the all-round advantages are obtained. The top half section of a turbine casing while not of great dimensions serves as an excellent illustration of the application of the "blocking out" system, which entirely supersedes the older method of "draw-backs" when such castings are made on a production basis. The under-cut portion of the casting when "blocked out" entails extra pattern making in terms of an additional core box. This is, however, well compensated alone by the amount of hand-moulding time which can be saved, irrespective of the possibility, that is distinctly evident, of jolting up the mould to the upper ring on a moulding machine.

DISCUSSION.

Mr. Glover asked for a rough idea of the relative costs of ordinary naturally bonded cores and oil-sand cores. Mr. West, in reply, stated that in comparing any costs the decision depended not merely upon the initial price but rather the ultimate results one had in view. The higher primary cost of oil sand had compensations in the way of quicker production, handling conveniences, reduction on fettling costs, and considerably better finish internally of the castings. These advantages were not so marked when using ordinary sand. As to actual data he had not any at hand which he could give with accuracy, but felt sure from his own experience that oil-sand cores could be made to do all that was required of them as cheaply, if not cheaper than, other mixtures.

Mr. Howarth asked if Mr. West had found that oil-sand cores sometimes gave way and sagged in the mould, even when chaplets were used, for ½ in. metal sometimes came out ¾ in. metal in the top portion. He referred to a straight pipe casting 7 ft. in length and flanged at either end.

Mr. West replied that cases had occurred, but he found that it was not due to sagging, for the use of chaplets in the bottom prevented that. The real reason was, that when the pipe core was made in halves, as described, a certain amount of subsidence took place during the drying in the oven, so that after pasting the two halves together the core would have been found eccentric had it been jigged. It became necessary, therefore, in general practice to allow ⅛ in. per foot for subsidence in the core-box.

Mr. Vernon inquired as to the compositions of the various core-oils which were offered to foundrymen.

Mr. West said that it was not possible on such an occasion to consider any proprietary mixture, but when once the basic principles of oil-sand mixing is assimilated, then any foundryman would be in a position to select the mixture best suited for his particular needs. It was always worth remembering that a straight oil, like linseed oil, has been well tried, and has been proved to be definitely reliable. Emulsions and creams invariably carried a large proportion of water in their compositions.

Mr. Meadowcroft, after complimenting the lecturer, said he was particularly interested in the drying question. There had been distinct advances in the method of drying cores, but he always found that very good results were obtained by passing 20,000 cub. ft. of air through the ovens per hour to get the fine nut brown colour, and maintaining the temperature about 250 deg. C. This was not obtained if the temperature was too low. The necessary amount of oxygen was an important factor. He had found that the presence of salt was no detriment to making of oil-sand cores—it helped to bind the sand grains. He did not hesitate to say that the base of all oil-sand cores should be linseed oil.

Mr. Pell asked if Mr. West had found difficulty in handling cores in the green state, which were made with an oil bond.

Mr. West, in reply, pointed out that the addition of gums, resins, molasses in certain proportions to the mixture gave a good green bond, sufficient to enable the cores to be carried about without any difficulty.

Vote of Thanks.

Mr. John Jackson, in proposing a vote of thanks to Mr. West, said he was most interested in the subject, because he had been through the Leyland Works and had seen the system of making cores there. The production of cores as outlined in the lecture was, he believed, only in its infancy, and he hoped that in the course of time it would develop extensively. **Mr. Vernon** seconded, and the lecturer having acknowledged, the meeting then closed.

Scottish Branch.

THE PRINCIPLES OF CENTRIFUGAL CASTINGS AS APPLIED TO THE MANUFACTURE OF "SPUN IRON PIPES.

By E. J. Fox and P. H. Wilson, respectively Managing Director and Foundry Manager of the Stanton Ironworks.

There are at present six plants in the world operating M. de Lavaud's patents (under licence from the International de Lavaud Corporation, Limited), namely:—In Canada—The National Iron Corporation, Limited, Toronto; in the United States—the United States Cast-Iron Pipe & Foundry Company, Birmingham, Ala., and the National Cast-Iron Pipe Company, Birmingham, Ala. (sub-licensees of the United States Cast-Iron Pipe & Foundry Company); in Japan—Messrs.

Fig. 1.—Raw Material Bunkers.

Tsuda & Company, Osaka; in Belgium—Compagnie Générale des Conduites d'Eau, Liège, and, of course, the plant at Stanton, which may be claimed to be the most modern and largest plant in existence for the production of "Spun" iron pipes.

It is proposed to consider the principles governing the De Lavaud process as manufactured at Stanton, also the finished product, "the Spun iron pipe," and the tests to which it has been subjected, also how it acquits itself under these tests. Before doing so, a brief description of the plant will be given.

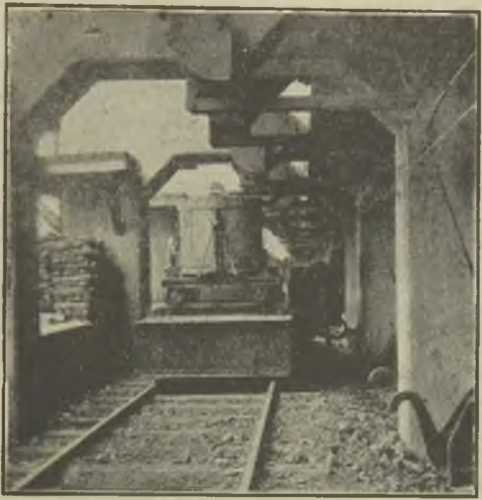

Fig. 2.—Travelling Carriage for Handling Stock.

The raw materials, pig-iron, scrap, coke and limestone are discharged from wagons on an elevated railway into bunkers. These bunkers (Fig. 1), twenty in number, are constructed of ferro-concrete with steel linings, and each has a capacity of 15 tons of coke, 40 tons of coal, 100 tons of pig-iron or 80 tons of limestone All raw materials are systematically analysed in the Company's laboratories before being discharged into the bunkers, the various grades of pig-iron being placed in respective bunkers according to the silicon content.

Travelling beneath the bunkers are electrically operated two-ton travelling carriages (Fig. 2), upon which is fitted a weighing machine. Skips are run on to these carriages, and can be put into position under any particular bunker. Special discharge apparatus at the bottom of the bunker enables the operator to control the withdrawal of the material from the bunker.

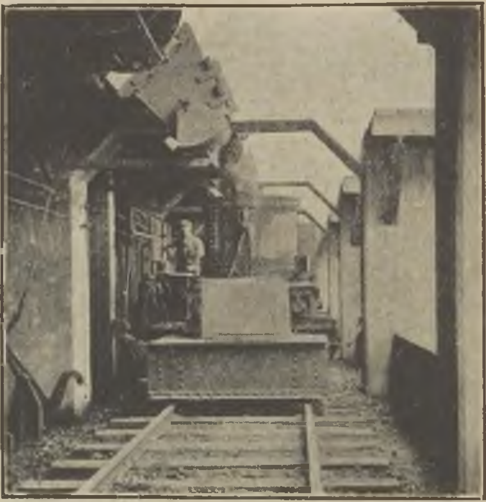

FIG. 2A.—REAR VIEW OF THE TRAVELLING CARRIAGE.

The skip is then withdrawn from the bunker carriage by an electric haulage gear, and coupled to the charging hoists, as is illustrated in Fig. 3.

These hoists are hydraulically operated, the arm upon which the skip is suspended is raised to the top of the cupola. The opposite end of this arm is guided by means of rollers running on rails.

These rails are so shaped that the skip is taken into the top of the cupola, when the contents are discharged automatically by bottom doors. The empty skip is then lowered to the carriage and returned to the bunkers. The cupolas (Fig. 4) are of modern design with drop bottoms, and have a melting capacity of 10 to 15 tons per hour. Blast is supplied by fans having a capacity of 8,000 cub. ft. of air per minute at a pressure of 16 to 30 in. water gauge. The molten metal is tapped into three-ton casting ladles (Fig. 5), which are conveyed to the casting shop by means of a five-ton electric crane running on a telpher runway.

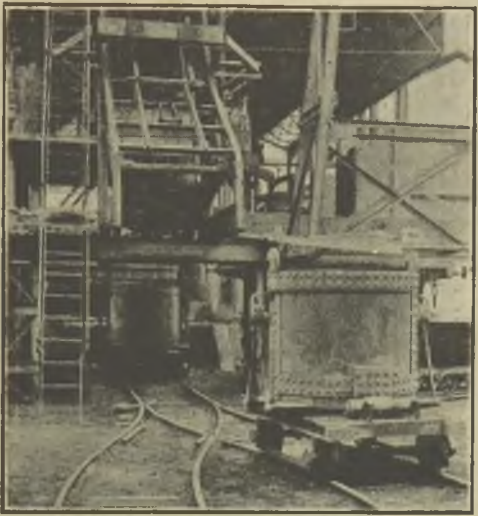

FIG. 3.—CHARGING HOIST.

The casting machine used and the processes followed have previously been described and illustrated.*

The output per man per shift is eight times greater by the "Spun" process; at the same time improving considerably the conditions under which

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* FOUNDRY TRADE JOURNAL, August 14, 1924.

the worker can operate. Fig. 6 illustrates the conditions which exist in a vertical sand cast pipe pit. Further, on account of the increased strength of the "Spun" metal, which will be shown later, it is possible to effect a saving of 25 per cent. in the weight of the pipe, in consequence of the metal in the "Spun" pipe being not less than 70 per cent. stronger than that in the standard sand cast pipe.

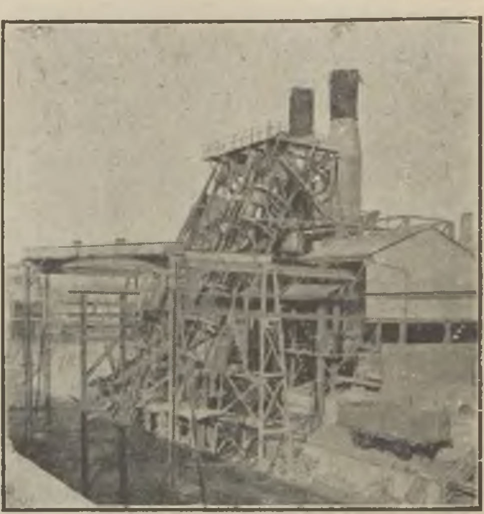

FIG. 4.—THE CUPOLA PLANT.

Fig. 7, *et seq.*, show the difference in the fracture or "Spun" iron and sand cast pipes, also the micro-structure of similar metal in the two pipes at the same magnification.

Speed of Rotation of Mould.

The speed of rotation of the mould is an important factor in the satisfactory production of centrifugal castings. This speed lies between a minimum, below which the metal fails to hold up against the mould face; and a maximum which is determined by the speed capabilities of the casting machine. The optimum speed is known for each size of pipe cast, and has been found by numerous tests carried out on pipes cast at varying speeds.

Having determined the correct centrifugal force necessary to give the best results on any particular sized pipe, it was found that the ideal speed could be calculated for any size of pipe, the radius of gyration being taken at the mean diameter. It follows from this that the thickness of the pipe must be taken into consideration in arriving at the speed of rotation for pipes of various diameters. The rate of flow of the metal and the traverse of the mould relative to the spout (referred to later) have a distinct bearing on the peripheral speed of the mould.

FIG. 5.—CASTING LADLE FOR HANDLING THE IRON.

That an ideal speed should exist has been clearly confirmed by Pardun,* who states:—

"Whereas up to the critical speed the centrifugal force is sufficient in order evenly to spread the band of liquid, when the critical speed is exceeded the iron begins to '*lead*' in the mould,

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* Pardun: Stahl und Eisen. Vol. 44, No 25. Translated in FOUNDRY TRADE JOURNAL, Oct. 2, 1924.

thus causing the spirals to disappear or partially to overlap. The advancing liquid band becomes thinner in proportion to the amount of 'lead,' and hardens prematurely before the main jet travels over it. There is, therefore, a kind of welding effect produced.

"The phenomenon of 'lead' is caused by the fact that centrifugal force acts in two ways, namely, axially and radially. In projecting liquids the axial pressure becomes a result of the radial pressure, the particles most remote from the point of rotation having a tendency to escape to zones of lower pressure exerted by adjacent particles. That is, these particles reach places where there are no particles already. With increasing speed of rotation and consequent increasing pressure this tendency to 'lead' must increase."

FIG. 6.—SAND CAST PIPE PIT.

Rate of Flow of Metal.

The process itself consists of the deposition of a continuous spiral of metal inside a rotating cylindrical mould. It is thus clear that to produce castings of uniform section the metal must flow at a constant rate (Fig. 10). This is achieved in practice by the simple yet ingenious design of the tilting ladle, which delivers metal at a uniform rate throughout the casting operation. Another important factor involved in the introduction of metal into the mould is the rate of delivery from the pouring spout, and the angle at which this delivery takes place.

From experiments made in the early stages, the ideal rate of flow was ascertained, giving sufficient velocity to the molten metal to ensure a smooth deposition in the mould, and a minimum loss in temperature in the pouring spout, which is approximately 14 ft. long.

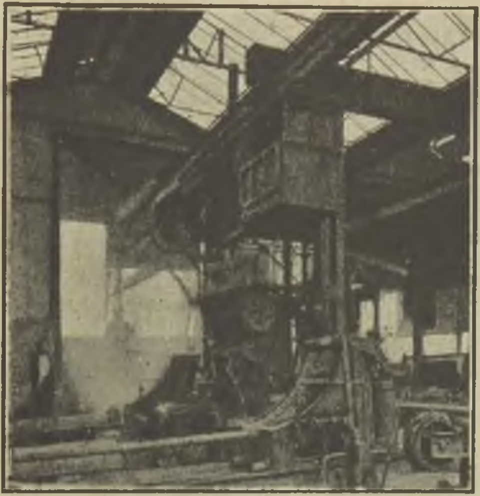


FIG. 6A.—CENTRIFUGAL CASTING MACHINE.

In order to maintain a regular rate of flow, the machine is so designed that the metal passes over a lip or weir giving it the necessary constant impetus. The ideal direction of flow of the metal leaving the spout would be if the tangent to the mould at the point where the metal touches it for the first time coincided with the tangent to the parabolic curve described by the metal. This is, however, in practice impossible, but the spout end has been so designed, and is placed in the mould in such a position as to make the angle between the two tangents very small.

Rate of Traverse.

From the foregoing remarks in respect to rate of flow it becomes obvious that the speed of traverse must be closely correlated with the rate of flow. Thus, the speed of traverse must be a constant throughout the casting process, otherwise uneven section of pipe longitudinally would result. The cross-sectional area of the trough varies according to the size of pipe made, different sizes being used for pipes from 4 in. to 15 in. dia.

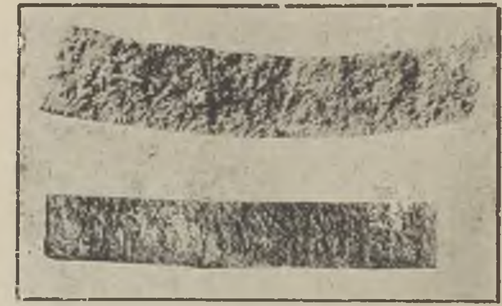


FIG. 7.—SAND CAST (UPPER) AND SPUN PIPE (LOWER).

The synchronising of these three movements, namely, the rate of tilting the metal, the speed of the traverse of the machine and the peripheral speed of the mould, is a very important factor in correctly deposing the stream of metal and avoiding excessive " lead " referred to above.

Casting Temperature.

In the production of satisfactory centrifugal castings it is important to observe the following conditions in respect to metal conditions:—(1) The metal must enter the mould in a truly *fluid* condition—it is essential that the metal should flow easily, otherwise the centrifugal action would be unable to exert its full effect; (2) the metal must enter the mould as a true *liquid*. The presence of primary crystals in any bulk make it impossible to secure a smooth inside to the casting; and (3) the metal must flow in an even stream down the pouring spout. Bearing in mind the small cross section and extreme length of the spout, it is clear that a sluggish metal would give an uneven flow, especially in the machines producing small pipes.

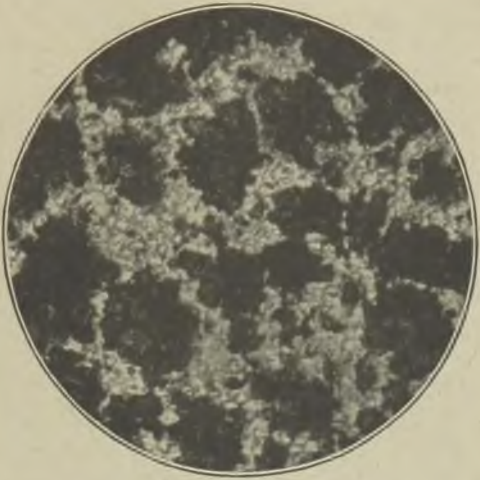


Fig. 8.—Microphoto. of Spun Iron × 100 dias., Etched 10 per Cent. Nitric Acid.

The requirements enumerated are only achieved by the use of hot metal. Excessive superheating of the metal is harmful, as excessive "lead" is thereby produced. It is not usual, however—assuming normal cupola practice—to obtain a temperature which is too great.

Since the trough dimensions of the machines making pipes of large diameter are greater in respect to section of channel, and since a larger mass of metal is being dealt with, it is not necessary that the metal used on these machines should be as hot as that used on the smaller ones. In actual practice, metal taken from the cupola in the large ladle is first used for the small machines and later for the larger machines. The range of casting temperature permissible in making pipes 4 in. to 15 in. dia. is 1,200 to 1,250 deg. C.

The necessity of arranging the cupola practice to secure a clean metal can be emphasised here. Dirty metal—owing to the inability to ensure thorough skimming—gives rise to rough insides and other defects in the castings.

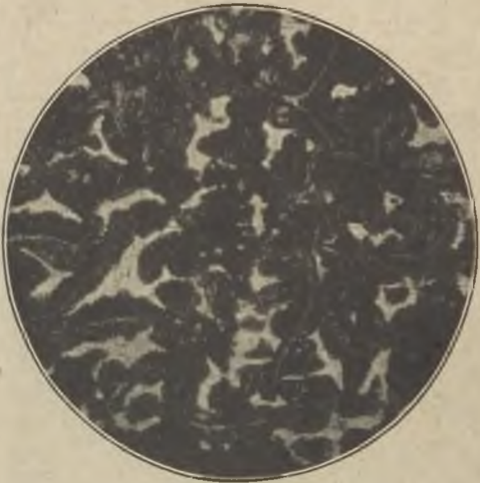


FIG. 9.—MICROPHOTO. OF SAND CAST IRON × 100 DIAS., ETCHED 10 PER CENT. NITRIC ACID.

Numerous tests have been carried out to ascertain the physical effect on pipes cast at different temperatures. By reference to the graph Fig. 11, it will be seen that best results obtained from Stanton iron are with a temperature lying between 1,200 and 1,250 deg. C. These curves are obtained from the average of a large number of tests made on ring and bar test pieces cut from the pipes cast with metal at varying temperatures.

Metal Composition.

It will be shown that very definite segregation occurs in metal cast centrifugally; thus to ensure freedom from excessive migration of the elements the metal needs to possess as short a cooling range as possible. The ideal composition is, therefore, a eutectic melt.

In the practice referred to pig-iron of one brand is used, Nos. 3 and 4 foundry grades being supplied. On this account the total carbon of the re-melted metal is almost constant, the only variable element is silicon. It is therefore possible to control the metal by silicon content alone.

Fig. 10.—The Spinning Machine.

For example, using a pig-iron giving a re-melted metal with 3.5 per cent. carbon, it can be proved—neglecting other elements—that 3.0 per cent. silicon will give a eutectic melt. Extensive experiments made on pipes cast from this iron showed that excellent results were obtained with 2.95 per cent. silicon. This proves the suitability of a very close cooling range.

Migration of Elements.

Segregation of elements in "spun" castings has been closely studied by taking successive planings from a section of pipe and subjecting them to analysis. The results are shown in graphical form in Fig. 12.

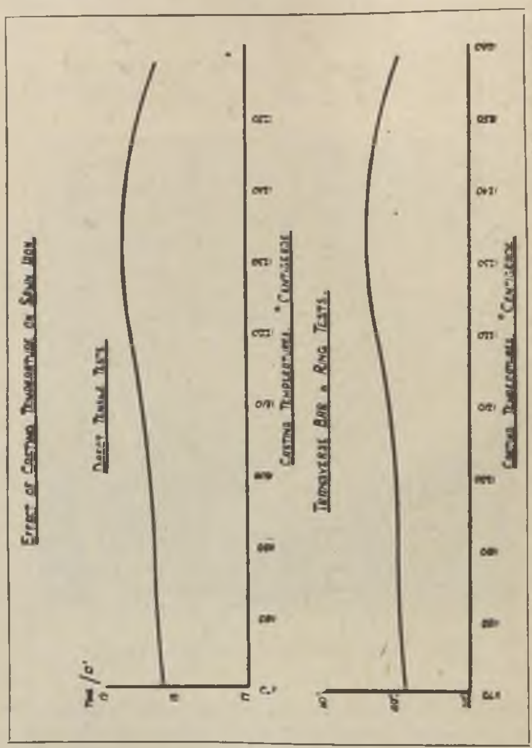


FIG. 11.—EFFECT OF CASTING TEMPERATURE ON MECHANICAL PROPERTIES OF SPUN IRON.

Silicon.—This element is uniformly distributed. Only substances in suspension can be segregated in the centrifugal process; no effect is produced on substances in solution. Silicon is present in the metal in solution, and therefore no migration takes place. The graphs for silicon are horizontal in each case.

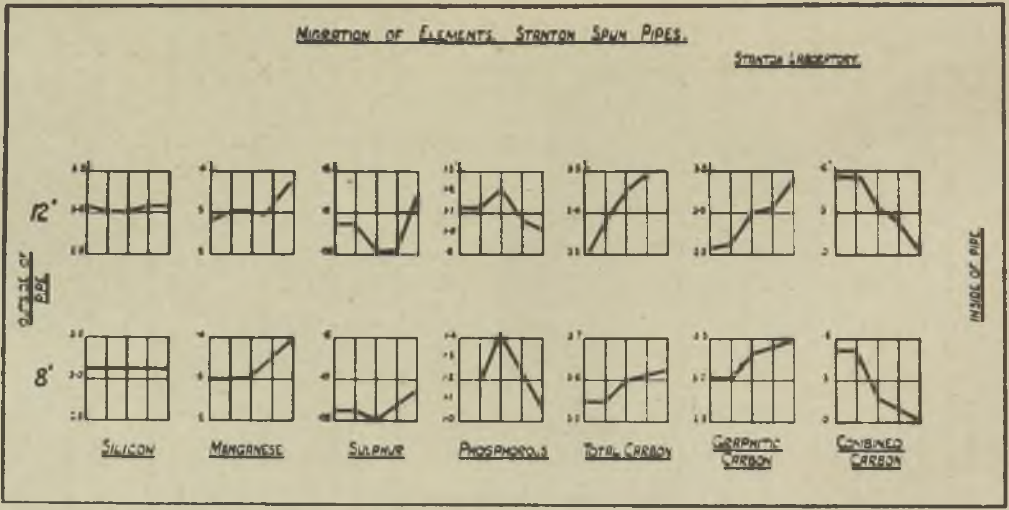


FIG. 12.—THE MIGRATION OF ELEMENTS.

Sulphur.—Manganese sulphide and iron sulphide are not soluble in Gamma iron, they possess a low specific gravity and the former has a high melting point. It is easy to realise that these compounds tend to accumulate on the inside of a centrifugal casting. The graphs show clearly the marked inward migration of sulphur.

It is remembered that no migration occurs in the extreme outer skin of the casting, owing to the quenching effect which it has undergone. With such high rates of cooling the outer layer of metal becomes solid so quickly that there is no time for any segregation to occur.

Manganese —Such manganese as exists as sulphide migrates inwards, as described under sulphur. The residual manganese, being in solution, spreads itself evenly through the mass.

Fig. 13.—Fracture of Spun Iron, showing Chilled Face.

Phosphorus.—The graphs show that this element accumulates towards the outside of the castings. This is explained by the low melting points and high specific gravity of the phosphide eutectic. This eutectic operated upon by radial force exudes outwards through the solidifying mass, and since it does not solidify above 950 deg. C. it builds up on the outside of the casting just beneath the chilled portion already referred to.

Graphite.

Carbon as graphite existing in the metal during the early stages of solidification migrates inwards on account of its low density. This is clearly indicated on the graphs. Since an approximately eutectic melt is used, the migration is not considerable; it would be much more marked in carbon-rich metal owing to the rapid decomposition of primary cementite; in fact, if such a metal were used the inside of the pipes would contain a large proportion of kish.

Combined Carbon.

In unannealed pipes the preponderance of the combined carbon occurs on the outside of the casting. This is to be expected, as the chilling effect of the mould causes a rapid rate of cooling in this part of the casting. The rate of cooling is much less rapid as the inside of the casting is approached, and for this reason the combined carbon percentage becomes considerably less.

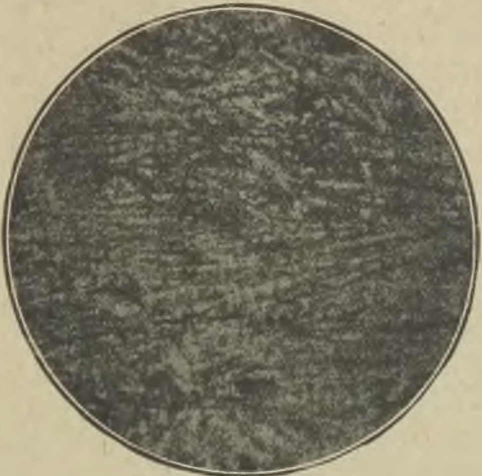


Fig. 14.—Microstructure of Chilled Portion of Spun Pipe × 120 dias. Etched 10 per cent. Nitric Acid.

Effects of Elements.

Silicon.—From the point of metal control this element is the most important. Silicon possesses the property of promoting graphitisation—it is easier to saturate a silicious iron with carbon than it is to saturate pure iron. By varying the silicon content it is possible to obtain an iron supersaturated, saturated, or under-saturated in respect to carbon. Control of the silicon content makes it possible—knowing the carbon content—to secure an almost eutectic melt, which for the process is ideal. Silicon tends to destroy chill, but if present in large quantity is prone to make the metal sluggish.

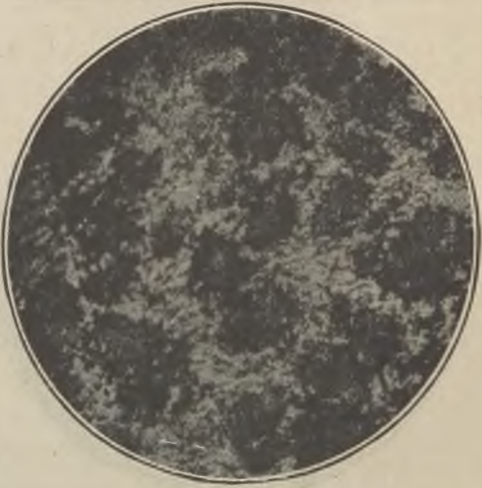


FIG. 15.—MICROSTRUCTURE OF SPUN PIPE CAST IN HOT MOULD × 120 DIAS. ETCHED 10 PER CENT. NITRIC ACID.

Manganese.

This element exerts its usual effects. It favours the production of chill, exerts a hardening influence and improves tensile strength. By combining with sulphur it causes the inward migration of the latter element. The manganese content, 0.3 per cent., in the metal used in the process under review is too low to cause much effect.

Phosphorus.

Tensile and bending strengths are improved by this element up to 0.8 per cent. P., and little detriment to mechanical properties occurs if 1.5 per cent. P. is not exceeded. Above this amount the hardening and embrittling effects of phosphorus make themselves apparent. Phosphorus aids spinning by making the metal more fluid; by making the cooling range longer it tends to promote graphitisation. This can, however, be counteracted by the adjustment of the silicon content.

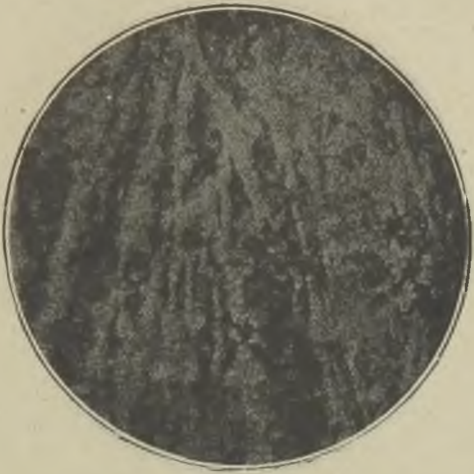


Fig. 16.—Microstructure of Chill × 350 dias. Etched 10 per cent. Nitric Acid.

Sulphur.

This element is opposite to silicon in its effects. It favours production of chill and generally tends to close the grain of the metal. If present in any quantity it is most harmful.

Carbon.

The carbon content is fixed by the class of pig-iron in use. High carbon gives a sluggish metal quite unsuited to the process. Low carbon gives a free-running iron which has a decided tendency to chill. The requirement for the process is the correct adjustment of the silicon and carbon contents so as to secure a metal just saturated with carbon.

Production of the Chill.

A remarkable feature of the castings produced by this process is that the outer skin of the metal is chilled (Fig. 13). Normally a cast iron of such a composition cannot be chilled by most severe quenching when cast in sections other than centrifugally, comparable with the thickness of a "spun" pipe. Three interesting simple experiments were performed to study the conditions producing this chill:—

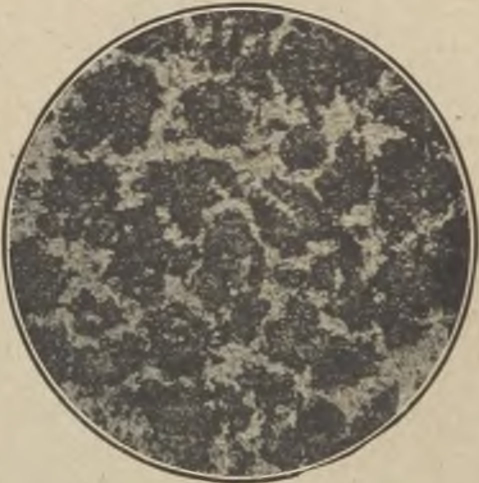


FIG. 17.—MICROGRAPH OF THE MIDDLE SECTION OF A SPUN PIPE × 100 DIAS. ETCHED 10 PER CENT. NITRIC ACID.

(1) A pipe was centrifugally cast under normal conditions. The usual chill was produced. Fig. 14 shows the micro-structure of the extreme outer edge of the pipe. (2) A pipe was cast in a hot

mould, no cooling water being used. No chill was formed. Fig. 15 shows the micro-structure of this outer edge; and (3) Metal was poured into a stationary water-cooled mould. No chill was found.

These experiments show that water cooling and centrifugal action contribute to the formation of the chill. The mould, rotating in water which is constantly circulating, must possess a chilling surface capable of securing maximum cooling effects. The metal nearest to the mould face suffers the maximum quenching effect, and thus cools so rapidly that, in spite of its composition, it has no time to graphitise.

Fig. 18.—Microstructure of the Inner Section of Spun Pipe × 100 dias. Etched 10 per cent. Nitric Acid.

Microstructure.

Unannealed Castings.—The section of pipe reveals, on microscopical examination, three distinct fields:—(1) The outer chill; (2) the middle cellular structure; and (3) the inner fibrous structure.

The *chill* (Fig. 16) is definitely the well-known austenite-cementite eutectic along with primary austenite, in the case of under-saturated metal; or with decomposed primary cementite in the case of super-saturated metal. The chill exists, as already explained, on account of the high rate of cooling secured in the process. The crystals of cementite and austenite are trapped in their original forms, having no time to decompose. The micrograph (Fig. 16) shows the nature of the chill, the crystals are elongated, having their orientation normal to the chilling face of the mould.

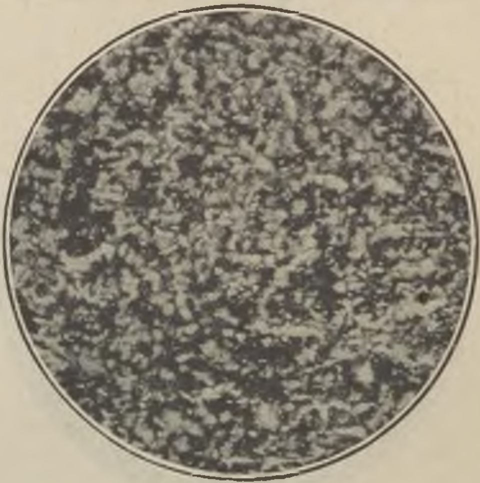


FIG. 19.—MICROSTRUCTURE OF ANNEALED SPUN PIPE × 120 DIAS. ETCHED 10 PER CENT. NITRIC ACID.

The *middle section* is cellular (Fig. 17). In this section the rate of cooling is less severe and decomposition of the original austenite and cementite has occurred. Graphitisation is almost complete, although the rate of cooling has been sufficiently high to cause the graphite to separate in an exceedingly fine form. Some martensite sorbite is occasionally present. The phosphide eutectic is shown to be distributed in a very fine form.

The *inner section* is of a coarser nature (Fig. 18); it is found in all but small pipes of thin section. This structure is representative of a still slower rate of cooling, the general field being graphite in a matrix of silico-ferrite. The graphite is noticeably coarser, being in the form of rosettes, Again the phosphide is in a finely distributed form.

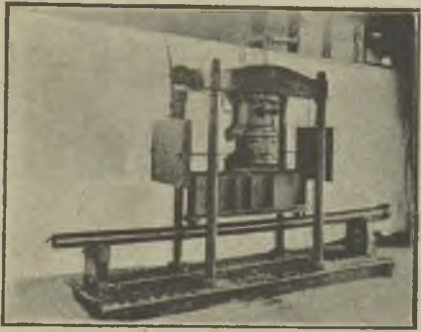


Fig. 20.—Special Transverse Testing Machine for Pipes.

Annealing or Normalising.

The chill on the outer skin of the pipe described is hard and must be destroyed. The austenite cementite being in an extremely unstable condition, readily responds to heat treatment. This heat treatment is a time-temperature process of the usual kind; the continuous furnaces used are arranged in respect to both time and temperature so as to enable the chill to be completely decomposed. The eutectic cementite graphitises, and the remainder of the structure decomposes to an approximately ferrite-graphite structure, some martensite-sorbite also being usually present. The micrograph (Fig. 19) shows the structure and emphasises its extremely fine nature.

It has frequently been suggested that the chill formed on this type of casting is harmful. It is agreed that chill itself is not desired, being hard and brittle, but when completely normalised it possesses extremely good mechanical properties, which do much to improve the quality of the pipe.

Annealing or normalising as practised does not affect to any extent the middle and inner sections of the pipes.

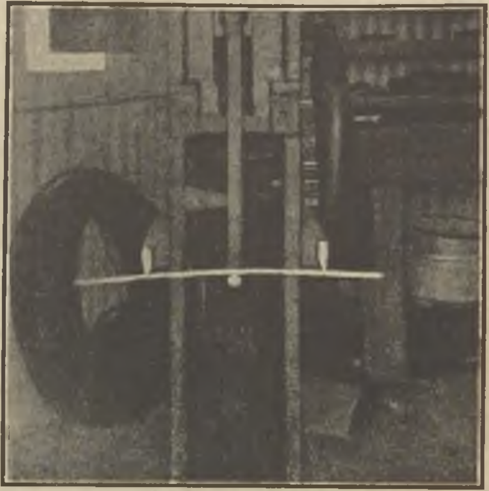


FIG. 21.—TRANSVERSE TESTING MACHINE FOR CUT SAMPLES.

The enhanced properties of spun metal can be ascribed to the structural features obtained by the rate of cooling in conjunction with centrifugal force, producing a fine deposition of the graphite, the fine distribution of the phosphorus, also a general reduction of grain size.

Mechanical Tests.

The mechanical tests may be divided into two sections—" Tests on pipes as pipes " and " Tests on the metal as produced by the centrifugal process."

The tests in the first section were designed to determine the resistance of the pipe to such stresses as are likely to occur under working conditions, *e.g.*, internal pressure, external load and transverse strains due to incorrect laying or earth subsidence.

The tests in the second section include the determination of tensile strength, moduli of rupture, moduli of elasticity and hardness tests.

For these tests five different sizes of pipes were chosen, namely, 4, 6, 8, 10 and 12 in. dia. Some two hundred of these pipes were used for the investigation, and well over ten thousand observations were made. The average of all these tests will be given.

In order to obtain truly representative results the collecting of the sample pipes for test was spread over a period of fourteen months. As it was deemed advisable to compare the results from different experiments with certain factors constant, a system was devised to obtain this. The pipes were manufactured singly, in batches of three, and in batches of six, but in no case were two sets of the same size of pipe taken on the same day. The pipes received no special treatment, they were spun and annealed in the usual way, and the details of manufacture, temperature of metal, etc., were noted.

Hydraulic Pressure Tests on 12-foot Lengths.

The object of this test was primarily to determine the ultimate bursting pressure of pipes of varying size and thickness. The method of testing these pipes to destruction was as follows:—Suitable cast iron end plates, machined to form a joint capable of withstanding a high pressure, were held in position by external tie rods. The hydraulic pressure was applied by a high-pressure hand pump and the bursting pressures were read on a gauge with a tell-tale pointer. The gauge used was checked after each experiment against a standard gauge.

Before testing, each pipe was carefully measured, and after bursting the thickness was obtained by means of a micrometer at twelve places along the length of the pipe, the maximum, minimum and average being recorded.

Due to the high end-pressure necessary to make the joints in this test, it was evident that longitudinal stress was exerted on the pipes by tightening the bolts. The test was, therefore, repeated on short sections 5 ft. in length cut from different portions of the pipe.

The object of this test was threefold:—(1) To ascertain if any one sectional length of the pipe was stronger than the other; (2) to find the errors due to the possible bending of the longer length of pipe; and (3) to compare the bursting pressures with results from other experiments carried out on sample bar cut from the pipes.

The tensile figures obtained from the bursting pressures can only be looked upon as relative.

The formula used for calculating these is:—

$$ft=\left(\frac{(R_1{}^2)+(R_2{}^2)}{(R_1{}^2)-(R_2{}^2)}\right)p.$$

ft = tensile strength in lbs. per square inch.
R_1 = outside radius of the pipes in inches.
R_2 = inside radius of the pipes in inches.
p = hydraulic pressure in lbs. per square inch.

The figures shown in Table 1 give the average results obtained.

Table I.—*Tensile Figures Obtained from Bursting Tests.*

Bursting pressure. Lbs. per square in.					Calculated tensile strength. Tons. per sq. in.	
Dia. of pipe in ins.	Average thickness in ins.	12 ft. length.	Average thickness in ins.	5 ft. length.	12 ft. length.	5 ft. length.
6	0.367	2,800	0.351	3,200	12.75	14.51
8	0.354	2,500	0.398	2,850	13.30	14.41
10	0.427	2,250	0.444	2,650	13.58	14.45
12	0.442	2,000	0.448	2,300	13.46	14.65

No results are available for the 4-in. pipes as the bursting pressure of these is higher than that obtainable by the pump and tackle used, viz , 6,500 lbs. per sq. in.

For comparison with the above there is given in Table II the figures obtained from similar tests on 5-ft. lengths of sand cast pipes.

TABLE II.—*Tensile Strength of Sand Cast Pipes calculated from Bursting Pressures.*

Dia. of pipe in ins.	Thickness in ins.	Bursting pressure. Lbs. per sq. in.	Calculated tensile strength. Tons per sq. in.
6	0.424	2,050	6.94
8	0.481	2,200	8.87
10	0.507	2,050	9.58
12	0.545	1,550	8.04

The figures for the short lengths are consistently higher than those for the full length pipes, this being due to the greater bending effect on the longer pipes due to end pressure exerted by the bolts.

From the above figures it will be seen that the strength of the spun pipes was on an average 74 per cent. above that of the sand cast. The average calculated tensile strength was 14.5 tons per sq. in, for "spun" pipes 5 ft. long, compared with 8.36 tons per sq. in. for sand cast pipes. These figures appear low, but it will be proved later by other tests that this is due to combined stresses set up in the pipes by this method of testing.

External Pressure Test (Line Load).

In order to obtain a measure of the resistance of the pipes to external loads, such as heavy vehicular traffic and trench filling, this test was made.

The press used consisted of four hydraulic cylinders suspended from a cross-piece forming part of a substantial frame. Sections 24 in. and 12 in. in length cut from different portions of each of the pipes were tested in this machine. Before being tested the external diameter of the sample was measured at four different places to the accuracy of 1/100 of an inch. After the test the thickness was measured with a micrometer at six points along the fracture and the average noted.

The modulus of rupture was calculated from the formula:—

$$\text{Modulus of rupture} = \frac{6}{2\pi} \times \frac{(W\ (D_1 - t)}{bt^2}.$$

where W = weight applied in lbs.
t = thickness of pipe in inches.
b = length in inches.

The point of the first fracture was observed, which occurred at the top or at the bottom of the pipe, these being the points at which the maximum stress takes place.

The average results are given in Table III:—

TABLE III.—*Modulus of Rupture of Spun Pipes calculated from External Pressure Tests.*

Dia. of pipe in ins.	Thickness in ins.	Load per foot in tons.	Modulus of rupture.
4	0.383	8.56	60,060
6	0.379	6.72	54,767
8	0.394	5.47	53,595
10	0.442	5.78	55,257
12	0.441	4.46	52,081

Transverse Test on Pipes.

Pipes were laid in the ground or when supported on beams are subjected to bending stresses, and this test was designed to determine the strength of the pipes under such conditions A machine (Fig. 20) was designed consisting mainly of a heavy bed plate to which was attached a hydraulic ram as shown. The pipe to be tested was supported on the bed-plate on two supports 10 ft. apart. The supports were of cast iron and shaped to fit one-quarter of the circumference of the pipe, and the bearing surface was 1-in. broad.

The load was applied at two points, 4 ft. apart, symmetrical with the end supports. The packing pieces were similar in shape to the supports. The pressure in the cylinder was read on a set of gauges. The area of the cylinder was exactly 112 sq. in., and consequently 1 lb. in the gauge represented a load of 1 cwt. on the pipe. The deflections were measured to an accuracy of 1/1,000 of an inch by means of a vernier depth gauge on a tail rod, which was fixed to the ram.

As before, the pipe to be tested was first carefully measured. The amount of the deflection was noted under five different loads. After this the load was increased steadily up to the breaking point, and gauge readings were recorded. The thickness was then measured at the fracture with a micrometer.

It was deemed preferable to apply the load at two points rather than one, because, by this means, the maximum strain was put on a fairly long length of pipe instead of at only one point. Also, in this way, the deformation of the pipe in its cross-sectional plane was reduced, with a consequent reduction of error.

Under the conditions of this experiment the deflections were measured at the point of application of the load, and therefore the maximum deflection at the centre had to be calculated.

The modulus of elasticity was calculated from the formula $\frac{Wa^2}{12\ EL}(3I - 4a)$ = deflection at point of application of load.

Where W = load: a = one-half the difference between the distance between the points of application and the distance between the supports; E = modulus of elasticity; I = moment of inertia; L = distance between supports.

The value of I being determined from:—

$$I = \frac{\pi}{64}(D_1^4 - D_2^4)$$

The deflection used for the calculation of E was that which was measured when the pipe carried a weight equal to about 25 per cent. of its breaking load.

The modulus of rupture was calculated from the formula.

Modulus of rupture $= \frac{M}{Z}$ where $M = \frac{Wa}{2}$ and

$$Z = \pi \times \frac{(D_1^4) - (D_2^4)}{32D_1}$$

$\therefore$ Modulus of rupture $= \frac{Wa}{2} \times \frac{32D_1}{\pi(D_1^4) - (D_2^4)}$

with $a = 36$ ins., modulus of rupture $= \frac{183.5\ WD_1}{D_1^4 - D_2^4}$

Although the bed-plate was designed to be as rigid as possible, it was obvious that there would be some slight movement. The machine was, therefore, calibrated, and the results were corrected accordingly. Table IV gives the average result of this test.

TABLE IV.—*Transverse Test Results on Spun and Sand Cast Pipes.*

Dia. of pipe in ins.	Thickness. Inches.	Breaking load. Lbs.	Maximum deflection at centre in ins.	Modulus of rupture.	Modulus of elasticity.
SPUN.					
4	0.320	14,900	2.11	53,000	17,350,000
6	0.391	31,400	1.13	45,600	16,850,000
8	0.381	50,400	0.80	41,000	16,910,000
10	0.373	77,300	0.82	41,400	12,700,000
12	0.437	103,000	0.64	34,950	11,290,000
SAND CAST.					
4	0.432	7,560	1.20	23,200	11,400,000
6	0.454	21,000	0.97	27,200	11,930,000
8	0.513	33,600	0.62	21,600	11,150,000
10	0.615	76,100	0.64	26,600	10,650,000
12	0.603	100,800	0.55	25,600	9,560,000

Transverse Tests on Sample Bars.

The following tests were made from pieces cut from the sample pipes to enable a comparison to be made with spun metal and the figures usually specified for ordinary cast iron. The bars were cut longitudinally from different portions of the pipe. There were two bars cut from each portion, one being 1 in. broad and the other ½ in., whilst the thickness was that of the pipe.

The tests were carried out on the machine shown in Fig. 21. The load was applied at a point central between the knife-edge supports, which were 12 in. apart. The bars were loaded with regular increments, a hundred lbs. for the 1-in. bars and 50 lbs. for the ½-in. bar up to the breaking point, and the deflections were measured. These measurements were taken by means of a vernier.

The moduli of rupture and elasticity were calculated from the usual formula.

$$\text{Modulus of rupture} = \frac{M}{Z} \text{ where } M = \frac{Wl}{4}$$

$$\text{and } Z = \frac{bt^2}{6}$$

$$\therefore \text{Modulus of rupture} = \frac{3Wl}{2bt^2}$$

$$\text{Modulus of elasticity} = \frac{Wl^3}{48\ I \times \text{deflection}}.$$

$$\text{Where } I = \frac{bt^3}{12}$$

$$E = \frac{Wl^3}{48\ \text{defl.}} \times \frac{12}{bt^3} = \frac{Wl^3}{4bt^3\ \text{defl.}}$$

Both these formulæ assume that the section of the bar is rectangular, but as these were cut out of a pipe, this is not the case, two sides being curved. Due to the shape of the section, the modulus of the figure is evidently something slightly bigger than $\frac{bt^2}{6}$, and a corrective factor has to be introduced.

Using the following notations:—

Where b = breadth in inches.
t = thickness in inches.
R_1 = outer radius } of the pipe from which the bar has been cut.
R_2 = inner radius }

the following corrective factor for t was devised:—

$$1 + \frac{b^2}{10R_1 R_2}$$

This factor is approximate, but the error is only in the third decimal place, and is therefore negligible, and no greater than the possible errors of observation.

From the figures in Table V it will be seen that the average results for "Spun" metal and sand cast are as follows:—

	Spun.	Sand cast.
Average modulus of rupture	59,768	45,025
Average modulus of elasticity	15,870,086	13,910,000

The figure specified for the British standard transverse bar 2 in. × 1 in. tested on 3-ft. supports, is 28 cwts., with a deflection of 0.33 ins.

The figures in Table V (see page 501) give the average result of all the bars tested.

The figures in Table VI show the equivalent breaking load on a standard 2-in. × 1-in. bar calculated from the above results.

Table VI.—*Equivalent Breaking Loads on Standard Bar calculated from Table V.*

Dia. of pipe. in ins.	Width of bar in ins.	Calculated breaking load. 2″ × 1″ bar × 3′ 0″ support. Spun.	Sand cast.
		Cwts.	Cwts.
4	1	47.46	26.8
	½	45.25	28.7
6	1	42.66	31.85
	½	42.07	31.54
8	1	42.77	27.25
	½	41.32	29.63
10	1	37.82	30.42
	½	39.23	29.66
12	1	38.05	27.98
	½	38.29	29.96

Tensile Tests.

Tensile test pieces were cut from all pipes on which experiments were made. In those cases in which the whole pipe was used for other tests, the

TABLE V.—*Transverse Tests of Bars Cut from both Spun and Sand Cast Pipes.*

Dia. of pipe in ins.	Width of bar in ins.	SPUN.		SAND CAST.	
		Modulus of rupture.	Modulus of elasticity.	Modulus of rupture.	Modulus of elasticity.
4	1	71,767	16,050,000	40,500	—
	½	68,422	15,295,000	43,400	—
6	1	64,500	15,870,000	52,700	13,470,000
	½	63,610	15,990,000	49,200	—
8	1	64,300	16,750,000	41,200	13,000,000
	½	62,300	16,450,000	44,800	—
10	1	58,400	16,000,000	46,000	14,270,000
	½	59,400	15,550,000	44,850	—
12	1	59,000	15,850,000	42,300	14,900,000
	½	58,000	15,100,000	45,300	—

pieces were cut from broken fragments, otherwise they were cut from the spare pieces. In every case two pieces were cut from the same longitudinal section of the pipe and the average result used. The average results of 170 tests are given in Table VII:—

Table VII.—*Tensile Tests of Pieces Cut from Pipes.*

Dia. of pipe in ins.	Tensile strength.	
	Spun.	Sand cast.
4	19.98	10.58
6	19.10	10.71
8	18.43	11.00
10	18.05	11.65
12	18.00	10.90
Average	18.71	10.37

The British Standard Specification for cast-iron pipes calls for a tensile test of 9½ tons per sq. in.

Ring Tests.

Since the physical properties of spun iron are so widely different from those of the same iron cast in sand moulds, in order to test the strength of the metal in spun iron pipes it is obviously useless to cast transverse and tensile test bars in the ordinary way. To cut them out of pipes is an expensive operation, so it was suggested that rings should be cut from the pipe and tested in a similar way to that of the link of a chain.

This method of testing the strength of the spun iron has been adopted by the Stanton Company, and is much appreciated by engineers by virtue of the fact that the result obtained from the test ring represents the strength of the metal as it exists in the finished pipe. A large number of experiments were made, in which the rings were tested and compared with tensile tests pieces cut from an adjacent portion of the pipe, and it was found that the following formula is approximately correct:—

$$f = \frac{W\ (D-t)}{4{,}000\ bt^2}$$

Where W = breaking load in lbs.; D = outer diameter of ring in inches; b = breadth of ring, and t = thickness.

This formula may be deduced theoretically as follows:—It is commonly known that if a cast-iron bar is broken transversely and the maximum skin tension calculated, this maximum will be about 1.72 times the tensile strength of the iron in direct tension. In breaking a ring the bending moment is $\frac{W\ (D-t)}{2}$ and the resisting moment is $\frac{bt^2}{6}$, ∴ the maximum skin tension in lbs. per square inch is $\frac{6\ W\ (D-t)}{2\ \pi\ bt^2}$

This will be equivalent to a direct tensile strength of $\frac{6\ W\ (D-t)}{2\ \pi\ bt^2 \times 2{,}240 \times 1.72}$ in tons per square inch, *i.e.* $\frac{W\ (D-t)}{4{,}034\ bt^2}$ which agrees very nearly with the above formula.

The average results of the series of tests under consideration are given in Table VIII, also the results obtained from a similar number of rings cut from sand-cast pipes for comparison.

TABLE VIII.—*Ring Tests on Spun and Sand Cast Pipes.*

Dia. of pipe in ins.	Modulus of rupture.		Calculated tensile strength in tons per sq. in.	
	Spun.	Sand cast.	Spun.	Sand cast
4	79.280	47.800	20.75	10.8
6	72.113	46.200	18.89	11.09
8	71.300	47.650	18.68	11.1
10	67.800	47.200	18.2	10.64
12	65.600	46.650	17.8	10.58

From this test the average modulus of elasticity of the spun pipe calculated from the increase of vertical diameter = 15,877,000.

Brinell Hardness Tests.

Small pieces were taken from every broken pipe and also each ring used on this test, and were tested on a Brinell hardness machine, using a ball 10 mm. dia. and pressure 1,000 kilo. for

15 secs. Readings were taken from the outside of the pipe, the inside, and the middle of the fracture. The average hardness number of approximately 2,000 results is 182.

Conclusion.

In conclusion, it is the opinion of the authors that in the course of time the methods of casting iron described in this Paper will take the place of the more usual methods which have been the practice in the past.

In expressing this opinion, the writers do not overlook the fact that the Stanton Company, who are certainly by far the largest pipe makers in Europe, and probably in the world, will be the greatest sufferers, in consequence of having to discard plant, patterns, jigs, etc., on a scale obviously in excess of what would be necessary in the case of an undertaking with a smaller capacity of plant.

The characteristics of the spun iron are so outstanding that it can only be a question of time before the process replaces older methods.

From a commercial point of view perhaps the greatest disadvantage to the universal adoption of the centrifugal method of making iron pipes is the fact that unless the pipes are made on an extensive scale, and unless manufacturing operations are continuous, namely day and night, the full advantage is not being taken of low manufacturing costs; and it follows from this that the process will only be adopted by those concerns, and in those countries where an extensive demand is assured. In plain language, the advantages of the spun pipe can be summarised under the following headings:—

(1) The resulting pipes are stronger, and can consequently be made thinner than the ordinary sand cast pipes. The latter are purposely made thicker than the actual requirements demand, to allow for irregularities in moulding and possibilities of flaws in the metal.

(2) The resulting pipes can be relied upon as being uniform one with the other, independent of the skill of the manual labour employed. The necessity in the case of the process of making spun pipes lies in the direction of maintaining the machinery in good condition, and does not rely to

the same extent upon labour. It will be agreed that of the two it is easier to maintain machinery at concert pitch than it is to rely upon the more varying factors associated with every-day labour.

(3) The fact cannot be overlooked that the ordinary methods of making iron pipe necessitate employment of labour under conditions far from congenial, and there is no disguising the fact that during recent years there has been a difficulty in getting apprentices to follow in the footsteps of their fathers. Not unnaturally, the youth of the coming generation drops into work where the surroundings and working conditions are as amenable as possible. It follows from this, therefore, that a process which largely dispenses with the disagreeable conditions of ordinary pipe making, must have its advantages.

(4) Last, and not least, the process is one which cannot fail to produce pipes more cheaply than present methods.

Finally, it is always difficult to introduce anything new into so conservative a country as England. The fact, therefore, that up to the end of November, 1925, over 1,673 miles of these pipes have already been made and supplied must be looked upon as satisfactory, and that of these 1,673 miles of pipes, 73 per cent. represent repeat orders placed by those who have given the pipe trial, speaks for itself.

The plant laid down at Stanton for making these pipes is turning out some 25 miles per week, in sizes varying from 4 in. up to 15 in. dia.

There is no reason to believe that pipes of larger diameter could not be equally well made by this process, but the demand for the larger sizes of pipe is a good deal more erratic, and it is doubtful whether a plant would be justified unless it was kept in fairly continuous operation. This it would be difficult to do when making sizes over and above the ordinary "bread and butter" sizes.

DISCUSSION.

Synchronisation of Movements.

Mr. Herbert raised the question of the speed of moving the mould and the tipping of the discharge synchronising with each other. These two movements were worked by hydraulic pressure, and, so far as he understood, they were not geared. Therefore, one had to depend on the opening of the hydraulic valve for synchronisation, and he did not think that was practicable.

Mr. Wilson replied to the effect that the pumps which supplied water-pressure for operating these machines were of the centrifugal type, and, in addition, there was fixed on the main a special type of air receiver with a capacity sufficiently large to make up the slight variation in pressure caused by the various machines working together. In practice, they found that it was possible to work within limits sufficiently accurate for the production of a pipe uniform in thickness.

Mr. Herbert added that it would be interesting to learn whether they could spin the mould too fast.

Mr. Wilson pointed out that the speed of rotation of the mould was a very important factor, and that the correct speed had been ascertained for each size of pipe cast, this speed having been arrived at by numerous tests carried out on pipes cast at different speeds. It is possible to spin a mould too fast, as, if the speed increased to any extent beyond the optimum speed, it would have an adverse effect on the quality of the pipe.

Tests for C.I. Pipes.

Mr. Herbert said that 20 tons per sq. in. tensile strength had been mentioned for spun pipes, and there were also some figures relating to the actual bursting pressures. In the spun pipes he believed it worked out at about 14½ tons per sq. in., and, on an average, a little over 8 tons per sq. in. for sand-cast pipes. He added that the only thing he could say was that 8 tons per sq. in. on the metal in the ordinary cast-iron pipes corresponded with what they would get in an ordinary test, but understood that 9½ tons was asked for in the British standard specification, which he considered too much.

In answer to the first part of Mr. Herbert's question, **Mr. Wilson** referred to the part of the Paper in which it was expressed that the tensile strength calculated from the bursting pressures was low, both for sand-cast and spun pipes, and this was due to combined stresses set up in the pipes, due to the high end-pressure necessary to make a satisfactory joint to withstand such a high pressure. The results given later, on separate test bursts, proved that the metal in both classes of pipe was considerably stronger than that calculated from the bursting pressures.

Mr. Fox pointed out that he did not agree with Mr. Herbert that 9½ tons per sq. in. tensile strength specified by the British Standard Association was too high for ordinary cast iron; at Stanton Works they had no difficulty in obtaining a figure something higher than this in their ordinary sand-cast metal.

Water Hammer.

Mr. Gardiner asked if any enlightenment could be given with regard to the manner in which these pipes stood up to shock, say, through water hammer. Were they quite as good as sand-cast pipes?

Mr. Wilson pointed out that they had paid particular attention in their investigations in testing pipes to ascertain their resistance to shock. For the purpose of their investigations they had constructed a special type of machine for drop testing. For the purpose of this test the pipes were supported on a cast-iron saddle, and the weight dropped at various heights, whilst the pipe was under internal water pressure. The results obtained from this test proved that the spun pipes, although 25 per cent. lighter, gave better results than the thicker sand-cast pipes.

Migration of Elements.

In reply to Mr. Campion on the question of the migration of the manganese, this element tends to migrate to the *inside* of the pipe, when present as manganese sulphide. In the Stanton spun pipe, the manganese is present to the extent of 0.35 per cent. The sulphur present is sufficient to convert the whole of the manganese into manganese sulphide, so that, in the case of Stanton spun iron, there would be no manganese present other than the sulphide.

In the case of an iron with a higher manganese content, the excess manganese over that required to combine with the sulphur would be present as manganese carbide.

Mr. Campion suggested that this manganese carbide would migrate along with the iron carbide.

Mr. Wilson stated that in their opinion this manganese carbide would be spread evenly through the mass. The authors have no definite data to support this statement, except the fact that the manganese carbide would be in solution along with the iron carbide, and solutions do not migrate. The carbon as graphite migrates, but not the combined carbon.

Carl Pardun, in "Stahl und Eisen," August 28, "Principles of Centrifugal Casting," expressed a similar opinion to the above. He said:—

"So long as manganese is combined with sulphur it migrates towards the inner zone.

"If the amount of manganese combined with sulphur is deducted from the total manganese it is found that the residual manganese is practically equal in extent in all zones."

The figures given in the Paper refer to the total manganese.

Growth of "Spun" Iron.

In regard to the question of the growth of spun iron, this is a matter which at present has not been investigated. Grey cast iron, generally speaking, commences, to grow as soon as heating begins; in grey cast iron the graphite is much coarser than in the spun iron. In the latter it was distributed in a very fine form; this fine graphite distribution accounts to a large extent for the increased strength of the spun iron.

It had been noticed that this fine structure and also the strength do not suffer by annealing for a short time.

Spun iron had been found very good for piston rings, but they had no definite figures to hand as to the question of growth.

He agreed with Mr. Campion that this subject offered a distinct field for research.

Life of Steel Moulds.

With regard to the life of the steel mould, the suggestion had been made that a mould made from some special alloy might be used. They had several well-known metallurgists working on this subject in this country, and they were also carrying out experiments with different materials in the U.S.A. Several special alloy steels have been tried, and the difficulty they had found was that, if they obtained an alloy which was ideal from one point of view, it was weak from another. What was required was a material which would stand repeated outside cooling and inside heating, or the continual " breathing," as it was termed, which took place in the mould itself during the casting of a pipe.

A member asked as to the method to be adopted in cutting pipes produced by the centrifugal process, inquiring as to whether in cutting a spun pipe the wheel should be used. It was sometimes difficult, he said, to get the cutter into use owing to congestion in streets, for example. With regard to boring, he asked whether spun pipes were more difficult to drill than sand-cast pipes?

Mr. Wilson said it was his experience that users of both spun and sand-cast pipes preferred using a diamond point and a flat chisel for cutting pipes underground, particularly in congested streets. Wheel cutters could be used for pipes that required cutting above ground. He also pointed out it had come to his knowledge that recently a machine using a cutting-off tool had been placed on the market. This machine was in two parts, and could be clamped round the pipe to be cut, the cutting off portion being drilled from the ground level by means of a chain and sprocket wheels.

With reference to the possibility of cracking the pipe when drilling for surface connections, he had had no experience of this trouble, but this might possibly happen in any pipe if an attempt was made to feed the drill too quickly. As far as tapping was concerned, his firm had been complimented on this point, as the thread produced was much stronger than that obtained in ordinary cast iron. Samples were on the table for the members of the audience to inspect after the meeting.

Centrifugally Casting in Sand Moulds.

Another question was put from the audience asking whether centrifugal pipes could be cast by sand moulds instead of steel moulds?

Mr. Wilson replied that he had had some experience of casting centrifugally pipes in sand-rammed moulds, running the metal into the mould in a similar manner to what they were doing to-day, and that he understood experiments were now being carried out in America on these lines. The objection to this method of casting was, in the first place, the production was considerably slower than that which could be obtained from a permanent mould; secondly, the internal surface of the pipes was considerably rougher; and, thirdly, due to the slow rate of cooling, the pipes were very little stronger, if any, than those cast in the ordinary method, and that he did not consider any advantage could be claimed for this method of casting over that of the ordinary vertically cast pipes.

Mr. Lawrie pointed out that in the tests made with pipes made by the centrifugal method and pipes made in the ordinary way, it was stated by the lecturers that the metal was taken from the same ladle. That might be, but he would like to say that in this particular case the metal might be suitable for centrifugal casting, and not suitable for sand casting; consequently, the test would probably be against the sand-made casting. He thought that, in fairness to the old method, that should be taken into account. If the silicon was reduced down to the necessary degree to give a strong sand casting, they would get a far better test. He congratulated the Stanton Company on what they had accomplished.

Mr. Wilson agreed with what Mr. Lawrie said with regard to the silicon content in the metal used for sand-cast pipes and spun pipes, but pointed out that the figures shown were taken at an early stage in their experimental work, and that the iron used in this case was suitable for sand-cast pipes. In other words, the metal was taken from a cupola which was supplying metal to the vertical pipe pits and was not specially melted for the production of spun pipes.

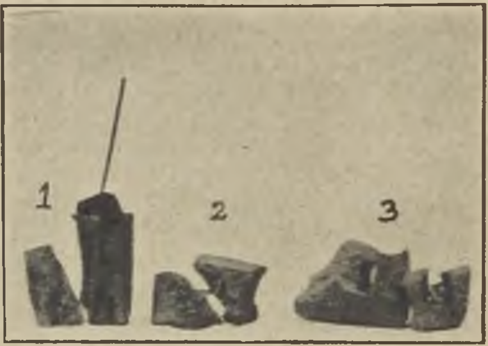
A question was asked if any attempt had been made at casting thin pipes by this centrifugal process, and Mr. Wilson, in his reply, stated that his firm had experimented in this direction, and had been able to produce pipes 6 in. external diameter, 12 ft. long, as low as $\frac{1}{8}$ in. thick.

Wales and Monmouth Branch.

GASES EVOLVED FROM HEATED IRON.

By Ben Hird, Member.

In the following experiments an attempt was made to discover the nature of the gas which is given off from solid pieces of iron when their temperature is raised. This frequently occurs when nails, studs, chaplets, pieces of bar or pipe, chills or denseners are placed in moulds, and their temperature raised by pouring molten iron around them. The gases given off under these conditions form gas holes in the vicinity, or directly connected with the nails, etc., which often cause serious trouble, and sometimes, loss of the casting when they occur on machined faces, or, where pressure tests are required. Figs. 1 to 3 show blowholes caused by gas given off from a clean 6-in. sprig (Fig. 1); a tinned stud (Fig 2); and a tinned pipe nail (Fig 3). These were cast open in green-sand experimental moulds 2 in. × 3 in. × 6in. long, four in each mould. When the castings were broken, all the sprigs and pipe nails



Figs. 1 to 3.

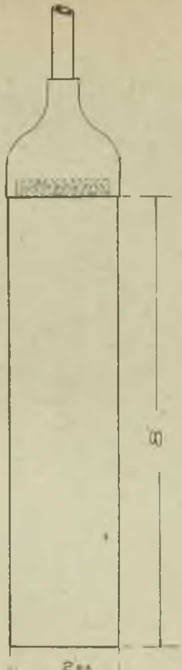


FIG 4

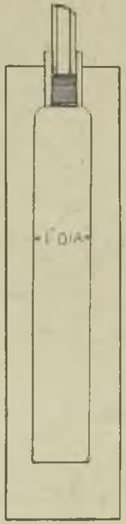


FIG 5

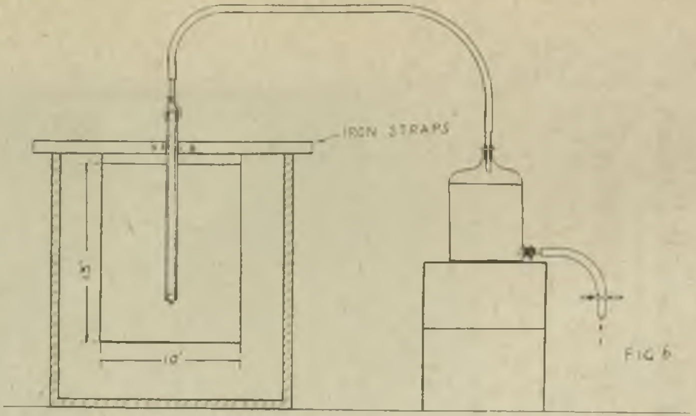


FIG 6

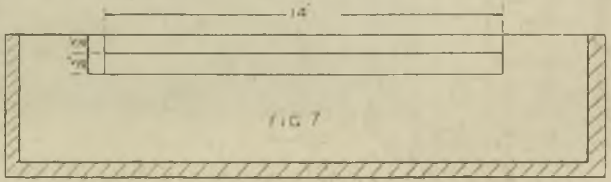


FIG 7

showed blowholes, of the studs, two were solid and two were blown.

The first experiment was carried out as shown in Fig. 6. A mould was made in green sand from a pattern 10 in. dia. by 13 in. long and left open at the top. A piece of 1 in. wrought-iron pipe 5/16 in. thick in section, sealed at one end and screwed at the other to take a reducing socket into which a short piece of $\frac{1}{4}$-in. pipe could be fixed was made. The pipe was ground up bright on an emery to remove all traces of oxide, and afterwards heated to redness in a flame to remove all moisture, then allowed to cool (*circa* 80 deg.C.). When the mould was filled with molten iron, the pipe was pushed down in the centre and held there by weights on the iron straps, which were clipped on to the pipe and took a bearing on the edge of the moulding box. A length of rubber tube connected at one end to a 500 cc. gas-collecting bottle was pushed over the $\frac{1}{4}$-in. pipe. Gas began to

FIG. 8.

come through at once; after four minutes it came very freely in pulses of four to five seconds intervals. The bottle was filled with gas in twelve minutes, and a second 500 cc. bottle was connected up. The gas now came more regularly, this bottle was filled in 28½ minutes, making a total of 1,000 cc. of gas in 30½ minutes. The rubber pipe was disconnected and a light applied to the end of the ¼-in. pipe; gas was still coming off and ignited for an instant with a pale blue flame. Looking down the tube it was possible to discern about 1 in. from the top of the casting a number of small bubbles, the gas apparently forcing its way through the pipe at this point. Next day, when the casting was broken, the top portion, close to the pipe, where the small bubbles were seen, was honeycombed all around with blowholes, for a depth of 2 in. Large gas holes extended from the pipe into the casting in many directions (Fig. 8).

Fig. 9.

Experiment with Hollow Cast-Iron Chills.

A second experiment was made with cast-iron chills (or tubes) on similar lines to the first. Four cast-iron chills were made 2 in. dia. by 8 in. long with a 1 in. hole in the centre, one end solid and a ¼-in. gas union cast in the other to take the piece of ¼-in. pipe, as shown in Fig. 5. The chills were quite free from rust or moisture and were heated to 200 deg. C. before casting the iron around them. Several countersinks were put in each chill, the object being to assist the gases to penetrate to the centre hole. Each mould was 10 in. deep and the chill was set in the centre just before pouring the iron.

No. 1, $4\frac{1}{2}$ *in. Diameter.*—Hot iron was poured into the mould and gas was evolved at once with a very quick flow, easing off to very slow after two minutes. Forty-five minutes later there was a sudden increase in the flow for about two minutes. The 500 cc. bottle was filled in 85 minutes. This casting was quite solid when broken, as shown in Fig. 9 (1).

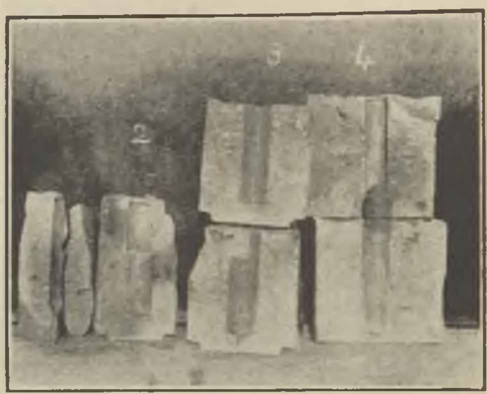


FIG. 10.

No. 2, 6 *in. Diameter.*—Hot iron was again poured into the mould; gas came off quickly at once, easing off after one and a half minutes; from then on it came away very slowly. The 500 cc. bottle was filled in 82 minutes. This casting was quite solid when broken, as shown in Fig. 9 (2).

No. 3, 8 *in. Diameter.*—Once more hot iron was poured into the mould; gas came off at once very quickly; it reached maximum in one and a half minutes and could be seen coming into the bottle like a thin white mist. The gas continued to evolve freely, the 500 cc. bottle being filled in eleven minutes. Gas was still coming away after disconnecting the bottle. When this casting was broken large blowholes were found, which showed distinct proof of coming from the chill, as shown in Fig. 9 (3).

No. 4, 10 *in. Diameter.*—This time dull iron was poured into the mould; the gas came off very slowly at first, but after two minutes it came more freely, gradually increasing. About 400 cc. of gas was collected in 48 minutes when the flow ceased. This casting was quite solid when broken, as shown in Fig. 9 (4).

The condition of the chills when the moulds were burst open was quite sound and perfect, showing no signs of seizing on or distortion.

Experiment with Solid Cast-Iron Chills.

The chills were made as shown in Fig. 4, that is 2 in. dia. × 8 in. long. Three moulds were made 10 in. long × 6 in., 8 in. and 10 in. dia. respectively. They were all cast with hot iron and the chills were warmed to 100 deg. C. before placing them in the moulds.

No. 2, 6 *in. Diameter Mould.*—Gas came as soon as the mould was filled with iron, the flow was very slow. There was a distinctly noticeable increase in the flow of gas about 30 minutes after casting, which lasted for about ten minutes; about 200 cc. of gas was collected in 77 minutes.

No. 3, 8 *in. Diameter Mould.*—When the mould was filled gas came at once very quickly; about 200 cc. of gas was collected in eight minutes, the 500 cc. bottle was filled with gas in 45 minutes.

No. 4, 10 *in. Diameter Mould.*—Gas came off at once very quickly and could be seen gathering in the top of the bottle like a thin white mist. The water flowed from the outlet tube in a steady stream for thirteen minutes, then eased off to 115 drops per minute. The bottle was filled with gas in 20 minutes.

When these castings were burst open, the chills showed a peculiar distortion, varying in intensity with the diameter of the castings as can be seen in Fig. 10. No. 2 (Fig. 10) was very slightly distorted; No. 3, more so; whilst No. 4 was quite pronounced. When the chill was broken out of No. 4 the hole formed by the chill was pressed back behind where the distortion to the chill is seen in the illustration and a crack about $1\frac{1}{2}$ in. long ran back into the casting. When the portion was broken through, a large cavity extending a considerable distance was disclosed, a portion of this being shown in Fig. 11 (1). A part of the same cavity can be seen in the left-hand corner of the top half and right-hand corner of the bottom half of Fig. 10 (4). Apart from this the holes formed by the chills were quite true to shape. The appearance of the chills suggested that some extremely high pressure had been exerted upon them whilst in a semi-molten state. The fact of the holes formed by the chills being quite true and smooth suggests that this distortion was caused by the gas pressure. Fig. 12 shows the condition of the sides of the hole very clearly, also the method of collecting the gas.

Fig. 11.

When broken, No. 2 showed a characteristic pipe opening up into larger cavities where the gas, reaching the more liquid metal in the centre of the section, has more freedom to expand. This is shown more clearly in Fig. 11 (2 and 3). A piece of string and a piece of wire were placed in one of the many pipe holes to emphasise this point, which the author has often noticed when gases have been given off from solid metals inserted in moulds, whether in the form of chills or to be cast-in. A personal theory is that the gases are given off from the solid iron, after it has been raised to a certain temperature by the surrounding molten metal, the metal around the chill having solidified to a soft, putty state before the gas is given off, so that the gas has to force its way forming small pipes or channels to where the metal is more liquid. Here the gas has room to expand, and forms larger cavities. The casting shown in Fig. 11 (3) had several similar blowholes, but the piping was not quite so pronounced.

Fig. 12.

There is here a phenomenon which is very difficult to explain. The chill in the smaller diameter casting is the least distorted, and the gas has penetrated into the casting, obviously whilst it was in a plastic condition. The chill in No. 3 has more distortion and less evidence of pipe-shaped blowholes. The chill in No. 4 is badly distorted, and there is only one distinct gas hole leading from the chill which had the appearance of being caused by an intense pressure of gas bursting through the almost-solidified metal surrounding the chill. One would have expected the opposite to occur, and the larger diameter casting to be penetrated by the pipe-like holes if the outlined theory is correct. It is not desired to advance any dogmatic conclusions, but merely to state, as clearly as possible, the results of the experiments made in the hope that others will take up this question which is so important to foundrymen.

FIG. 13.

(The mark on 2A Casting is a scratch on the film.)

From these experiments and past experience it is recommended that all who use round chills of this type provide them with a hole through the centre, like a vent, to give the gases a means of escape.

Heating Chills in a Coke Fire.

The chill was of the same type as used in the previous experiments with solid chills, that is to say, 2 ins. dia. × 8 ins. long., and also was connected up to the gas bottle in the same way.

The chill was placed in the furnace fire at 3.25 p.m., and gas started to be evolved at 3.29 p.m. The bottom part of the chill was showing a dull red at 3.30, when the pressure of gas caused the water to flow from the bottle in a small, steady stream, which reached its maximum about 3.33. At 3.35 the chill was red hot about half way up, and the water from the bottle had diminished to rapid drops 120 per minute. The 500 cc. bottle was now about half-full of gas. At 3.40 the drops had further diminished to 52 per minute, and the bottle was about three-quarters full of gas. The chill was now red hot at the top and white hot at the bottom, in fact the chill had just started to melt. At 3.45 the water was coming away at the rate of ten drops per minute, and there was about half an inch more gas in the bottle. At 3.50 drops of water had almost stopped—being 5 per minute—half of the chill was now melted away. At 3.55 three drops per minute, and at 4.0 o'clock the gas had stopped coming away from the chill and the part which remained unmelted was taken out of the fire.

The gas from these experiments was tested in an Orsat Lougue gas analysis apparatus containing four tubes. The author was not able to check the results very carefully, but Table I shows the average of the results obtained.

TABLE I.—*Composition of Gases evolved in the experiments described.*

	CO_2	CO.	H_2.	O.
Experiment No. 1 Wrought iron tube	Nil.	3.3	66.0	Nil.
Hollow Chills, No. 1 ..	5.5	22.0	Nil.	15.5
,, ,, 2 ..	6.2	21.3	Nil.	12.8
,, ,, 3 ..	4.3	13.3	6.2	14.2
,, ,, 4 ..	7.6	20.1	Nil.	13.6
Solid Chills No. 2 ..	14.5	17.5	Nil.	5.0
,, ,, .3 ..	30.5	36.5	4.66	3.0
,, ,, 4 ..	9.0	12.0	Nil.	8.0
Solid chill heated in fire ..	5.0	7.5	Nil.	Nil.

As a result of another simple experiment made to prove that gases are given off from solid iron when it is at a certain temperature, it is thought that by careful research the exact temperature could be found. In this case two open sand-moulds were made as shown in Fig. 7. Iron was poured in to a thickness of three-quarters of an inch into each of the moulds. Fig. 13 (1a) illustrates a casting which was allowed to cool down to 870 deg. C. (taken with an optical pyrometer), and then plate No. 1 was poured on top of it. Gas could be seen coming up through the layer of iron and burning for an instant with a pale blue flame until the iron set. When the plates were broken apart the top plate was honeycombed with blowholes, as shown in Fig. 13 (1).

In the case of the casting illustrated in Fig. 13 (2a) the first layer was allowed to cool down to 115 deg. C., taken with a thermometer, before pouring on the top layer. When these plates were separated after cooling the top one, Fig. 13 (2) was quite sound and free from blowholes.

It is well known amongst those who use chills for various purposes, such as chilled plough shares, rolls, etc., that when chills are over a certain temperature the molten iron will not lay quietly against the chills.

Although these experiments are rather crude and incomplete, the author is confident that further investigation of the phenomenon along the lines indicated will be of considerable value to the foundry industry.

Lancashire Branch.

LIQUID SHRINKAGE IN GREY IRON.

By J. Longden, Associate Member.

Existing Theories.

Continental foundrymen, notably Ronceray, Brunelli and Leonard, had given a good deal of thought to the question of whether the cavities and porosities found in grey iron are to be attributed mainly to the action or presence of gases, or to a simple increase in density of the metal on crystallising. They leaned to the view that the chief cause was gas, either "entrained" in the act of pouring, or given off from the mould or cores. They further suggested that important changes, about which little was known, took place in cast iron, in passing from a high temperature to solidification. In their view the liquid grey iron expanded with falling temperature and if a mould was soundly rammed and no risers were provided such expansion helped to procure soundness in the casting. Fletcher, in this country, had long held somewhat similar views as to the importance of the question of gas influences, though his conclusions were not quite in line with those just referred to.

Some important principles of a practical character were dependent upon the answer to this question of the cause of cavities in grey iron. The technique of the foundry had been slowly built up by generations of foundrymen who believed that cast iron shrinks on solidifying. Without losing sight of the importance of venting, experience taught them the need for feeding, by rod or head, or for some alternative or supplementary method. If the "gas school" were correct attention must be directed mainly to questions as to melting conditions, venting, and pouring, and as to mould materials.

C, Fig. 1, shows the broken boss of a pinion with cast teeth, weighing 52 lb. The boss had $1\frac{1}{4}$ in. of metal all round the core, and was joined

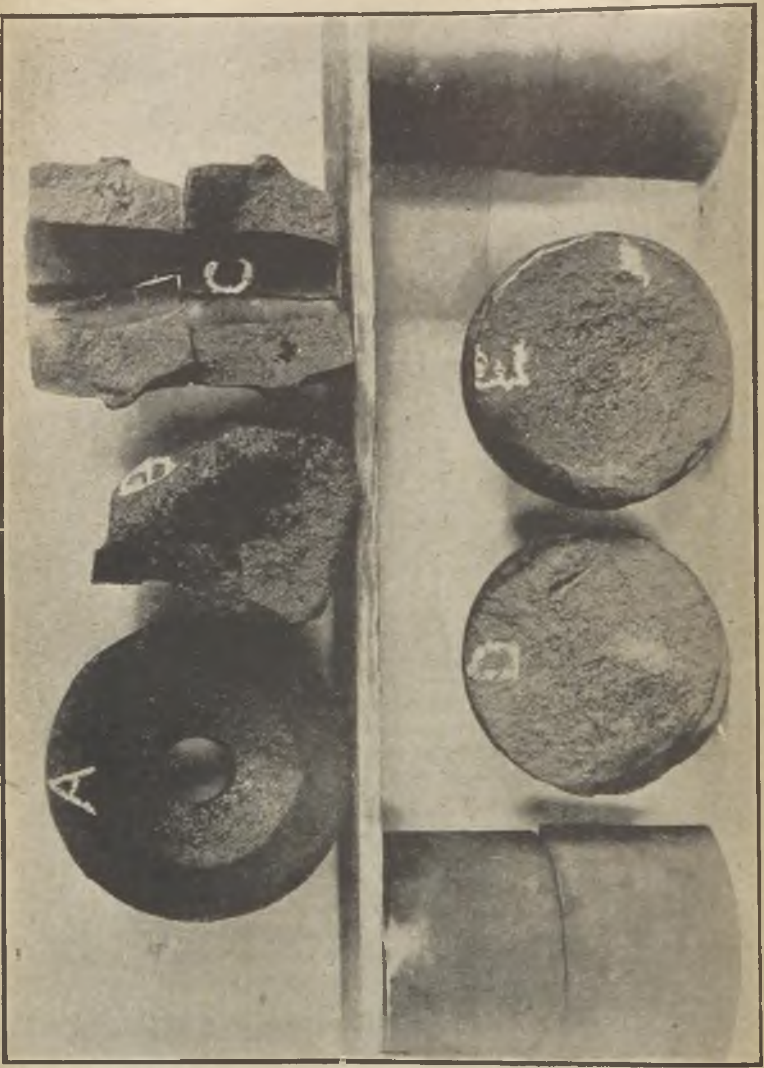


Fig. 1.—Sample Castings Exhibiting Defects.

to the rim by a solid web, $\frac{7}{16}$ in. thick. The casting was poured through a pencil runner placed on the rim; the metal was of the following composition:—Silicon, 2.40; total carbon, 3.40; manganese, 0.45; phosphorus, 1.30; and sulphur, 0.10 per cent. Was the cavity shown due to gas which had been entrained in the act of pouring, or to gases from the mould or core which had not found a way out?

With a properly-made runner basin there appeared to be no reason why air should be entrained. If a basin of proper size was used and kept full whilst casting was going on, the runner was as well sealed as it would be if a filter core were used. In this case a pencil runner was used, so presumably no air could have been entrained. Unless dull iron was used there was no reason why air carried down with the metal should not at once free itself on entering the mould and pass out through the interstices of the sand of the mould or the riser, together with the air which filled the mould at the commencement of casting. The relative difference in gravity of cast iron and the gases concerned was so great as to make it extremely difficult for the latter, if free, to stay below the surface of the metal. In hot metal (leaving out of consideration for the moment the question of dissolved gases) gas must rise to the top; if it could not escape it would be found later at the top or lodged under some projection. Such bubbles could always be related to some unsuitable mould condition, and "blowing" would have taken place at the runner or riser. Therefore it could not be admitted that entrainment of air might be responsible for the cavity in the boss.

Is gas emitted from the core or mould at a later stage, when it cannot rise to the top owing to the partial solidification of the metal? The author rejects this suggestion. It could not be imagined where, at that stage, the metal could have gone to which occupied the space supposed to have been taken up by the gas. A conclusive point was that the cavity was penetrated by crystal growths. Crystallisation could not proceed in gas, only in molten metal; therefore the space where the cavity was must have been previously filled with liquid which had drained away leaving the stark skeleton outstanding.

Leonard Effect.

In respect of examples A and C, Fig. 1, the question might be discussed whether the defects were due to what had been called the "Leonard effect." In other words, had gas lodged in the location of the defect, because such a location presented the line of least resistance? Where a core was insufficiently dried or vented, or the mould was insufficiently vented, it might, sometimes, whilst the metal in the runner or riser was fluid, be easier for the gases to force their way through the liquid metal than back through the core or mould. But here, again, the cavities shown had evidently been formed when solidification was rather advanced. If a bubble of gas had been trapped in that central position whilst the metal was fluid, no crystals could grow in the rounded space occupied by the gas, and the cavity would have the smooth, round form which was always associated with simple gas cavities. One could not conceive of gas forcing its way from mould or cores into a section in which solidification was so far advanced that a skeleton crystal growth had been formed. At such a stage runners and risers were frozen, and metal could not be squeezed out from the casting. How, then, could gas force its way into partly-solidified metal? Probably gas could not cause cavity or porosity in that way.

On the face of it, the idea behind what had been called the "Leonard effect" was very plausible. A cavity was attributed to the emission of gas from some local piece of the mould or core. Very often such defects were found near to parts of the mould which were difficult to vent properly, but that was only coincidence. The important fact was that such parts lost heat relatively slowly, and when a portion of a mould or core was badly vented, a part of the casting was thereby kept hotter than it otherwise would be. A good vent was also a good conductor of heat—that of hot gases from the mould face. The resulting hot spot might serve as a feeder for surrounding parts of the casting.

Many foundrymen expressed themselves as doubtful whether the appearance of a cavity could be said to show whether the cause was gas or not.

There were difficult marginal cases, but generally speaking the difference was very marked, in minute cavities as well as in large ones. This statement is confirmed by a microphotograph (Fig. 2) of an open-sand-cast bar, 1 in. × 1 in., the last of four which were poured out of one shank of metal, each bar representing a stage in the process for the elimination of sulphur. The fourth was cast when the metal was rapidly nearing the pasty stage. It was fluid enough to allow the gas bubbles to distend in spherical form, but the fluidity was exhausted just in time to hold the bubbles at or near their points of generation. The important thing to notice is the bright, rounded appearance of these microscopical bubbles, which were photographed at a magnification of 350 diameters. The agent was definitely gas, as the appearance showed. No dendrites were seen penetrating them.

Gas Content of Metals.

Allerman and Darlington had stated that ferrous alloys might occlude large quantities of gases, in some cases equal to 200 times the volume of the metal; and that hydrogen was the most readily set free, carbon monoxide next, whilst nitrogen was held most tenaciously. Very little information was available as to the amount of gases soluble in cast iron at any given temperature, though the fact was well established that cast iron, when molten, did contain large quantities of gas. It was equally well established that large quantities of gas were kept in solution after solidification was complete. Cast iron, however, on passing from the ore in the blast furnace to the ladle under the cupola spout, had reached whatever degree of saturation by gas represented equilibrium; and it did not seem reasonable to suppose that such cast iron could take up into solution further quantities of gas in the mould. The conclusion, therefore, was that gases generated in the mould must pass away as bubbles or be trapped in the same condition. This statement might require to be modified, in line with the views expressed by Fletcher, namely, that mould conditions might be responsible for the presence of iron oxide in the metal whilst liquid in the mould, and this, reacting with carbon, might produce CO, which then became instrumental in producing cavities. Hadfield told them that free oxygen had never been extracted from either solid or molten steel. Therefore, if oxygen was present it must be as oxide. J. E. Johnson was said to have found 0.065 per cent. of oxygen in a cast iron, but he obtained his results by bessemerising a low-silicon iron from a cool-running furnace. Relatively little British foundry iron to-day came from such furnaces.

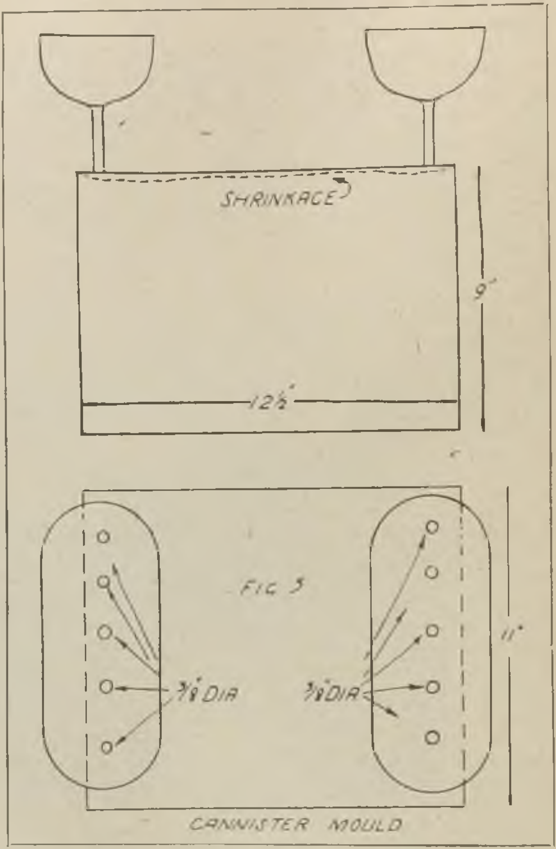
Fig. 2.—Open-Sand-Cast Bar × 350 dias. Exhibiting Gas Bubbles.

Comparison with Steel Conversion.

It was well established, however, that silicon, carbon and manganese were strong deoxidising agents, and small quantities added to molten steel were found to prevent or reduce the tendency for gases to come out of solution on solidification of the metal, and thus to prevent blowholes. That the reactions between iron oxides and silicon, carbon and manganese were very rapid might be gauged from the fact that, in a 10-ton acid Bessemer blow, 8½ cwts. of these elements were oxidised out in 9 minutes. In the cupola the great bulk of the metal in the well was in contact with incandescent coke for as long a period or longer. Circumstances, therefore, did not seem favourable to the retention of iron oxide in the metal up to reaching the mould for casting. Bubbling in the mould, due to dampness or lack of venting, might induce a slight bessemerising of the metal locally. It was not certain, however, that carbon would be oxidised. At that low temperature it might be silicon which produces no gas.

Influence of Dissolved Gases.

The influence of dissolved gas was put by Fletcher in this way in 1918:—"Growing first normally to the cooling faces of the mould, the primary austenitic crystallites, as they freeze, eject the gases they contained, when liquid, into the surrounding molten liquor. Forcing their way between the dendritic branches and stems, increasing in volume and the smaller bubbles coalescing during the advance, they strive to reach the centre of the ingot. The smaller skin crystallites, growing rapidly, close up their ranks in the rear, driving before them the gas streams as the envelope thickens." In this description one saw a possible explanation of the presence of cavities, which did not depend upon volume change in the metal. But it could only explain the cavities shown at A, B and C of Fig. 1 if the gas were out of solution and suspended finely throughout the metal before runners or risers were set; otherwise the gases, if there were no shrinkage cavities to receive them, could only occupy the space which they held when in solution, which was relatively negligible. That is to say, if there were no liquid shrinkage gas could only form cavities



by ejecting the metal which had hitherto occupied the spaces.

After a fairly long experience the author could not recall having seen on the surface of molten or solidifying cast iron any evidence of gases being given off except that which is often seen creeping up from the sides of the ladle, or from underneath slag on the surface of the metal—each of which cases carried its own explanation.

In proof of his views Fletcher advanced the

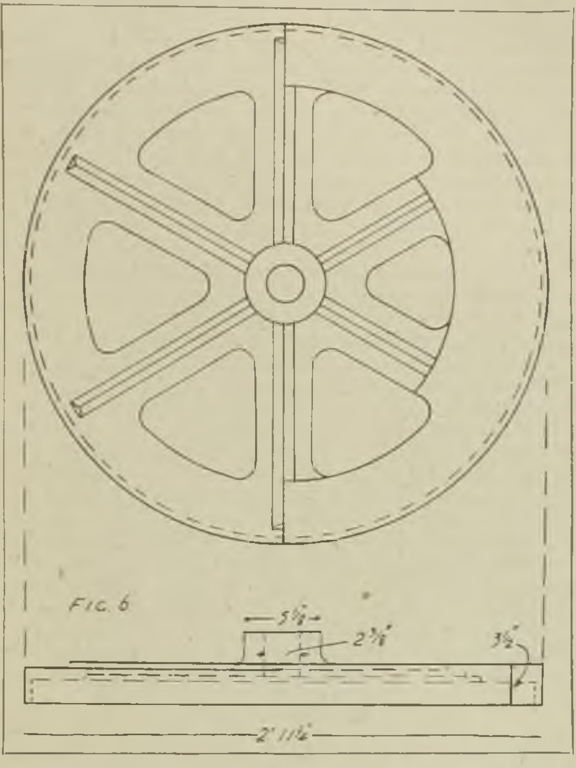


FIG. 6

fact that an open-sand-cast iron plate would show bubbles on its upper surface on examination when cold. These, Fletcher thought, were due to gases freed from the metal riding at the surface. But this was by no means conclusive. Let anyone cast two open-sand cast plates in hot cast iron. Let the first be left uncovered and the second, immediately after casting, be covered with a thin layer of fine dry sand, sieved on carefully. The upper surface of the first would be found to be full of holes, just under the skin, whilst the second would be as solid as if a top part had been used. If gases came out of solution in the first case, why not in the second case? There could be no question of pressure. He leaned to the view that the subcutaneous bubbles found in the first were not, strictly speaking, gases from the metal, but were formed by reactions between the rapidly forming skin of iron and iron-oxide on the surface; the oxide giving up its oxygen to the carbon, bubbles of gas were formed and held between downward-growing dendrites and under the fairly strong skin at the surface.

When gases were coming off molten steel it boiled. On solidifying aluminium alloys ejected gas sometimes produced small blisters. If, however, steel was degasified (or at any rate the gases were kept in solution over the solidifying period) the pipe became more pronounced. Probably the metal which was most gas-free was the metal which piped most readily and had the greatest apparent liquid shrinkage. Recent experiments had demonstrated that in certain aluminium alloys, when treated by a process which removed gases (included if not occluded), the liquid shrinkage factor was increased and an increase in density followed. This was also true of steel. All this evidence seemed to show that, whatever be the degree of importance of the influence of gases, there remained, at the back of it all, an independent and substantial liquid shrinkage factor, which had to be dealt with as a separate problem.

Experimental Data.

In a Paper read last year before the Falkirk Section, the author outlined some experiments undertaken by him to ascertain the amount of liquid shrinkage in certain grey irons. The irons used were of the medium order in composition. He proceeded upon this principle: A runner, of any dimension, is capable of feeding a casting, in some degree, after pouring is complete. Hence, if liquid shrinkage is to be measured in any quantity of metal, that quantity must be isolated from any supply of head metal. In moulding, the upper surface of the pattern was kept perfectly level whilst the joint was kept full and sharp to the top of the pattern. When such a mould was being cast the mould filled; then, if the head was kept full, the metal ran away through the channel provided for it; at the same time there was some little pressure on the flat upper surface of the mould. When pouring ceased all metal not required to fill the mould drained away. Such a casting had no head from which to draw supplies of new metal. With each example of this kind a further mould was made and cast out of the same shank of metal. In the second case, however, the mould was provided with a 2-in. diameter riser for feeding with the rod. The one was then weighed against the other, the idea being that equal weights of metal of the same composition represented equal volumes, and therefore, that the difference in weight fairly represented the difference in volume. In green-sand-made castings the difference was found to be round about 4.5 per cent., in dry-sand-made castings about 2.35 per cent. Further experiments with the same pattern disclosed the fact that, soon after casting, the shell of the green-sand-made casting expanded, increasing the capacity of the block by 2.737 cub. in., whilst the dry-sand-made casting increased its capacity by 0.707 cub. in. This showed that the higher resistivity of the dry-sand mould reduced the shrinkage cavity, because the forces which made for expansion were directed inwards to a greater degree than in the green-sand mould. The general conclusions arrived at were:—

(1) Grey iron shrinks round about 4.5 per cent. of its liquid volume on crystallising.

(2) If the expansion which immediately follows crystallisation be directed wholly inwards, there is a residual loss of volume, due to liquid shrinkage, of round about 1.5 per cent.

(3) Quick cooling (as by the use of chills) does not reduce the rate of liquid shrinkage, but makes for greater solidity only if solidification is so speeded up thereby as to enable new metal to reach the part concerned.

(4) The aggregate loss of volume due to liquid shrinkage does not appear to be appreciably affected by temperature of pouring or composition.

(5) Slow pouring does not reduce the rate of liquid shrinkage, but may alter its distribution throughout the casting.

The late T. D. West, from experiments made with spheres cast in dry sand, concluded that, generally, cast iron shrinks about 1 per cent. on solidification. Later, after further experiments, he concluded that the shrinkage factor was round about 2 per cent. for sand-made castings and 4.5 per cent. for chilled castings. Now if the cavities found in castings were due solely to simple volume change, the absolute shrinkage factor for an iron of a given composition would remain constant; if the cavities were simply due to gases which had come out of solution the shrinkage factor would become a cavity factor

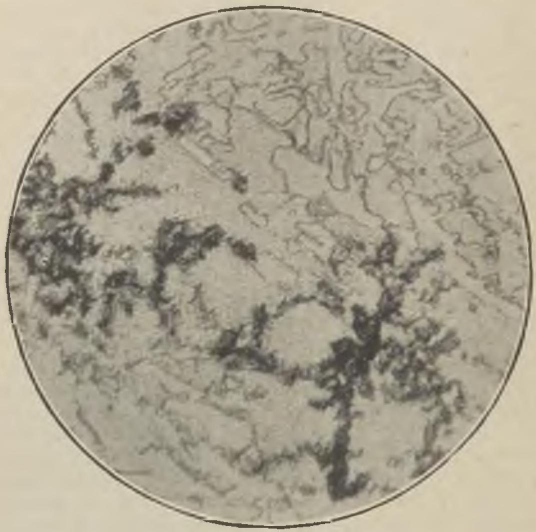


Fig. 7.—Showing Presence of Graphite in Rapidly Cooled Cast Iron.

varying with the amount of gas held in solution and that which may be released on solidification. These last factors might depend upon the vagaries of furnace practice.

In respect of the irons used by the writer in the experiments referred to above, the phosphorus contents of the metal ranged from 0.6 to 0.7 per cent. It was also pointed out that, having regard to Turner's conclusions in respect of the post-solidification expansion of phosphoric irons, that such irons, in certain circumstances, might show no residual shrinkage. In respect of experiments in plumbago and ganister moulds, which have recently been made with a view to proving that cast iron does not shrink on solidificaton, it is worthy of note that the irons used were of the phosphoric order. The writer has cast a 5¾-dia. sphere in a plumbago-lined mould, through a runner, on the joint, of 2½ ins. by ⅛-in. cross section, in similar metal, which proved to be solid to the eye. The metal analysed as follows:—Si. 2.43, C.C. 0.37, G.C. 3.1, P. 1.2, S. 0.1, Mn 0.42. On the other hand, the writer has cast many similar blocks in plumbago moulds, with low P. iron, without succeeding in getting a block free from shrinkage cavities. One such block is shown at E, Fig. 1, whilst D is the solid sphere in high P. metal.

In order to see whether a ganister mould would give solidity in the absence of any adequate source for the entry of new metal, a mould was made in ganister of the dimensions and form shown at Fig. 5. Five runners, each ⅜ in. dia., were placed at one end of the top part of the mould, and five risers of the same size were placed at the other end. The mould was kept on the stove bogie for a week, going in and out with the jobs for drying each day. It was then cast with metal of the composition—Si. 2.53, T.C. 3.66, P. 0.65, S. 0.08, and Mn. 0.42. The metal was not very hot, but was very fluid, running quietly through the mould and filling up the riser head, which weighed 50 lbs. When examined, the casting was found to have piped, in the form of a shallow depression, which covered most of the upper surface of the casting, varying in depth from ⅛ in. to 3-16 in. Before closing the mould, great care had been taken to ensure that the top face of the mould be perfectly smooth and flat. The void thus apparent in the casting was about 15 cub. in., representing about 1 per cent. of the total capacity of the mould. Whether the interior is solid or not, the writer does not know, not having been able to get it sectioned. In view of these experiments, the writer cannot agree that all grey irons, when cast into plumbago or ganister moulds, do not shrink on freezing.

It was probable, however, that high-phosphorus irons showed relative solidity in such circumstances, though not when cast into green-sand moulds.

Influence of Temperature on Castings.

The author's experience led him to the conclusion that temperature differences did not much influence absolute liquid shrinkage, yet there was no doubt that pouring temperature had important influences on solidity in the casting. Anderson and Johnson were of opinion that the higher the temperature at which a metal entered a mould the greater would be its liquid shrinkage, and hence the weight of metal which could be poured into a mould at a higher temperature was less than at a lower temperature. As neither writer expressly excluded cast iron from this generalisation, it might be assumed they both included it.

Table I.—*Experimental Data.*

	Weights in lbs.		
Test.	First Cast.	Last Cast.	Difference.
1	228	222¾	5¼
2	230	228	2
3	232	225	7
4	226	225½	4½
5	229½	222	6
6	228		

Analyses.

4	C.C. ..	0.39	0.35
	Gr.C. ..	3.27	3.38
	Si. ..	2.51	2.50
	P ..	0.78	0.71
	Mn. ..	0.41	0.40
	S. ..	0.68	0.67

Specific Gravity.

4	.. ..	7.101	7.094

But whilst the principle was possibly true of some grades of cast iron, it was not true of a soft iron which the author had investigated. A casting was moulded on a jar-ram turnover machine. The pattern was of cast iron, highly finished, mounted on a machined plate. The moulding boxes were uniform and machined on the joint faces. Each day, before moulding began, the sand was thrown into a single heap. Each box was given the same number of bumps in ramming, and the air pressure was constant. Each day, eight moulds were cast out of a one-ton ladle, eight minutes elapsing between the commencement of casting to the finish of casting the eighth (Fig. 6). A summary of the data in respect of six days' casts is given in Table I. In every case which he examined, the last to be cast was lighter than the first. There was no perceptible difference in the castings except in weight; the last cast was as sharp as the first.

Graphite in Molten Cast Iron.

Some light was thrown on the subject by the analysis of No. 4 series. The one cast at the lower temperature was lower in combined carbon and higher in graphitic carbon, whilst the last cast was of lower density than the first. When the eight of that series had been cast some of the remaining metal was caught into a hand-ladle and a little was poured, in as thin a stream as possible, into cold water. A small button of this of some 6-mm. diameter was polished and etched, and a microphotograph taken. The microphotograph (Fig. 7) showed the unmistakable presence of graphite, with a matrix of cementite and martensite. From the lay-out of the graphite particles it might fairly be assumed that they formed a number of flakes which were broken up in the crunch consequent upon chilling. It was too often assumed that graphite could not exist in ordinary grey irons whilst molten. From the analysis it was apparent that the metal in question was hyper-eutectic in respect of carbon; but so were a good many cast irons used in the foundry. In this case the graphite had probably come from decomposed primary cementite.

The view that molten iron tended to expand in the mould might find some support in respect of irons of the type here mentioned. If graphite was liberated in the metal whilst liquid, the latter would tend to gain in bulk before freezing. If such metal was in the mould before separation took place, and there was no opportunity to throw back the metal up the riser or runner, the metal would be denser than if cast at a lower temperature. It was generally admitted that pressure alone was sufficient to hinder the formation of graphite. This would seem to afford some explanation as to why castings which were cast hot were denser than those which were cast with dull metal. Whether this was equally true of eutectic or hyper-eutectic irons was not quite so certain.

Smalley had presented a mass of original data upon the subject, which was of immense value to every foundryman. The author did not agree, however, with Mr. Smalley's principal conclusion, namely: "Cupola-melted grey iron, of normal chemical composition, does not shrink on solidification, if poured with a sufficient degree of superheat, and if cooled faster than a certain critical rate." That conclusion was based on results achieved by the use of chills on a bedplate casting and on the results obtained from the use of various compositions cast in sand and chill moulds. Nothing in Smalley's data proved that the more rapid cooling reduced absolute shrinkage. It had been shown by the writer that quick cooling did not reduce shrinkage, and that chills only gave increased solidity or fullness if solidification was thereby so speeded up that new metal could flow to the part concerned whilst a liquid channel was open to it. This may be proved very simply. Specimens B, C, D and E, of Fig. 8, are sections of four cylindrical block castings, of the dimensions shown in Fig. 13. Each mould was made out of the same heap of sand. The bottom face of each mould was formed by a chill, which was as big as the pattern—in fact, the chills were similar castings. The head of each was 9 ins. The diameter of the runner of B was ⅝ in., of C 1⅛ in., of D 1⅝ in., and E 2⅛ ins. These dimensions give cross-sectional areas as follow:—B 0.31, C 0.99, D 2.1, and E 3.5 sq. ins. Rate of pouring was equalised by placing suitable cores in

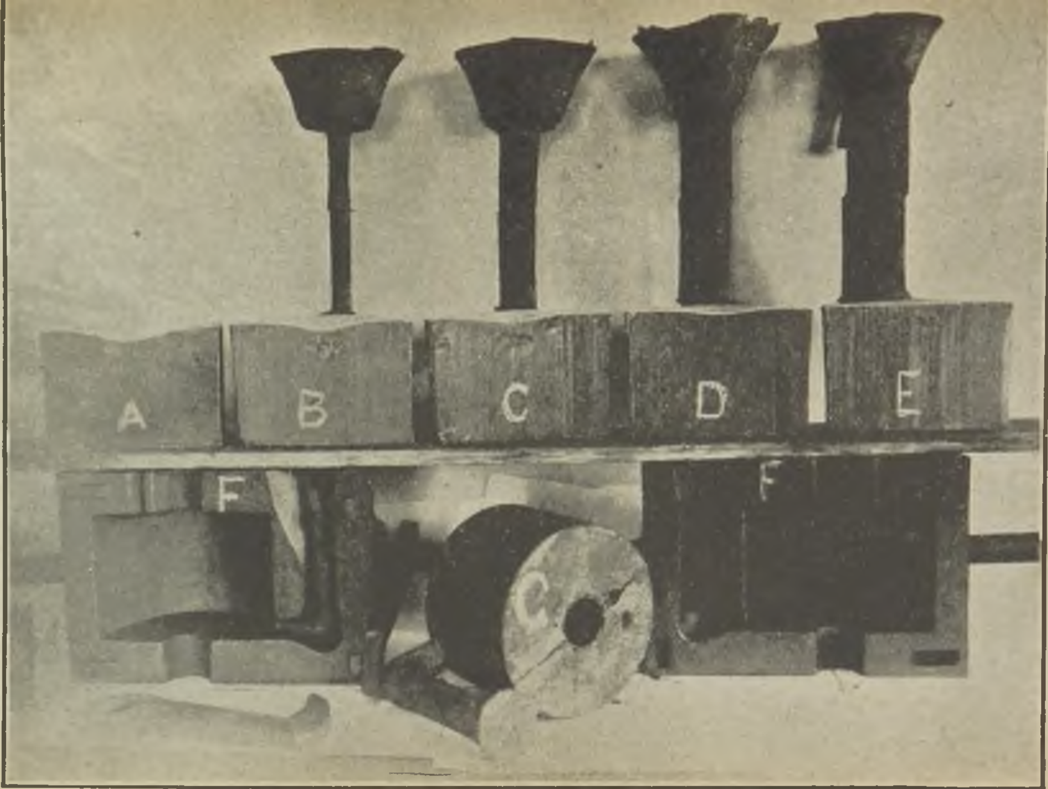


FIG. 8.—EXPERIMENTS TO SHOW THE INFLUENCE OF SIZE OF RUNNER PIPING.

the bottom of the runner basins of C, D and E, which were lifted out with a rod after pouring. All four were cast in quick succession out of one shank of iron, at an initial temperature of about 1,345 deg. C. The metal had the following composition:—T.C. 3.07, Si. 1.41, P. 0.31, S. 0.094, and Mn. 0.41.

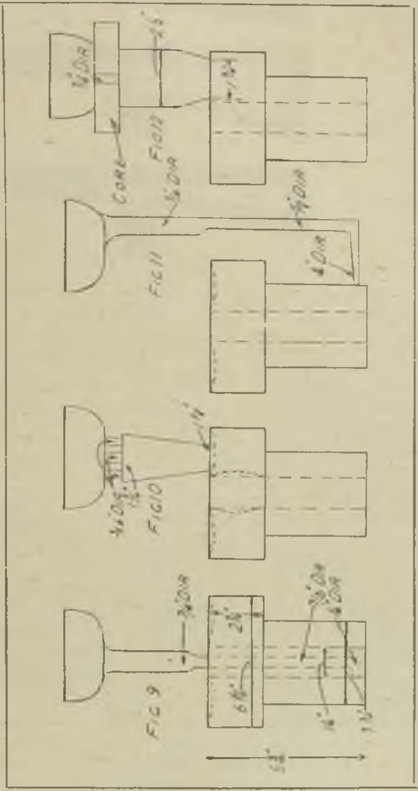
The whole were cast within 80 seconds, so that the temperature variation could have been very small. B was cast first, and so on to E. Specimen A, Fig. 7, was cast, under similar circumstances, on another occasion. The mould was made, however, as shown at Fig. 13, with provision for all metal to flow away which was not necessary to fill the mould. A chill, equal in size to the pattern, was placed on the bottom face, and the mould was cast, some 16 lbs. of metal being run through it. The metal used had the composition:—T.C. 3.48, Si. 1.51, P. 0.39, S. 0.11 and Mn. 0.50.

The series A to E show a decided progression. A, having no head metal whatever, pipes in somewhat the same amount as it would have if no chill had been used. B shows a decided pipe, due to the inability of the small runner to keep liquid long enough to feed the void consequent on shrinkage; and so, progressively, to E, which is quite solid.

In the two half-moulds made of cast iron, shown at F F, Fig. 8, the writer casts clutch blanks, a casting from the chill mould being shown at G. If very fluid metal be poured into it, the mould fills, and the metal in the riser can be seen to freeze instantaneously. When pouring ceases, the metal in the runner stands up, roundly convex, owing to surface tension; but this quickly flattens and changes into a shallow pipe. This shows that, even with such a rapid rate of cooling, a shrinkage loss needs to be made up from the runner. This noticeable loss, however, is not the total shrinkage loss. Heat conduction is very rapid, and a good deal of shrinkage is compensated for whilst pouring is proceeding.

Influence of Length of Cooling Range.

Largely owing to Smalley's work, a good deal of attention had been directed to the increased solidity which could be obtained in suitable circumstances by the use of iron having a short freezing range. Such irons were also the harder having low silicon and phosphorus, whilst the long freezing range irons had high silicon and



phosphorus. If a given volume of metal be taken, hard irons tend to shrink more than soft irons. How, then, is it possible to account for greater solidity in a casting made in hard iron than if cast in soft? Whilst absolute shrinkage must be measured as a proportion of the whole of the

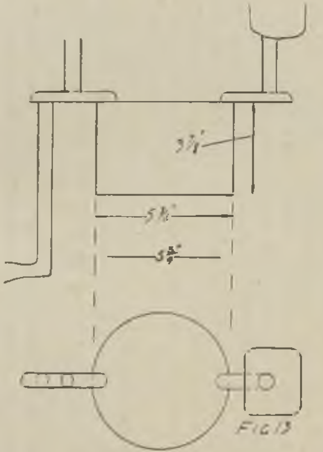


FIG 13

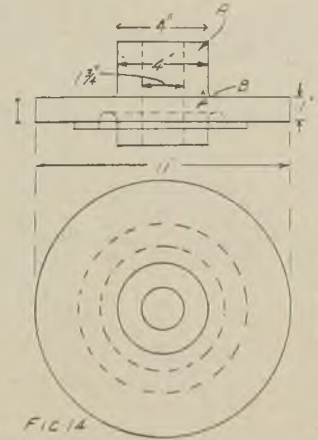


FIG 14

FIG 15

FIG 16

FIG 17

metal used—*i.e.*, runners, risers and casting together—the practical problem related to the casting only. If it was sound it was a matter for congratulation that runners, risers, heads and composition had been so arranged that they each played their part in securing the result. The harder, denser cast irons were more freely piping, and consequently might be expected to be more readily self-feeding. But that was not to say that such irons did not shrink in solidifying.

If two representative metals were taken of the following orders: (1) T.C., 3.50; Si, 1.25; Mn, 0.60; P, 0.20; and S, 0.10 per cent., and (2) T.C., 3.30; Si, 2.30; Mn, 0.60; P, 0.78; and S, 0.10 per cent., there was a great difference in the mode of solidification. In (1) crystals would begin to grow when the temperature was as high as 1,230 deg. C., and with a further fall of 80 deg. C. its whole volume would be solid except some 2.5 per cent. of phosphide eutectic, which froze at about 960 deg. C. In (2) crystallisation would begin at about 1,165 deg. C., and with a further temperature fall of 16 deg. C. the only remaining liquor would be that of the phosphide eutectic, which would here amount to 9.75 per cent. of the total volume, also freezing at about 960 deg. C. Obviously the harder iron had the longer freezing range from incipient to main solidification, but it was then nearly complete, whilst the softer iron had yet 9.75 per cent. of its volume liquid. In the first case, freezing having begun at a higher temperature and proceeding more slowly to main solidification—probably in a more fluid liquor than in the case of the softer iron—the early formed dendrites might tend to drift away from their attachments in response to a downward sag of the metal consequent on a demand for more liquor from below. On the other hand, in the soft iron, the crystal skeletons having been formed at a lower temperature, and more quickly, were buoyed up somewhat by a more viscous liquor, and the growing tendrils might quickly grow right across a section, leaving shrinkage to proceed within intercrystalline compartments and preventing the flow of liquid to isolated heavy sections. Hence it was possible to reconcile the paradox that an iron with the higher absolute shrinkage might give a casting with the greater solidity.

Influence of Slow Pouring.

The practical foundryman had evolved his practice with a view to the elimination, as nearly as possible, of shrinkage defects. First, he chose metal of the right composition, then he cast very slowly; he might use chills, the feeding rod, or provide a substantial head of metal to serve as a reservoir to meet the requirements of the casting. Slow pouring, with hot metal, had an important sphere of usefulness. For many small troublesome jobs it was very successful, providing an easily applied and certain cure for many otherwise perplexing problems. The author had found it particularly useful as an aid to producing pulleys and gear blanks up to a weight of about 2 cwts. For pulleys he had found a runner to casting ratio of 0.25 sq. in. per cwt. of casting very successful. Such a runner, in the form of a rectangular sectioned slit, placed on the rim, produced a clean casting, clean on the rim and in the boss when bored. The usual method of casting a pulley was by placing a runner on the boss which needed to be fed with a rod; it had very indifferent results, so far as soundness was concerned, unless such a boss was chambered. For castings of heavier section than that of a pulley, a runner to casting ratio of not more than 0.2 sq. in. per cwt. of casting was sufficient.

He had never secured a definitely sound casting where any section was greater than 2 in. by means only of the pencil runner. A casting which had given a great deal of trouble was shown at Fig. 9. It was machined all over, a keyway being cut down the bore, and teeth cut all round the larger diameter. Slow pouring was tried with runners, as shown at Figs. 9, 10 and 11, but quite satisfactory castings could not be obtained, shallow depressions appearing at places though the interior was quite solid. A further step was taken. What was in effect a small feeding head was placed as shown at Fig. 12. The metal fell through this from the runner basin into the casting, filling up the head last. With this form of runner very different results arose from the use of different metal mixtures. With an iron of the order of Si, 2.5; T.C., 3.6; Mn, 0.6; P, 0.5; and S, 0.1 per cent., the result was that, when the head was knocked off the casting, a spongy place was disclosed just below it in the casting whilst the head was quite solid. When iron of the order of Si, 1.5; T.C., 3.4; P, 0.3; Mn, 0.6 and S, 0.1 per cent. was used, the casting was quite solid throughout, but a deep pipe appeared in the head at the top, just under the pencil runner. The pipe had a volume of about 1 cub. in. It was clear, however, that in both cases the casting needed feed iron. The iron with the shorter freezing range was the more readily feeding iron, and hence gave the more solid casting.

Filtering Cast Iron.

In a previous Paper the author has given his views as to the reason why slow pouring, with the avoidance of risers, was so relatively successful. It had nothing to do with filtering. Fluid iron could not be filtered—though large lumps of non-metallic matter might thus be prevented from going down the runner. In fact, slag was as often found to have gone down a pencil runner as down an ordinary one. Perhaps a contributory cause was that the metal used must necessarily be very hot, which also meant that any slag which was about would also be very fluid. Further, the success of the method had nothing to do with gas, entrained or otherwise. Though a slowly-run casting took a longer time to pour, less metal passed through the mould, for no riser was used; hence the metal in the mould was sooner quiet. Though the runner was small it had more heat in its immediate surroundings than a larger runner would have, owing to the longer time during which hot iron had been passing through. Consequently it remained liquid long enough to meet the requirements of liquid metal called for by shrinkage due to an advanced solidification in some parts of the mould, and various degrees of incipient solidification in others. By the time the runner had frozen up the partially liquid casting would be interwoven by a sort of lattice-work of dendrites which quickly grew together, dividing out, more or less generally, the sum of cavity remaining due to solidification of the liquor. The shrinkage then took the form of minute intercrystalline spaces. At. Fig. 14 is shown a sketch of a casting made with a pencil gate. The bore is important, and, if cast in the ordinary way without feeding, cavities sometimes appear at B. It is cast with invariable success with the pencil runner. One such casting was broken and density determinations were taken of specimens from A (the first place to solidify) and B (the last place to solidify). The specific gravity at A was found to be 7.075, whilst that of B was 6.977. The last place to cool was therefore 1.38 per cent. less dense than the first place to cool. This shows that, though the structure of the part B was reasonably close, there had been a more parsimonious distribution of crystal-making material.

Rod Feeding.

Feeding with the rod, or pumping, was a very laborious and doubtful method of securing solidity. The gear blank, for example, shown at Fig. 9, would rarely give a good casting by pumping, however big the riser might be. Almost invariably a cavity would appear in the bore when machined, at the opposite side to where feeding had taken place. The same characteristics would appear in many castings of a similar type, such as commutator bushes or couplings. The peculiar thing about it was that the cavity in a fed casting was often greater than that in a casting which was cast with an ordinary runner and riser and then left. The first point which suggested itself was that a casting which was being fed with a rod was thereby precluded from benefiting in any way from the expanding forces within the casting. Another explanation arose from the probability that the feeding rod, as it rose and fell in the casting, had particles of oxide rubbed off it, which particles were pushed or swirled away round the core. Any sponge formed at a later stage by reactions between the oxide and carbon could not be dislodged by continued feeding, the metal being pasty. That this suggestion was quite within the bounds of possibility might be proved at any time when feeding was taking place. If, when feeding was just completed, the pasty metal left in the riser was watched, it would be seen to be swelling. A piece of that metal cut off when cold would be found to be honeycombed, due to the reaction mentioned. It seemed very probable that the feeding rod only gave absolute solidity directly under it. The rod aided the passage of new metal into the mould generally during the early stages of incipient solidification, but it was doubtful if, when the metal became really "mushy," the rod could do any good at all except just below it. When the "mushy" stage had been definitely reached by the metal in the mould, the value obtainable from rod feeding was confined to the region of the riser or runner concerned.

Chills and Denseners.

In respect of chills or denseners, it was essential to remember that their use did not reduce the amount of liquid shrinkage. Their function was to hasten the rate of solidification of the part concerned, so that new metal could flow to it through surrounding sections whilst such sections were liquid. It followed that a heavy part connected with a thin section required to be cooled more quickly (and hence needed heavier chills) than a part of the same dimensions connected with sections which were not so thin. It was often remarked that the use of chills sometimes resulted in the chilled part being solid at the expense of some neighbouring section. This was proof that the hasty freezing of such a heavy part did make necessary the supply of fresh metal to make good the loss due to solidification If such neighbouring sections, in their turn, could find no source from which to make good the loss, the cavity or porosity would simply be transferred to that part. The obvious remedy was to hasten solidification in the heavy part, so that its losses of liquid were made good whilst the runner was still continuously open to it.

The use of chills was not without disadvantage. If the only part upon which they could be placed was to be machined trouble was sure to come, sooner or later. The same weight of chill, when used against a soft iron as against a hard iron, would often result in unmachineability in the latter case. This was more disturbing when it was remembered that the harder irons required heavier chilling than the softer. One could only feel quite safe in the use of chills when they could be placed on the opposite side of a section to that which was machined. For tightening up inner wall junctions the chill was indispensable.

Feeding Heads.

There remained to be referred to the use of feeding heads. The hot runner on a casting always functioned as a head of metal, upon which the casting might call, whilst liquid. A riser might also, but very infrequently, serve as a kind of head of metal for the same purpose. The cross-sectional area of these was necessarily very small and consequently did not remain liquid long enough to feed every part of the generality of castings.

Head feeding might be called gravity feeding. If the thickness of the metal above any section was greater than such section, it would tend to remain liquid longer than the section below it, and by gravity would meet its demands for new liquid.

In respect of the three types of head shown at Figs. 15, 16 and 17, the first is useless for feeding purposes, though it might have some little use as a dross head. By the time that the section below the flange was quite frozen the flange and head would also have frozen in the areas marked. The lines of demarcation between liquid and solid were not as clearly marked in a casting as they appeared in the sketch, because the process of solidification consisted of the growth of dendrites from the cooling faces, which soon became a solid mass—it might be likened to undergrowth—the pioneer crystallites continuing to forge ahead through the liquid, reinforced by their own branches and planes. Consequently, at the stage when the casting was solid to the degree shown by the sketch, the remaining core of metal would be intersected with elementary crystal growths. At such a stage the supply of liquor from above to the flange would be insufficient; the passage would be frozen too soon. Consequently, when the flange was cleaned up, a series of holes would be found in it, or the whole of the region under the head would be very open and porous. The difficulty which arose with any section which did not feed solid naturally was further emphasised when the moulder made large fillets, thus enlarging the pools of metal which were cut off from any supply of head metal.

The head shown at Fig. 16 was good, but, as shown by the isothermal lines, not without danger. The third was the best. It is perhaps the most expensive, and might entail the use of a great weight of metal, but if the casting was important such a head was a good investment.

The author wishes to express his thanks to Mr. R. K. Tullis, manager of the Kilbowie Laboratories, for the photographs, microphotographs, analyses, and density determinations which he had made use of, and to Messrs. D. & J. Tullis, Kilbowie Ironworks, for permission to carry out the experiments which had been referred to.

DISCUSSION.

Mr. A. L. Key, in proposing a vote of thanks to Mr. Longden, said many of the audience would have liked to have the experience of proving for themselves what Mr. Longden had told them, but to do so would involve much trouble, and they had other duties to perform, so these things had to be relegated to a secondary place; it was fortunate, therefore, that they were able to profit by the experience of others who had investigated these problems from a practical point of view. This was seconded by **Mr. J. G. S. Primrose**.

The vote of thanks was passed unanimously.

The **Chairman** (Mr. J. Masters) asked what Mr. Longden's experience had been with oil-sand cores. If they had not been thoroughly dried what was the effect with regard to producing soundness when the metal was getting to the point of solidification?

With regard to runners, it was not the size alone that had to be taken into account. The distribution was also an important factor in getting satisfactory results.

Mr. Longden said his experience was that success in the use of oil-sand cores all depended on how the core was made. Take a core which was struck off with a strickle, with a long cast plate at the underside of the core. At one time he had trouble with that type. In a casting, a sketch of which he showed, the bottom face was machined all over and highly polished. In one or two cases he found a number of holes on the machined surface, and the casting had to be scrapped. Looking at the core one day he observed drops of water underneath, and he came to the conclusion that in the scrapped castings referred to the water had condensed on the surface of the core and remained there until the molten iron reached it, spitting up the pellets of metal in the mould, which were later dug out by the cutting tool. Being in a hurry he had occasionally put cores in which at the moment were not sufficiently oxidised, not sufficiently dry. The result had been that in casting there was a great rush of flame through the risers. But in no case had he experienced any ill results which could be attributed to the use of oil-sand cores. If the core was dried so as to stand up well in the mould it would be satisfactory.

Mr. A. L. Key said it was only under certain conditions that gas was present in the liquid metal. Blowholes showing in a casting after machining, might be attributed to gas evolved from the metal in the mould, but it was dependent upon the condition of the metal before it entered the mould. He made a series of castings which were very hard, the silicon being 0.7 per cent. Usually he cast them with the hottest metal possible, the temperature being about 1,400 deg. C., and they were perfectly good, not a sign of blowholes. On one occasion, however, he waited till the temperature had fallen 150 deg. C. and that casting came out full of holes. In the case cited by Mr. Longden of the two open-sand-cast plates, the one which was left uncovered was speckled with holes, while the one which was covered with a thin layer of sand was perfectly sound. The reason was that the latter was not exposed to the atmosphere. He drew the inference that at a certain temperature iron had a great susceptibility to absorb oxygen from the atmosphere. His opinion was, and had been for a long time, that if hot metal was poured into the moulds there was little fear of gas being evolved from the metal itself. Blowholes were caused by the metal being at an undesirable temperature prior to going into the mould; assuming the moulding conditions were normal.

Mr. A. Jackson said it seemed to him that in casting metal out of the same ladle there would be differences in the resulting material. If poured very hot and settling quickly it would be an iron of close texture, because the carbon was present as combined carbon. As it stiffened the graphitic carbon was formed, making a lighter iron, the volume was greater. At the finish it was a light iron of open texture.

A heavy runner should have been used for sinkings, but where the machining was not an important factor very often a small fine runner could be used. Run with judgment, it produced the same effect, but the metal would not be as close an iron. The metal came in slowly and gradually set as it was poured out.

Mr. Key said his advice was, "Do not wait for the temperature to come down to a particular point. If the job has to be machined or has to withstand hydraulic pressure tests, cast with the metal as hot as you can get it, whatever the size of the casting." He had followed that rule with a massive-sectioned 7-ton flywheel, and it turned out a good job. When he had waited for the temperature to fall he had not been successful.

Mr. Jackson remarked that everyone must use his discretion in that matter. It depended on the particular article being dealt with. If it was something which had not to be machined and did not require a high polish, he would certainly take the colder metal, but if it had to be polished, use the hottest metal that can be obtained. The hotter metal would be closer in texture and better for polishing, because the graphitic carbon had not had time to form; it was in the combined carbon form, and the material was of much closer grain.

Mr. S. G. Smith said in the main he agreed with the statements put forward in the paper, but one or two matters had been raised on which he would like to say a few words. The last speaker was correct in what he said regarding combined carbon and graphitic carbon. With combined carbon, *i.e.*, carbide, the carbon was dissolved in the iron, it was not present in graphitic form. There were various types of graphitic carbon in the casting as modified by size, form, and distribution. Then reference had been made to the metal in the last of a series of castings from the same ladle being lighter than the first. It appeared to him that would be so naturally, because, supposing they were running with the same kind of runners, there would be a difference in the swelling pressure due to the higher temperature of the iron.

He did not quite follow Mr. Longden's suggestion that iron with a shorter freezing range could be fed longer than iron with a long freezing range, but he quite believed that a sounder casting would be got from the harder iron. He had often shown to young men a number of 12 in. cubes cast with various kinds of iron, from very soft to very hard. and pointed out to them the variations in liquid shrinkage. The conclusion he arrived at, from his experiments and observations, was that iron of medium hardness gave the least liquid shrinkage. With very soft iron he got about the same degree of shrinkage as with very hard white iron, but it was a different form of shrinkage. In the former there was a very porous patch with cavities; in the other case one got a depression at the top but underneath it was sound and hard.

He was in agreement with Mr. Longden's remarks on head feeding. He had had a good deal of experience of head feeding with all kinds of vertically run castings, probably more than any other man living, and his advice was: With head-feeding for vertical castings, never let the distance from the bottom of the flange to the top of the feeder be less than 9 ins. With a shorter distance there was often a cavity just at the top of the flange, and the machine cut it off. With certain grades of iron which had not much shrinkage it would clear with less than 9 ins., but that was his fixed figure.

Reference had been made to hot metal and dull metal. What was meant by those terms? If they could be defined by reference to colour by Pouillet as was given in Hiorn's "Elementary Metallurgy," or if people would speak in degrees Centigrade, they would get nearer to understanding one another. Of course some cupolas melted what would be called a dull iron compared with the white hot iron melted in other cupolas. In other words, what would be considered a very high temperature in one foundry, may be considered only a medium temperature in another foundry. Hence the need of some intelligible form of expression.

Mr. Key: In large castings what I describe as hot metal is in the region of 1,350 to 1,380 deg. C.; in smaller castings it is about 1,400 deg. C.

Mr. Longden said perhaps he had not made himself clear with regard to what he meant in saying that iron with a short feeding range would feed soundest. He did not mean to refer to the process of feeding by the rod; he meant natural feeding by gravity.

He was not sure he agreed that in the case of the castings, of which the last out of the ladle was the lightest, it was explained by eating-in of the mould face. He had practised casting very hot, and on the face of it that might appear to give weight to what Mr. Smith had said, but if Mr. Smith had seen the castings in question he would have agreed that for all practical purposes the last was equal to the first: he could see no difference in the degree to which the surface of the mould had been eaten into: there was no distinctive difference between the irons in that respect.

With regard to Mr. Jackson's remarks, he believed they were in practical agreement. He had no ground for assuming that cast iron, if of a eutectic composition, and which was not supersaturated with carbon, had graphite present in the liquid. It might be so, but he did not know. But he did think that a good many cast irons in the foundry were super-saturated in respect of carbon, and in those irons the carbon tended to come out of solution in the liquid in a more or less degree, and remain distributed and not float away as one might expect. Some of it remained distributed throughout the metal, reducing its density and reducing the weight of metal which could be put into a given space. That gave some degree of support, or rather tended to explain, why in such cases the last casting was lighter than the first.

Mr. Key was perfectly right in his suggestion regarding casting hot. It had been the experience of perhaps nine out of ten foundrymen—it was his personal experience—that hot castings gave the best results. He wondered whether in the case described the core was damp.

Mr. Key said the core was overdried and he was afraid of the metal getting into the straw band because of the metal being so hot.

Mr. Longden said apparently in such a case, if there is any bubbling, there is a tendency for a slight local bessemerising to take place, with resultant reactions which may later be responsible for holes.

Mr. A. Sutcliffe said if it was desired that a casting should not be drawn in any shape or form one must run it slowly or feed it with hot iron after it had been cast.

Mr. H. Sherburn said discussions of this kind reminded them of the complex nature of the material they dealt with, the varying conditions of moulding and the further complications arising from the human factor. They realised how great were the difficulties of the foundrymen's job. He was coming to the conclusion that those in charge of foundries, unless they possessed some form of second sight or of intuition which psychologists did not tell them much about, would have to rely to an increasing extent on purely scientific assistance in their difficulties. Few of those present had those resources.

Mr. Key remarked that he thought his statements were quite justified because they were based on his personal observations of the results of differences in casting jobs over many years.

The discussion then closed.

Scottish Branch
(FALKIRK SECTION).

SAND BLASTING AND OTHER AIDS TO FETTLING.

By F. W. Neville, B.Sc. (Eng.).

Sand blasting is the term generally used to describe a process for cleaning castings, stampings, and other metallic objects, which consists essentially of the projection of an abrasive at high velocity on to the object to be cleaned.

The abrasive may be sand, steel grit, or steel shot of various grades; and the high velocity is obtained by discharging the abrasive with air under pressure through a nozzle.

A typical general purpose plant consists of a chamber, the floor of which is gridded, so that abrasive, tailings, etc., fall through and slide down the sloping foundations to a worm conveyor, thence to be carried to a bucket elevator, from which they are discharged over a cleaning device. The tailings are collected separately, while the clean abrasive is delivered to the abrasive container to which the sand-blast nozzle is connected. From the top of the chamber, dust exhaust pipes lead through a dust separator to a fan; the fan discharge being made to atmosphere via a water tank, where the very fine dust is removed. Whenever possible the operator works from outside the chamber, the nozzle projecting into it, through, say, a rubber curtain or opening in sliding door. There are three systems of sand blast in general use—the pressure, the suction and the gravity feed.

The Pressure System.

In this system the abrasive is contained in a closed pressure chamber, to which is fed pressure-air, and from which a mixture of air and abrasive passes through a control valve into a pipe line in which pressure-air is flowing; the whole being discharged through a nozzle at the end of the pipe.

The simplest sand-blast unit for this system consists of the pressure chamber, below which is the control valve, and above which is an abrasive hopper. There is a hand-operated valve between the abrasive hopper and the pressure chamber. When the pressure chamber has been emptied of abrasive, air must be shut off to allow the chamber to be refilled from the hopper. Thus, continuous blasting-time is limited by the size of the pressure chamber. For many purposes, this fact, and the fact that time is needed to refill the pressure chamber are not disadvantageous—as for instance when the plant is applied to a tumbling barrel—providing a batch of castings is cleaned before the pressure chamber empties. This may be called a non-continuous plant.

In cases where continuous blasting is required, this can be obtained by providing a pressure chamber intermediate between the first chamber and the hopper. Thus, blasting can be taking place from the lower chamber, while the middle chamber is being filled from the hopper, by closing the valve between the two chambers. When the valve between hopper and middle chamber is closed, and the other open, abrasive is being collected in the hopper, and is also falling from middle to lower chamber, blasting proceeding meanwhile.

The plant can be arranged so that one movement of a single lever operates all the valves as required; and such a plant may be termed continuous working. The sand control-valve works under very bad conditions, and moving parts should so far as is possible be protected from the abrasive. It should be easy to inspect all valves, and air supply pipes should be generous in size.

The Suction System.

In this system the discharge unit consists of a discharge nozzle projecting from one end of a mixing chamber, into the other end of which is fitted an air nipple. A suction pipe leads from atmosphere past the sand control-valve to the side of the mixing chamber—the sand control-valve communicating with the sand-bin.

Pressure air is fed by a separate pipe direct to the air nipple, discharged into the mixing chamber, there depressing the pressure below atmosphere, with the consequence that air from the open end flows along the suction pipe, picks up the abrasive material, and carries it to the mixing chamber. There, pressure air, suction air and abrasive are mixed, and finally expelled through

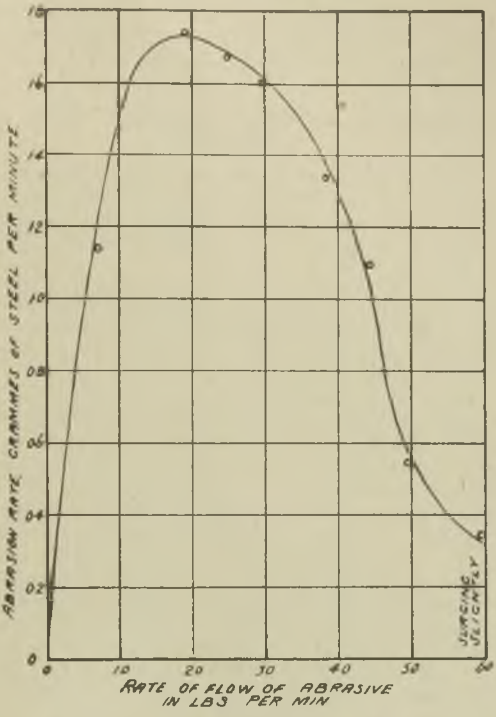


Fig. 1.—Showing Relation between Flow Rate and Abrasion Rate.

the discharge nozzle. The abrasive is collected and returned to the sand-bin. This system is therefore automatically continuous working.

Gravity Feed System.

This approximates to the suction system, the chief difference being that the abrasive is fed to a mixing chamber under the influence of gravity, additionally to any suction effect.

EFFECT OF VARIOUS FACTORS ON THE WORKING OF A PLANT.

A knowledge of the effect of changing various factors, such as the abrasive, air pressure, etc., is useful, if the optimum efficiency is to be obtained from any of the above systems.

(1) RELATION BETWEEN ABRASION RATE AND FLOW RATE.

In this paper the rate at which material can be removed by blasting is called abrasion rate, and the rate at which abrasive flows through the nozzle—flow rate, in lbs. or grammes per minute as the case may be.

If the amount of abrasive flowing is gradually increased by opening the control valve, a condition will be reached where the abrasive does not leave the nozzle steadily, but comes out in jerks—in fact surging occurs.

Using a pressure plant under standardised conditions, with stationary nozzle perpendicular to the test piece, an air pressure of 15 lbs. per sq. in., nozzle diameter $\frac{1}{2}$ in., and using No. 24 steel grit, measurements of (*a*) air consumption, (*b*) flow rate in lbs. per minute, and (*c*) abrasion rate from a C.R.C.A. plate in grammes per minute were made, and the results have been plotted.

The relation between flow rate and abrasion rate is shown in Fig. 1. It will be seen that the rate of abrasion increases as the flow rate is increased, until about 20 lbs. per minute of steel grit is flowing. Thereafter it decreases. Slight surging is not evident until 60 lbs. of abrasive is flowing per minute. Over a range of flow of from 10 to 35 lbs. per minute the abrasion rate does not change much.

(2) RELATION BETWEEN FLOW RATE AND BLASTING EFFICIENCY.

From the figures obtained above for air consumption the horse power required to keep the plant running under the various conditions has been computed. By dividing the abrasion rate by the horse power, a factor is obtained which enables us to compare what the author calls the blasting efficiency, i.e., abrasion rate per horse power, for different flow rates. These results are plotted in Fig. 2. and it will be seen in this case again that maximum efficiency is obtained considerably before surging point is reached.

It will be seen that maximum blasting efficiency is obtained when about 28 lbs. of abrasive flows per minute. Maximum rate of abrasion occurred with a 20 lbs. per minute flow. From 20 lbs. per minute to 28 lbs. per minute flow the abrasion rate decreases, but the blasting efficiency increases. This is because the air consumption is reduced.

Fig. 2.—Showing Relation between Flow Rate and Blasting Efficiency.

In practice, therefore, one should *not* pass the maximum quantity of abrasive through the nozzle. About half the maximum will give much better results, both as regards speed of cleaning and efficiency.

(3) EFFECT OF AIR PRESSURE ON ABRASION RATE.

This test was made under conditions as previously described, but at various air pressures. Results at each pressure are for maximum efficiency as regards flow rate.

The results have been plotted in Fig. 3, and the curve shows that abrasion rate increases with air pressure, and more than proportionally. Thus, *in practice*, to clean rapidly, increase the pressure, but there is a point to be noticed here as regards the test, which shows the rate at which material is removed from a steel plate. In practice the amount of material removed does not matter, so long as scale, adherent sand, etc., is removed, and it may easily occur that, at, say, 15 lbs. per sq. in., a casting is being cleaned as quickly as nozzle control permits. If that be the case it would be foolish to push up the pressure—for the only effect would be to dig rather more deeply under the skin.

(4) EFFECT OF AIR PRESSURE ON BLASTING EFFICIENCY.

Taking the results of the previous test, and dividing the abrasion rate by the horse power used in compressing the air to the various pressures, there is obtained, as before, a blasting efficiency factor. The curve drawn in Fig. 4 from these results shows that blasting efficiency is approximately constant at various pressures.

Thus, if other conditions permit, in a foundry, and work could conveniently be done at a greater rate, then increase the air pressure to obtain greater rate of cleaning without loss of efficiency.

It may be noted here, that blasting efficiency is only one factor in the all-important overall commercial efficiency. To obtain this latter capital expenditure and many other matters have to be considered. But conditions are so various that it is impossible to attempt a solution in this Paper.

(5) EFFECT OF ANGLE OF IMPACT ON ABRASION RATE.

The angle between the axis of the nozzle and the surface of the articlo cleaned is called the angle of impact. Working under conditions as outlined for experiment 1, as to pressure, etc., but with various abrasives and materials, abrasion rates were measured for various angles of impact (abrasive flow rate being arbitrarily chosen in each case). The results are plotted in Fig. 5.

Using 24 Angular Steel Grit.

(a) *On C.R.C.A. plate*, the less the angle of impact the greater the abrasion rate—the latter being 3.55 grammes per min. at 30 deg. and only 1.65 grammes per min. at 90 deg., *i.e.*, more than twice as much.

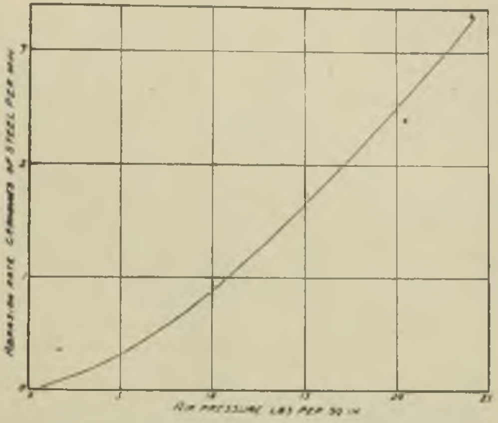


FIG. 3.—SHOWING RELATION BETWEEN ABRASION RATE AND AIR PRESSURE.

(b) *On Grey Cast Iron.*—In this case the abrasion rate increases as the angle of impact is decreased from 90 deg. to 50 deg., but thereafter decreases.

Using 24 Round Steel Shot.

(a) *On Grey Cast Iron.*—Again it was found that the abrasion rate increases as the angle of impact is decreased from 90 deg. to 60 deg., but then decreases.

Thus in practice, the nozzle should be held obliquely to the work—say, at about 45 deg.—and not perpendicularly to it.

(6) EFFECT OF DISTANCE BETWEEN NOZZLE TIP AND ARTICLE TO BE BLASTED.

Working under the standard conditions Fig. 6 shows that from 8 in. to 16 in. distance between nozzle tip and work there is very little change in the abrasion rate. Bringing the nozzle closer than 8 in. to the work results in a rapid slowing up of abrasion rate. This, however, only occurs appreciably with a stationary nozzle. If the latter is moved about over the work, the abrasion rate remains approximately constant. Hence under working conditions roughly the same amount of material is removed per minute, irrespective of the distance between nozzle and work. But the cleaned area increases with increasing distance, the cleaning not being so intense when the area is large. The position of the nozzle relative to the work, for greatest efficiency depends therefore on the nature of the work. If the article is cleaned with difficulty, the nozzle should be close to the work. If with ease, the nozzle can be further from the job, and the abrasive be allowed to spread.

(7) LIFE OF ABRASIVE.

At each impact a certain percentage of abrasive is pulverised and is taken away as dust to the fan. Sand is very quickly pulverised, and in consequence a large amount of dust is generated. Thus, of 43 lbs. of Leighton Buzzard sand, the weights collected after successive impacts at 15 lbs. per sq. in. on steel, were 37, 32, 29 and 25 lbs., *i.e.*, in four impacts, 41 per cent. of the original sand had disappeared to fan as dust—the up-current of air moving at about 160 ft. per min. Of the remaining 25 lbs., 18 lbs. would pass a 32 mesh sieve, and 6¾ lbs. a 25 mesh sieve. The original sand would not pass a 32 mesh. Despite the rapidity with which it is broken, sand is still used—giving in some cases a desirable finish and being cheap in first cost.

A No. 24 steel grit was tested, and from 30 lbs. it was possible to recover 29 lbs. after ten impacts, at 15 lbs. per sq. in., *i.e.*, one-third of 1 per cent. disappears per impact. Despite its comparatively high initial cost, it is probably cheaper than sand in the long run. The dust nuisance is much less and the steel is the more efficient abrasive. In practice with a steel abrasive, it is probable that more loss occurs due to imperfect reclamation than to pulverisation.

(8) EFFECT OF CHANGE OF ABRASIVE ON ABRASION RATE AND BLASTING EFFICIENCY.

Pressure System.—Conditions of the test were as for test 1 with regulating valve set to give various flow rates. The greatest abrasion rates for four steel abrasives working on steel and two abrasives working on cast iron are shown in Fig. 7. It will be seen that the angular abrasives clean very much more quickly than do the round abrasives—particularly when working on steel—and that the larger abrasives clean somewhat more quickly than the smaller.

Fig. 8 shows that roughly the same thing may be said as regards maximum blasting efficiency. At maximum abrasion rates there is a slight saving in air consumption when using the smaller abrasives. In practice, therefore, it pays to use an angular steel grit. A fine grit, while being slightly less efficient, gives a much nicer finish. Results for sand have not been plotted—chiefly because the abrasive varies so much. Speaking roughly, it can be said that using new Leighton Buzzard sand, results are obtained intermediate between those obtaining for steel shot and grit.

Suction System.—In this system the air consumption is practically constant, whatever the abrasive used, since pressure air is always discharged into the mixing chamber, through an air nipple which is not reduced in effective area by abrasive.

Results show that a coarse steel grit is the most efficient abrasive, and in general results as regards abrasives are roughly as with the pressure system.

(9) EFFECT OF WEAR ON NOZZLES.

Pressure System.—As the nozzle wears to a greater diameter, one of two things will happen: (*a*) If the plant is taking all the available pressure air with a new and therefore small nozzle, then the pressure will drop as the nozzle wears, with consequent decrease in power consumed, but with an approximately similar decrease in abrasion rate. (*b*) If the compressor is sufficiently big to keep up the pressure, then more air is being taken as the nozzle wears, with consequent increase of power consumption; and since the blasting efficiency will remain approximately constant, the abrasion rate will increase with the increased power consumption. That is, if, as the nozzle wears, the pressure drops, cleaning will probably be slower: while if the pressure remains steady, cleaning will probably be quicker. In either case it will be advisable to regulate the sand control valves to get maximum efficiency.

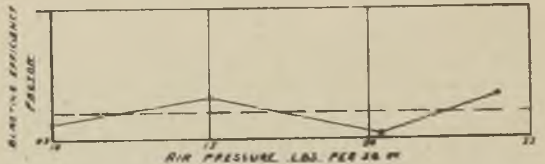


Fig. 4.—Showing Relation between Blasting Efficiency and Air Pressure.

Suction System.—As previously stated, the air regulating nozzle does not wear. Consequently receiver air pressure and power consumption remain constant. The discharge nozzle wears however, with consequent slight alteration of conditions in the mixing chamber, but generally it is not necessary to regulate the sand control valve. The blasting efficiency and abrasion rate do not change appreciably over the practical range of wear in a well-designed plant.

Nozzles are usually made of a hard cast iron, but gas piping is not infrequently used.

(10) FINISH OBTAINED ON CAST IRON CASTINGS.

Roughly, it may be said that the finish obtained on a sample of cast iron cleaned under standard conditions, but using different abrasives, is with (1) Fine steel grit, a bright silver grey; (2) coarse steel grit, a bright silver grey, but coarse finish; (3) fine steel shot, dull, but fine finish; (4) coarse steel shot, dull and coarse finish; and (5) sand, not quite so bright as with fine steel grit.

The notes so far given have dealt with the working of the sand-blast unit itself. The pressure air fed to the unit should be dry, or there will be a tendency for the abrasive to clog at the valves. If a large receiver or if a long pipe line

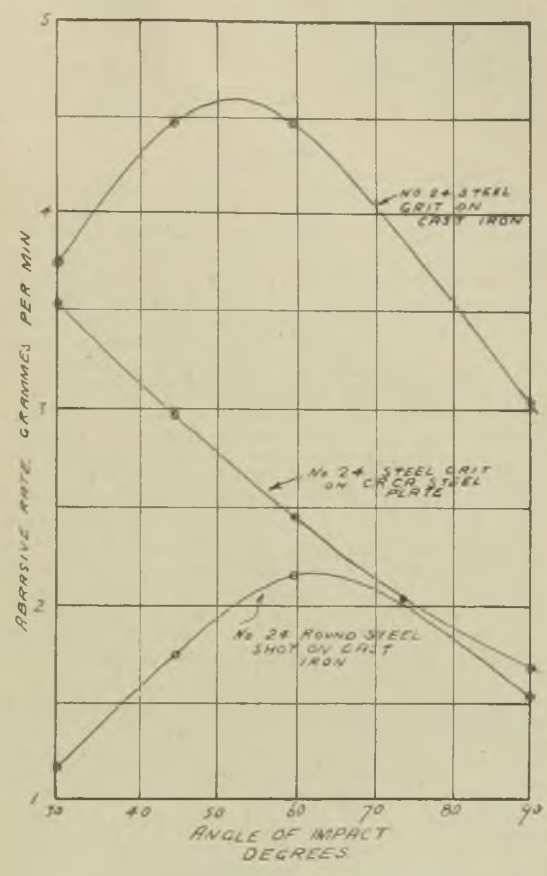


Fig. 5.—Showing Relation between Abrasion Rate and Angle of Impact.

is in use, the air is usually cooled sufficiently to condense the moisture which must be trapped.

In any case it is wise when shutting down a plant at the end of a day to close off the sand regulating valve and clear the hose by blowing through pressure air. It will be of interest now to consider a few complete sand blast plants, illustrating some of the applications of the process.

Chambers.

These are general purpose plants. In general they are used for cleaning the larger articles—such as locomotive cylinders, baths or a steel side-car frame. They are built to suit any set of conditions. Thus for heavy work, a runway may be provided. Usually one side at least consists of a vertically sliding door, the weight of which is balanced. A separate compartment may be provided for the operator separated from the actual chamber by a horizontally sliding door, in which case he is protected from much of the rebounding abrasives, while the fan suction creates a fairly high air velocity through the narrow opening of the doors and so keeps him more free from dust. But he should be provided with helmet and gloves. With a power-driven grid turntable in the chamber, controlled by a foot clutch in the operator's compartment, work placed on the table can be brought within range of the nozzle. With much large work, however, it is necessary for the operator to be inside the chamber, in which case also he must be provided with protective helmet and gloves.

For work such as, say, gas cookers, a small chamber may be built, with a vertically sliding door, provided with a window through which the work can be viewed, and a split rubber curtain through which the nozzle is controlled.

Chambers can be used in conjunction with either the pressure or the suction system. The abrasive may be collected mechanically as already described, or it may be collected pneumatically. In the latter case, the abrasive, etc., falls down the sloping foundation into a pipe through which air is being sucked by a fan. This air carries the abrasive, tailings, etc., to a separator from which clean abrasive is delivered to the container.

A vacuum of 4 in. of water is sufficient to elevate the shot to the separator, and the air of the chamber should be cleared at least four times a minute. It is perhaps better to specify that the mean vertical velocity of suction air reckoned over the full floor area should be at least 40 ft. per min. per sq. ft. of area.

Cabinets.

A cabinet is generally used for smaller work than a chamber, and as a rule its working level is above ground. The nozzle may be fixed, in which case the operator stands or sits outside, puts his hands, which are protected by guantlets or rubber gloves, through arm holes and passes the work as required, under the nozzle discharge. He sees the work through a window. Entrance to the cabinet is through a swinging door which frequently carries the arm holes and window. The fixed nozzle type is suitable only for light work. Control of the operation, *i.e.*, starting and stopping blasting, etc., should preferably be by single lever, operated from the working position.

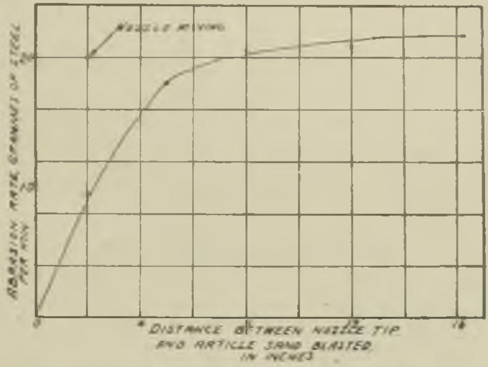


FIG. 6.—SHOWING RELATION BETWEEN ABRASION RATE AND DISTANCE BETWEEN NOZZLE TIP AND ARTICLE SAND-BLASTED.

With a portable nozzle, larger work may be handled—a runway being provided if necessary—and the nozzle may be either connected by flexible hose to a junction inside the cabinet or a longer hose may be taken through split rubber curtains or through the armholes. Ease of handling both nozzle and casting is important. The abrasive, etc., fall through a grid on to a sieve, below which cleaned abrasive is collected ready for re-use. Both suction and direct pressure may be used, and in either case the plant is generally placed immediately below the sieve and above ground level. Dust is usually sucked away from the top of the chamber.

A cabinet plant is again a general-purpose plant within the limits of its size. The collection of abrasive is automatic, the plant is simple and compact. The operator stands outside the cabinet, from which no dust can escape.

Lighting of both cabinets and chambers may be daylight through glass sides and top, or electric light through a glass top. The electric light is sometimes inside. Care must then be taken of the bulbs.

Sand Blast Tumbling Barrels.

These consist essentially of a closed barrel, through the one or both ends of which projects a sand blast nozzle. The barrel is supported on and driven by rollers.

In one form the barrel, rollers, etc., are enclosed in a casing provided with a sliding door, dust being sucked from the top or bottom of the casing, while the abrasive, after being discharged on to the contents of the barrel, falls through perforations in the latter and slides down a chute to be collected pneumatically or mechanically as the case may be. The perforated barrel is provided with a door usually on the cylindrical surface, through which the barrel is charged.

In another form the nozzle projects through the end as before, but the perforated barrel is surrounded by a solid taper barrel which collects the abrasive, conveys it to one end, where it is collected in an annular passage, and delivered from there to a hollow trunnion. From this point it may be delivered over enclosed screens to the sandblast plant ready for re-use, connection to the fan being made from the delivery end of the machine.

These machines may be worked with either pressure or suction system. For barrels, small compact work is the usual run, but long drop stampings can be cleaned, and even long and somewhat delicate textile castings have been successfully treated. Malleable iron in the hard condition can be barrelled without cracks developing later. Brass valves and cocks are cleaned, the cores being removed in the process. Sand-blast barrels do not rattle castings so drastically as do tumbling barrels.

Rotary Table Machines.

A machine typical of these consists of a gridded table rotating under power, half of the table always being inside a casing, through the top of which project the nozzles. The front of the casing usually consists of a split-rubber curtain, which runs diametrically across the table. In operation the castings to be cleaned are placed on the front, *i.e.*, open half of the table. This rotates, and the castings are carried into the casing and are subjected to sand blasting.

The nozzles rotate about an axis eccentric and inclined to their own axis, and by suitably proportioning their speed and the speed of the table approximately uniform cleaning can be obtained. Spent abrasive is collected and delivered to an elevator at the back of the machine, from where it is delivered to a container ready for re-use. The cleaned castings are brought out through the curtain by the rotating table, and can be removed by the operator or allowed to go round again if they are not completely cleaned. Gravity feed nozzles can be conveniently used on this plant, as rotation of the nozzles can be easily arranged; but direct-pressure and suction plants are made. Fairly open work is in general most suitable, such as stove fronts, gear wheels, pulleys, etc. Other special-purpose machines are made, but are not in great demand.

Dust Extraction and Separation.

Recently Home Office regulations have come into force with regard to sand blasting. These may be summarised as follow:—(1) Sand blasting shall be done only in an enclosed chamber used for no other work, and provided with means to prevent the escape of dust from the chamber; (2) no person shall be allowed to work in a chamber, or within 30 ft. of a sand-blast nozzle in the open air, while sand blasting is in progress without being suitably protected by helmet, gloves, etc.; (3) all persons working within the above limits must be provided with suitable protective devices; and (4) all ventilating plant used must be tested completely once every six months.

With regard to the plants described, the operator must be protected as described above when working inside a chamber, but with chambers, cabinets, barrels and rotary tables where the operator works outside, no helmet is necessary, so long as dust is prevented from getting outside the plant. This condition is obtained as described by connecting the plant by pipes from 4 to 20 in. dia. to a fan.

With cabinets, etc., it is necessary that doors be a good fit. Where possible, it is, in fact, preferable to make these seal, and rely for air admission on special ports protected to prevent rebound sand escaping.

The suction head will vary with conditions. The essential thing is that the air velocity at any port open to atmosphere shall be sufficient to keep dust from escaping. With properly designed ports and ducts, 3 in. of water at the fan will probably be adequate.

The dust sucked away from the plant must not be discharged direct to atmosphere. Usually a separator is placed between plant and fan. This may be of the cyclone type, which consists essentially of a cylinder closed at the top, provided with an inner cylindrical baffle and contained by a cone at the bottom. Air enters at the periphery near the top, and dust, etc., falls to the bottom, the cleaned air being taken away from the top. Very fine dust settles in a water tank.

In a different type the air is forced to take a spiral path inside a cylinder which has a number of fine longitudinal slots in it. The dust passes through these slots owing to contrifugal action, and is collected in an outer casing, while the air is drawn away through a central tube to the fan. The final discharge from this, as previously mentioned, is made *via* a water tank.

It is not easy to rid the air completely of all very fine dust, but the above plant gives good practical results. If the final discharge can be made into a high and large chimney, this is perhaps as effective as anything.

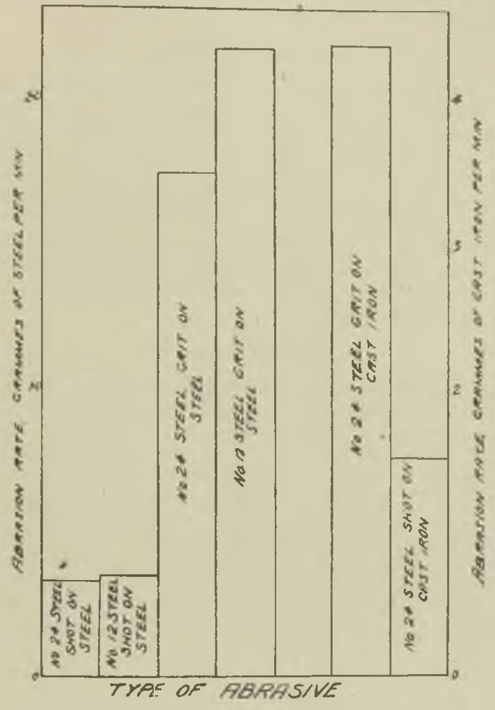


FIG. 7.—SHOWING RELATION BETWEEN ABRASION RATE AND TYPE OF ABRASIVE.

Protection of Operator.

For work in the chamber the operator must be provided with helmet and gloves, and overalls or an apron. Helmets may be made of leather, or an aluminium spinning may be used. A renewable window is provided, and air is fed through an adjustable valve to a distributor at the top by means of a rubber pipe. Expired breath escapes *via* the neck band. The pressure on the helmet being slightly greater than atmospheric, dust cannot reach the operator. The gloves are leather, and are armoured, or may be made of rubber. These are used also for work in a cabinet.

Other Aids to Fettling.

As regards the removal of scale, adherent sand, etc., sand blasting provides an efficient means and gives a good finish. There are other means available for removing sand. Castings may be hand-brushed, and with a certain class of work, where the area is large, the surface smooth, and the sand lightly attached—where, in fact, the sand may be blown off—it is questionable whether sand blasting affords a sufficiently great economy in time to pay for the necessary plant—unless it is desirable to get to virgin metal.

Core Remover.

A little instrument which was exhibited at the Düsseldorf Exhibition might prove useful for removing cores. It consists of a flexible spindle which is caused to vibrate by being continously tapped by a vibrator. The article is placed over it while the spindle is vibrating, and this removes the core. The spindle may be shaped. Both of these operations may be performed on a gridded table cased in below to collect chippings, etc., while the dust is drawn away by a fan through a pipe running the full length of the table. Such a table may be built at floor level, a pit being made as collector.

Tumbling Barrels.

Barrels may be used without sand blasting. They may be round, hexagonal or square in section, and are built from 1 ft. to 5 ft diameter. Dust may be extracted through a hollow trunnion at one end, or the barrel may be enclosed in a cabinet from which the dust is sucked. Hard iron stars may be loaded with the castings. The finish obtained is quite different from that obtained by sand blasting. The tumbling is generally more severe than in a sand-blast tumbling barrel and goes on for a longer time, with the consequence that edges become more rounded. The surface is, as it were, scraped, but virgin metal is not uniformly exposed. Whereas a charge in a sand-blast barrel might be cleaned in an average time of 15 minutes, the average time for a simple tumbling barrel might be 40 minutes or an hour. Barrels are sometimes packed with leather to reduce shock and possibilities of breakage.

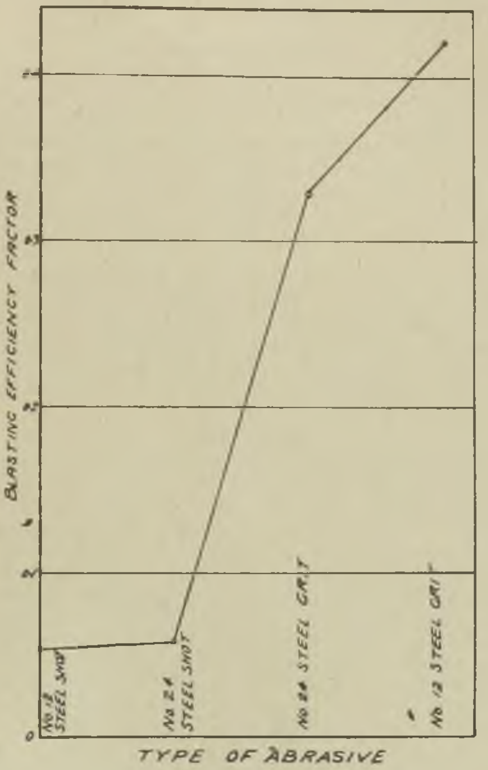


FIG. 8.—SHOWING RELATION BETWEEN BLASTING EFFICIENCY AND TYPE OF ABRASIVE.

Git Cutters.

These are power machines, usually mechanically operated, and consist essentially of a pair of cutters set in a rigid frame and arranged to exert great pressure in approaching each other.

Grinding Machines.

These are in very general use. Where the castings are comparatively small, stationary grinders are used.

Adequate guarding against the possibility of wheel fracture must be provided, and all dust must be intercepted and removed. This is done by the provision of a hood connected to a pipe leading to a fan. Again, Home Office Regulations have to be met.

Where large work has to be dealt with swing grinders are used. These consist of a light frame on which is supported an abrasive wheel, usually motor-driven. The frame is pivotally supported, and can swing about vertical and horizontal axes, so that the wheel can be guided over its work.

Conclusion.

All the machines described have their proper uses. Of sand blasting it may be said:—(1) It will remove scale, rust, etc., and it gives a surface which is particularly suitable for painting, enamelling, lacquering, etc. In this connection it has been found that enamel, etc., adheres better than to the non-sand-blasted article, and gives a uniform covering of more pleasing appearance. Less paint, etc., is required to give the requisite film, while if the coating is applied soon after sand blasting it has a longer life, as no oxidation occurs. (2) Fused sand and embedded particles are removed from the skin, with consequent increase in life of tools in the machine shop. In many instances this factor alone makes a sand-blast installation a paying proposition. (3) Dust from cores, etc., can be readily removed without spreading over the foundry; and (4) it is a much less dirty and inconvenient process than pickling, and less costly.

Simple tumbling will do much to remove cores and knock off sand, but it will not give a sand-blast finish. The core remover would be useful for some castings, but is generally slower than barrelling. Pneumatic chippers, git cutters and grinders help to reduce the time of fettling. It is certain that foundries generally are installing more mechanical equipment, and not the least important part of this consists of sand-blast plant.

The author desires to express his thanks to J. W. Jackman & Company, for slides and information; and for facilities for making, and permission to publish the results of, the experiments described in this paper, and to The Tilghman Sand Blast Company for certain diagrams and information.

Scottish Branch.

A GLIMPSE INTO A NON-FERROUS FOUNDRY.

By J. D. Frame.

A lecture on this world-wide subject at any time seems interesting either from a historical point of view or from a study point of view. In order to mark the progressive steps of man, his early history has been divided into three periods, each being named after the materials chiefly used in them for supplying weapons, tools and ornaments. Thus there is the Stone Age, the Bronze Age, and the Iron Age. A similar development has been going on for some considerable time past with regard to bronze, but inasmuch as no class-term has ben invented in these very inventive times for the new variations of that most ancient and useful alloy, it is difficult to designate this fifth age by a new title, and so one must be content to consider it as a revival of the Bronze Age in a more advanced and more highly-developed form.

As the Stone Age, however, was divided into two parts, namely, the old Stone Age, when men simply chipped stones, and the new Stone Age, when they learned to grind and polish them, so perhaps it may be permissible to consider the present as the Newer Bronze Age. Nor is it altogether inapt so to consider it when there are many varieties of bronze which have been produced within the last forty years, possessing very distinctive features from the ancient alloys, and some very remarkable qualities as compared with them, and very numerous are the purposes to which these qualities are applied, superseding as they do in many instances iron, and even steel itself. These considerations and the knowledge of the great value of these alloys to the present-day engineers have been the means of some of their greatest achievements in modern engineering.

That metals are capable of uniting with each other to form a series of bodies having more or less the properties of their constituents has long been known, and probably this knowledge has been usefully applied from remote antiquity. The Ancients were acquainted with seven metals—gold, silver, mercury, copper, tin and lead. They knew and employed various compounds of antimony, arsenic, and zinc, although we have no evidence that these metals were known to them in the metallic state. Gold and silver, which occur in nature in the metallic state, were probably the first metals with which man became acquainted, and as other metals were discovered, especially copper, efforts would doubtless be made to alloy the base metal with gold, in consequence of the comparative rarity of the latter.

Iron, in meteoric form, is a native alloy of iron, nickel, and small quantities of other elements, said to have been used by Esquimaux and other tribes for making knives and other weapons. Copper is also occasionally found *native*, and to persons accustomed to melt the precious metals, they had no difficulty in melting copper and alloying it with gold and silver. The Latin word "Aes" in ancient writings sometimes signifies copper and sometimes brass, so the two metals are consequently confounded occasionally. Pliny, the historian of his time, says that copper was first discovered in Cyprus. The proper name for brass in those days was Aurichaleum, or golden copper, and it may be inferred that ores of copper and zinc were sometimes melted together, forming brass, as the metal named zinc was probably unknown until the sixteenth century. Pliny describes four different varieties of what was known as Corinthian copper: (1) White in colour, it resembled silver in lustre, and contained an excess of silver; (2) red, in this kind there is an excess of gold; (3) in this kind gold, silver and copper are mixed in equal parts; and (4) this variety was termed Hepatison, having excess of copper, giving to it a liver colour, which gives it its value.

Copper was used by the ancients for many of the purposes to which it is put by the moderns, but the art of making tempered articles in copper —such as the ancients made—has been lost, and has baffled the efforts of scientists to regain this lost art for the last two centuries. An American is supposed to have found this ancient formula on a rubbish heap, but time will reveal the truth of this or otherwise. The alloys of copper with tin were used in various proportions; thus bronze for statues were composed of 100 parts copper, 12½ tin; another mixture, 100 parts copper, 10 parts lead, and 3 to 4 tin. The arms of these ancient warriors were often made of bronze which was rendered hard by a process of hammering, then heated and cooled slowly.

Tin was in common use in the time of Moses. It 'was doubtless Phœnicians who supplied the Egyptians with this metal, which the former obtained from the Scilly Isles and Cornwall. Cassiterous or tin is mentioned by Homer in the time of Pliny as being used for coating the interior of copper and brass vessels. Mercury was used by the Romans for alloying with gold and silver to form amalgams, which were used for gilding and plating as at the present time by laying the amalgam on the base metal and subsequently volatising the mercury with heat, leaving a thin coating of precious metal on the article. Lead was well known to the ancient Egyptians and Arabians as well as the Romans. Large quantities of lead were obtained from Spain and Britain. Sheet lead and piping were used for similar purposes to those which are employed at the present time. A mixture of lead and tin was also used as solder. Iron was known in very early times, but in comparatively small quantities, being obtained from meteoric stones or easily reducible oxide. Moses speaks of iron being used for swords, knives and axes, which seems to imply that steel was known at that early period.

Homer represents warriors as armed with bronze swords and never as using iron weapons. Achilles proposes a ball of iron as a valuable prize to be contested for in the games, which showed its scarcity during that period. That the Romans were acquainted with the hardening and tempering of steel there is abundant evidence. Thus the ancients knew the six malleable metals and their alloys, but they left us scant information respecting the method of extracting them from their ores. It is probable that only those ores of a simple character, or those readily acted on by reducing agents were employed, unless the appliances at their disposal and their general chemical knowledge were superior to what known facts warrant us believing. It has to be admitted that modern science has to be thankful for even such knowledge as has been handed down by these early historians.

That brass was known to the ancients is beyond dispute, but its direct preparation from copper and zinc is an invention of modern times. With the exception of iron, there is no product of man's industry that is earlier spoken of than brass, but the words thus used in all probability referred to bronze, an alloy of copper and tin. The brazen serpent in the wilderness, the brass vessels of Solomon's temple, and the so-called brass armour of ancient Greece and Rome were all doubtless bronze.

Bronzes of the Ancients.

The bronzes of the ancients varied considerably in the proportions of their ingredients, for in the main copper and tin only were used, according to the purposes for which they were intended. Thus modern chemical analysis shows that ancient bronze nails contained 20 parts copper, 1 tin; soft bronze consisted of 9 copper, 1 tin; medium bronze, 8 parts copper, 1 tin; hard bronze, 7 parts copper, 1 tin; and mirrors, 2 parts copper, 1 tin. The bronze weapons and tools of the ancients contained from 8 to 15 per cent. of tin. A Roman sword-blade found in the Thames showed 85.70 and 10.02 tin, whilst another found in Ireland gave an analysis of 91.39 copper and 8.38 tin. The bronze weapons of the Greeks and Romans have been found not only to be of the truest composition for ensuring the greatest density for alloying itself, but the cutting edges, by undergoing a process of hammering, were brought up to the highest degree of hardness and tenacity. Even to this day some of the finest steel is made in the simplest and rudest manner by natives of the Belgian Congo, Egypt, and other countries.

It is to be observed that most of the ancient coins were of bronze, a small percentage of zinc being added in some cases to improve the colour. According to analyses made by Mr. J. A. Phillips. the quantity of tin relative to copper varied very slightly even over the range of 300 years. The following are the proportions of copper and tin (the other ingredients being omitted):—

	B.C.	Copper.	Tin.
Alexander the Great	335	86.72	13.14
Philippus V	200	85.15	11.10
Athens	—	88.41	9.95
Ptolemy IX	70	84.21	15.59
Pompey	53	74.11	8.56
The Atilla Family	45	68.72	4.77
Augustus and Agrippa	30	75.58	12.91

Bronze pure and simple consists of a mixture of copper and tin in certain proportions, according to the purpose for which the compound is intended. Other metals, such as zinc, lead, phosphorus, manganese, silicon, may have been added without declassifying the product, which is still called bronze, provided that copper and tin are the chief constituents. The bronzes of France are known to contain nearly always four metals, namely, copper, tin, lead and zinc. It is also stated that some contain minute and variable quantities of nickel, arsenic, antimony and sulphur. It is the addition to bronze, pure and simple, of certain proportions of one or other of the metallic substances previously referred to that constitute the modern development of bronze manufacture, which has given us some of the most useful and at the same time some of the most remarkable alloys known. These comprise no fewer than twelve distinct products, all of which find their uses in connection with the practice of engineering. These are as follow:—Phosphor bronze, silicon bronze, manganese bronze, delta metal, phosphor copper, phosphor manganese bronze, phosphor lead bronze, phosphor tin, aluminium bronze, silveroid, cobalt bronze and vanadium bronze.

Phosphorus and Copper Alloys.

These alloys form the subjects for present-day consideration and investigation, each alloy functions in its own particular sphere. There are other bronzes which are used as substitutes for gold in cheap imitation jewellery, but they are in the main only variations of some of the bronzes. Attention was directed some years ago to the use of phosphorus in improving the character of bronze for various purposes, and eventually with very successful results. The action of phosphorus on copper alloys is principally due to its reducing qualities, by virtue of which the oxygen absorbed by the molten metal is removed or rather the oxides thereby produced are eliminated, and there is imparted to the metal that degree of homogeneity, strength and toughness which is peculiar to the chemically pure metal. The phosphorus, in producing these effects, is converted into cuprous oxide, which floats on the surface of the molten metal in the shape of a very fluid slag, whilst the superfluous quantity combines with the metal. This being the case, it is not desirable to add to the bronze a larger quantity of phosphorus than will suffice to reduce the oxide present. It is thought by some that the phosphorus itself imparts to the bronze the qualities of hardness and strength, and therefore the more phosphorus put into the metal, the better the results as regards hardness. This, however, is not the case inasmuch as hardness would be obtained at the expense of toughness.

The question of producing the various qualities of this class of metal depends, not so much on the quantity of phosphorus, as upon the correct proportioning of the various ingredients, phosphorus included. These alloys are formed by the addition of a small proportion of a compound of phosphorus-copper or from phosphorus-tin. However, great care is required in determining the exact proportions of the ingredients in making phosphorus-bronze alloys. A 15 per cent. phosphorus-copper to analysis is preferable. Phosphorus-tin, very often supplied, has too much lead alloyed with it, which makes it unsuitable for certain alloys in this group; also, it is inclined to rise in little white patches on the top of the casting through oxidisation of the compound. Phosphor-bronze was invented by Dr. Kunzel, of Blasewitz, Dresden, and was brought into practical use in this country early in 1873 by the Phosphor-Bronze Company, who have from time to time patented several improvements, both in respect to alloys and methods of manufacture. Phosphorus-bronze alloys are composed of copper, tin, phosphorus and other ingredients in definite proportions, and are made to be either as ductile as copper, as tough as iron, or as hard as steel, according as the proportions of the constituents are varied. The alloys used for rolling and drawing have very different proportions from those employed for castings, for bearings, and parts of machinery. The casting of the metal, owing to its greater fluidity when melted, is perfectly sound and homogeneous. Wherever strength, toughness, and durability are desired, phosphor-bronze is found to be far better adapted than gun-metal and brass, and in many cases than iron-steel. With regard to the applications of phosphor-bronze, it may truly be said that their name is legion. This remark applies in the main to most of the modern bronze alloys. Chief among their many applications is the manufacture of wire, rods, tubes, sheets, screw-propellers, pinions, slide valves, bearings, bushes, axle boxes and other parts of machinery exposed to friction. Phosphor-bronze possesses the advantage of not becoming crystalline under the action of repeated shocks and bends, and is therefore well adapted for making wire ropes, etc.

In the manufacture of castings from phosphor-bronze alloys, a new or clean plumbago crucible is desirable so as to avoid any admixture of other metals. It is best to place some small charcoal or char-dross in the bottom of the crucible, then add the copper. When this is thoroughly melted all charcoal or char-dross will rise to the top of the molten metal. Then remove the crucible from the furnace to the casting pit, where will be added the various ingredients. The charcoal or char-dross prevents oxidation, and should remain on the top of the molten metal until the casting temperature is assured, then skim and cast. The casting temperature is 950 deg. C. A very good practical way of getting the temperature is to blow with a pair of hand-bellows on the top of the molten metal. If ready for casting, a skin will come and go through the cold air coming in contact with the alloy. This indicates to the practical man that it is time for casting. For large castings, the moulds are thoroughly dried and dressed with a mixture of plumbago and thin clay water. Small work is cast green, and dressed with plumbago. These castings should come out with a very sharp and smooth surface, free from blowholes and oxide. In order to avoid segregation, it is necessary not to pour phosphor-bronze at too high a temperature, and to see that the alloy is well stirred, or, in other words, thoroughly mixed before casting.

Durability of the Metal.

Having referred to the great durability of phosphor-bronze under conditions of work, the author has made phosphor-bronze crosshead slippers to replace cast-iron slippers, which had only been in service three months when they were worn out. These same slippers have now been running four and a half years, and show little or no wear. Gun-metal slippers usually wear two years. A very interesting statement relating to phosphor-bronze was made forty years ago. A pair of slide-valves which had been taken out of one of the North-Eastern Railway Company's express engines, after six and a half years' working, during which the engine had run 261,182 miles between Newcastle and Edinburgh, they were taken out to replace the cylinders with a pair of a different type. The engine was of the following dimensions: cylinders 17-in. dia. by 24-in. stroke, four coupled wheels 7-ft. dia., working pressure 140 lbs. per sq. in.; weight of engine in working trim, 39 tons 16 cwts.; weight of tender, 26 tons 4 cwts. Mr. Fletcher, the Assistant Locomotive Superintendent of the North-Eastern Railway Company of that period, stated that the slide valves in six and a half years had only worn down to the thickness at which they generally took out gun-metal slide valves, and that had it not been that they were putting in a pair of cylinders of a different type he certainly would have let them run longer, as he considered them quite safe, taking into consideration the great superiority of phosphor-bronze over gun-metal. The original thickness of these slide valves was 1 in., and they were worn down to $\frac{5}{8}$-in. thick. Gun-metal slide-valves rarely exceed eight months' work when they are worn out. The cylinder faces were in excellent condition, the wearing being as it should be on the valves. Even to this day the locomotives of the L.N.E.R. Company, which have slide-valves, have them all made of phosphor-bronze. The composition is 86.5 copper, 13.0 tin and 0.5 per cent. phosphorus.

Some bearings which were giving considerable trouble in a rolling mill had bushes made of gun-metal which only lasted about five weeks before scapping. After replacement by phosphor-bronze the bearings have now been running eight months without complaint. Undoubtedly phosphor-bronze seems neglected by the consulting engineer or designer. They have proved to those engineers who have tried and experimented with these alloys to have been of great service and value to them in some of the great triumphs of engineering, which otherwise would have been complete failures. The beneficial effect of phosphorus on copper consists mainly in producing a material of definite closeness and of the highest possible degree of toughness and elasticity. These excellent qualities must not be attributed alone to phosphorus in the metal or only in a secondary degree, but are owing chiefly to the absence of oxygen, which by the energetic reducing action of the phosphorus is entirely eliminated.

Copper forms with other metals a series of alloys far more numerous and important than that of any other metal. This may be accounted for by its red colour, high malleability, ductility, toughness and softness, and tenacity, which properties it imparts in a great measure to many of its alloys, when united with metals opposite to it in character. The very properties which make copper so useful are sometimes a disadvantage for certain purposes; for instance, the toughness and closeness of grain makes it more difficult to turn in a lathe than brass and its softness makes it unfit to be used alone for making castings subjected to great wear and strain. In the vast majority of cases in which pure copper is used, it has to be melted and cast into moulds of various kinds in order to prepare it for further treatment. The difficulties in producing sound castings are so great that it can only be successfully manipulated in the hands of very skilled and experienced workmen. Great attention has been directed to this subject of late years in consequence of the demand for solid drawn tubes, rollers, etc., and different physics have been added to the copper in melting with a view to overcoming the inherent defects.

Modern practice in producing gun-metal castings has resulted in the exclusive use of copper and tin. They should be very tenacious, with sufficient hardness and elasticity to resist distortion. They are indifferent to ordinary chemical influences. While the addition of a third metal may be useful in strengthening one particular property, it may be injurious to the required properties taken as a whole. The addition of a little phosphorus is very useful to this alloy as a deoxidiser and purifier. Zinc is used in the manufacture of copper-tin alloys for bearing purposes, but this has to be used carefully, so that it will not deteriorate the wearing properties of these alloys, for if in excess the bearing wears very quickly; from 1.5 to 2 per cent. is ample as a deoxidising agent, and should not be exceeded.

These personal observations are purely practical, but in this field the author is one of many foundrymen who would welcome more definite and sustained co-operation in its investigations into the gun-metal alloys for bearings. One can solicit very little information from modern text-books, and upon such a complex problem opinions are divided. If this co-operation were sustained, foundrymen would obtain a higher state of efficiency in the gun-metal alloys. The standard alloy of 88 copper, 10 tin, and 2 zinc is only on the fringe of more complex alloys in the higher tin groups.

The analysis of the gases obtained by heating pure copper resemble that of the gas obtained from the copper-tin alloy, and this suggests that the gases which cause unsoundness in gun-metal are actually in the copper group. The volume of gases is also about the same, and when once in the metal it is almost impossible to extract them. Zinc and tin act as deoxidising agents to copper, and thus reduce the cuprous oxide and become themselves oxidised in the process. Zinc oxide comes to the top, and is skimmed off with the tin oxides. Cuprous oxide, on the other hand, is soluble in molten copper, and only separates after the alloy commences to solidify. This gas only

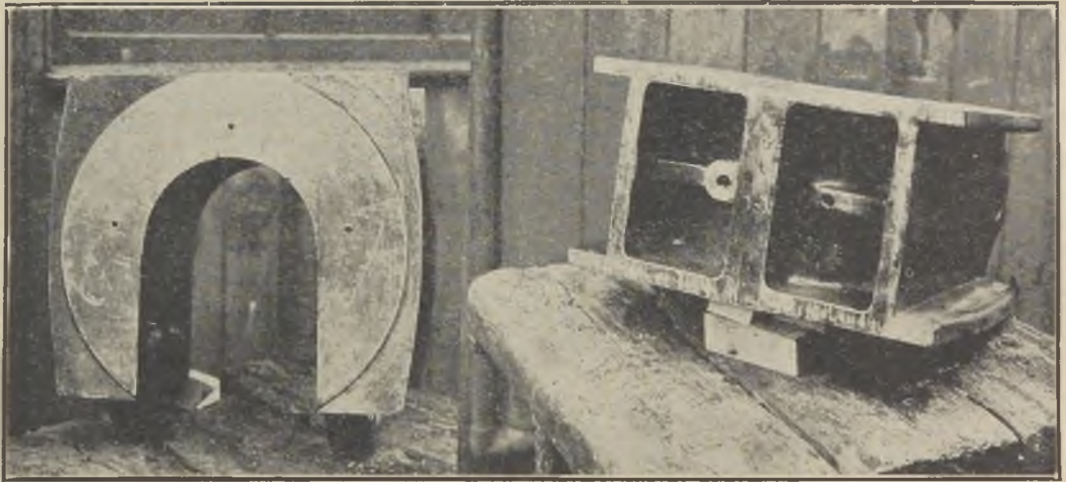


FIG. 1.—TWO VIEWS OF A PACIFIC AXLE-BOX MADE FROM GUN METAL SHOWING CLEARLY THE UNEQUAL SECTION. THESE AXLE-BOXES HAVE BEEN RUNNING APPROXIMATELY 200,000 MILES WITH THE L.N.E.R.

attacks the delta constituent, the alpha being impervious to gas holes. Alpha and delta being the structure of high-tin alloys, we find the alpha constituent solidifying first. This probably causes the gas to be driven from the alpha constituent into the delta constituent, and on solidification the gas escapes, leaving local cavities where the metal is farthest away from quick solidification. If founders could solidify gun-metal castings as rapidly as the chilled ingots, they would minimise this escape of gas, and as a result we would have, as near as possible, a homogeneous casting.

In the design for large gun-metal castings, such as Fig. 1, much assistance towards a "sound job" would be given by uniformity of sections—variations of thickness do not help foundrymen, and are the root cause of many flaws in the gun-metal group. The outlined metal flaws are wholly accounted for by the varied times of freezing; even in an ingot or chilled test pieces there are variations not so pronounced, however, as in castings. Gas holes being the premier trouble in gun-metal, should not be confused with other gases so numerous and of different origin from the gas escaping during solidification of the metals. For example: (1) Water gas (steam) due to moisture in the moulding sand which can be eliminated; (2) gases from the various cores, and if they have no free exit during casting, there will be serious segregation, and also serious blow-holes appearing through the body of the metal; (3) sands, which on contact with the metals become glass, and form oxides; (4) opinion is that oxygen gases play a considerable part in the cause of unsoundness in gun-metal castings. It is thought if it were permissible to use a strong deoxidising agent before casting, it would help to eliminate the gases from the crucible before casting. This, however, coupled with pursuits of the chilling methods and the necessary assistance of the designer in the uniformity of sections previously stressed, will help to solve this serious problem.

In comparison with the steel group, one cannot adapt normalising towards gun-metal bearings. Any attempt in this direction destroys their vital composition. If the normalising process be applied to axle box or slide valves, by treating them in a temperature of 700 deg. C. for half an hour, then the result is to bring the whole of the delta into one alpha solution. In effect, it increases ductility and malleability only, and gives a stronger metal, but it is at the cost of the durability of the initial structure, viz., as a bearing metal, which is the distinct property of the delta constituent; it has meant the sacrifice of an essential factor. It is obvious that this must not be sacrificed, as would happen in any attempt at normalisation. Recent practical tests on modern locomotive slide valves confirm this, and prove conclusively that any such treatment was abortive as applied to non-ferrous alloys when a bearing metal was desired.

The tensile test for high tin alloys is not exactly what it should be, and a load test or Brinell test for hardness would be of more value for this class of material. The reason for this opinion is the uneven distribution of the delta structure. Temperatures have been very often discussed, and it is thought that there is no constant in casting temperatures, but they must vary with weight of the casting.

It is stated that some of the ancient bronzes have been found on analysis to contain a small percentage of iron, but it does not appear that any traces of manganese have ever been discovered. It is thought probable that the ancients knew that the addition of iron to bronze would increase its hardness, and introduced it for that purpose.

Iron, Manganese and Brass Alloys.

Inventors have proposed combinations of iron with brass alloys, and some have also introduced manganese by reducing the black oxide of manganese and combining it with the copper. However, none of these alloys appears to have been brought into permanent practical use. It is more than a hundred and fifty years since James Keir proposed an alloy—100 parts copper, 75 parts zinc and 10 parts iron—and in later years, Sir John Anderson, when superintendent of the Royal Gun Factories, carried out a number of experiments with similar alloys, and with some very good results, but none of them appears to have been used consistently commercially. The addition of iron unquestionably increases the strength and hardness of these alloys, but according to some experiments made a few years later by Mr. P. M. Parsons, they would appear to acquire these qualities at the expense of ductility and toughness, and it is probably on this account that this class of alloys had not come into general use up to the time of Mr. Parsons' experiments. Mr. Alex. Parks, and Mr. J. D. Morris Stirling, both eminent metallurgists, appear to have been the first to propose and carry into practice, the use of manganese. Mr. Parks combined manganese alone with copper, and used this alloy to form improved alloys of brass and yellow metal of which to make sheathing, wire, nails, and tubes. Mr. Stirling, in 1848, proposed to use manganese in various alloys in which iron was present. At first, he combined about 7 per cent. of iron with zinc, and added to the copper a small percentage of manganese, by reducing the black oxide of manganese with the copper in the presence of carbonaceous materials, and then added to it the requisite quantity of the iron and zinc alloy to make the improved brass required. Mr. Stirling's idea was to combine the iron with the zinc by fusion, but in practice, he found a more ready means of procuring the zinc and iron alloy by employing the deposit found at the bottom of tanks containing the melted zinc for galvanising iron articles. This product consists of zinc with from 4 to 6 per cent. of iron, but this percentage is very variable, and the results of its use, therefore, are in some cases unreliable. Probably metal made by this process was in use for some time for carriage bearings on the London & North Western and other railways, with very good results. It does not appear, however, to have ever been introduced for any purposes where the requirements were great strength, hardness and ductility.

Manganese Bronze.

The time, however, arrived, namely, in 1876, when these requirements were met by the aid of manganese in the manganese bronze of Mr. P. M. Parsons. This alloy is prepared by mixing a small proportion of ferro-manganese with copper. The ferro-manganese is melted in a separate crucible and is added to the copper when in the melted state. The manganese, in a metallic state, having a great affinity for oxygen, cleanses the copper of any oxides it may contain by combining with them and rising to the surface in the form of slag, which renders the metal dense and homogeneous. According to Mr. Parsons, a portion of the manganese is utilised in this manner, and the remainder with the iron becomes permanently combined with copper, and plays an important part in improving and modifying the quality of the bronze and brass alloys prepared from the copper thus treated. The effect is to increase greatly their strength, hardness and toughness, the degrees of all of which can be modified according to the quality of ferro-manganese used and the proportion of iron and manganese it contains. It will thus be seen that this method of making manganese bronze is altogether different both in principle and effect from the inventions of either Mr. Parks or Mr. Stirling.

Another point of importance is the nicety with which the iron and manganese can be adjusted, and their effect controlled by adding the ferro-manganese to the copper as pursued in the manufacture of manganese bronze. The amount of manganese required for deoxidising the copper and for permanent combination with it being well known by experience it is found that very slight variations in quantity have a perceptible and ascertained effect in modifying the qualities of the alloys produced, the toughness can be increased and the hardness diminished, or *vice versa* at will. In preparing the ferro-manganese for use, Mr. Parsons prefers that which is rich in manganese containing from 50 to 60 per cent. This is melted with a certain proportion of the best iron scrap so as to bring down the manganese to the various proportions required, at the same time any silicon it contains is reduced and the metal refined. About four qualities of ferro-manganese are made in practice, containing from about 10 to 40 per cent. metallic manganese. The author has been manufacturing manganese bronze for the last nineteen years under these principles, and has found them very successful.

During the war many drop stampings were made. A great number of these alloys forge like mild steel, but care has to be taken not to overheat the bronze, for at high temperatures it will powder away. About 500 deg. C. is the correct temperature for forging and stamping. Hot working and rolling improve these alloys considerably, and it is recommended where possible to forge the material.

Manganese-bronze castings should always be studied from a productive point of view, as only the most expert founder can be successful where these alloys are concerned. Standards of thicknesses should be kept as uniform as possible, for in the solidifying of these alloys great contraction takes place and cracks and segregation are not uncommon. Chilling methods have great and beneficial effect as far as sand castings are concerned, but these have to be carefully thought out. When casting, all gates should be immediately choked or filled to ensure clean castings; oxide or dross forms very rapidly when the metal comes in contact with the sand. The inlet gate should never exceed $\frac{7}{8}$ in. in diameter, and a skim gate provided as an inlet to the casting, which will counteract the dross going into the casting with the first drop of metal. Head pressure varies with weight of casting. In the manufacture of these particular alloys great care has to be exercised in the melting. It is the author's practice to make a ton at a time and remelt the ingots. This process gives the founder a fair idea of both composition and structure. If in the remelting, overheating takes place the zinc will oxidise freely, which will have a serious effect on the strength of the alloy. Alloys of this group should never be heated above 1,060 deg. C. and cast around 960 deg. C. Castings made under conditions outlined are homogeneous after machining. Castings up to 5 cwts. have been made in green sand successfully under personal directions. Some of the most successful main-line locomotives are running at the present time with manganese-bronze bearings weighing $4\frac{1}{2}$ cwts. each, and manufactured by the North British Locomotive Company, Glasgow. (Fig. 2.) These bearings stand considerable wear and pounding, which is one of the greatest virtues of manganese-bronze bearings for axle-boxes.

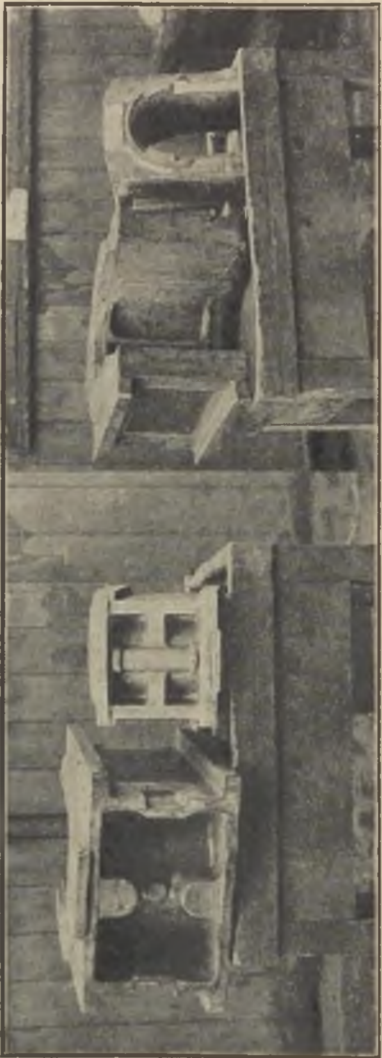


Fig. 2.—Manganese Bronze Axle-boxes made for the Southern Railway, showing Unequal Section.

Metallic packing should at no time be cast in sand moulds. The reason for this assertion is that being cast in sand moulds it takes too long to arrive at the freezing point, with the result that the denser metal separates from the lighter alloy, and uneven distribution is clearly shown. In the system of chilling a uniform structure throughout is got with no separation, a closer grain is obtained and all the particules are closely united, freezing point in many cases being instantaneous, which is one of the vital points in counteracting the separation of the different metals which are used in its manufacture.

White Metal for Bearing Purposes.

The metals used for the compositions of the various alloys are copper, tin, lead, zinc and antimony, but seldom more than three of these are used in any alloy. With machinery running at high speeds or with great pressure, the bearing surfaces are subjected to considerable friction, and in many cases the object of the engineer is rather to reduce this friction to the lowest degree than provide a bearing which will stand greater pressure without wearing. The common practice at the present time is to make the foundation of brass or of bronze, and to line the bearing surfaces with a renewable lining of white metal. One great advantage of white-metal alloys is their low melting point. A worn-out bearing can be readily melted out and replaced by a new one. Care should be exercised not to raise the metal to too high a temperature, as it causes the constituent metals to oxidise unequally, the volatile metals escape, and thus the composition is considerably altered. White-metal bearings are indispensable for certain purposes, for example, where the shaft in the bearing does not run smoothly. If the bearing is made of hard metal, considerable friction is set up, and a struggle will take place between the axle and the bearing, the softer of the two being worn away, causing the axle to be pitted or corded. By the use of a soft white-metal lining the axle is not worn, but it adapts itself to the condition of the bearing and runs with much less friction. Great diversity of opinion regarding high-tin alloys and high-lead alloys exists, but a great deal depends on the load which the bearing has to carry. This proves the usefulness of the alloys. For example, the truck axle-box bushes of the first Atlantic engines were lined with a high-tin alloy, and these bearings had to carry a heavy load. They gave considerable trouble at first until a high-lead bearing was substituted, and to the present day they are running on high-lead bearings. Zinc alloys of white metals have been very common, but they seem to have been discarded of late. They stand much heating, but this is at the expense of the axle, which in many cases becomes corded, and the axle has been known to give way in consequence. Some of these bearings actually have to be cut off the axle. When they become hot they do not fuse like a high-tin or a high-lead white metal and run out, but become a black mass of oil and grit and decomposed metal. Therefore engineers through practice can adopt the alloys most suitable for their requirements.

The man who aspires to the formation of new alloys or wishes to produce metals suitable for different requirements as circumstances arise must be well acquainted with the nature and properties of the simple metals in order to accomplish his object successfully, and although a knowledge of the components is not sufficient in itself, it is of advantage in assisting the operator who combines practical experience with theoretical knowledge in the mixing of metals.

Foundry Furnaces.

Furnaces, like a great many other parts of foundry equipment, have undergone considerable change, but still the author does not consider the tilting furnace an advantage in any way compared with a good hearth crucible furnace. The only improved furnace type from which consistent results may be expected—as regard melting and suitability—for the casting of high tin and gunmetal alloys will be the electrical furnaces, a goodly number of which are working in America where electrical power is cheap. The advantages to be gained from electrical melting are:—(1) Practical and desired temperatures can be obtained; (2) temperature can be controlled with accuracy; (3) introduction of impurities with fuel avoided; and (4) oxygen is not necessary in the furnace.

The drawback in installing electric furnaces is their initial cost and the high cost of electricity. Until electric power becomes cheaper the progress of this class of furnace will be hampered, but they will, it is thought, supersede all other types of furnace. In the manufacture of non-ferrous material much depends on the way it has been handled in the furnace. This is where a great deal of trouble lies, and without the aid and skill of highly-trained furnacemen who thoroughly understand the melting of the various metals one can anticipate failure and loss. Metal should at no time lie for a prolonged period when molten, as oxidation takes place very often and variation of composition is the result.

FIG. 3.—CRUCIBLE MELTING PLANT AT THE NORTH BRITISH LOCOMOTIVE COMPANY, LIMITED, GLASGOW.

The furnaces (Fig. 3) are natural draught and consist of a battery of twelve furnaces. They are built from the best refractory materials which must be able to withstand violent fluctuations of temperature. They melt steel, iron and manganese with little or no trouble. A crucible of alloy containing 240 lbs. from a copper base can be melted and ready for casting in 1 hr.

10 mins., with a consumption of 56 lbs. coke. By 240 lbs. of metal is not meant yellow brass but gun-metal. Copper only is melted in furnaces as the author prefers to do all mixing for gun-metals, phosphor-bronze, etc., on the hearth. When the foundry is in full working order the first six furnaces give five heats per day with no less melting capacity than 240 lbs. per heat, the others giving four heats per day.

Fig. 4 shows one of two reverberatory furnaces where is refined all copper scrap from boiler fire-box plates, copper stays, etc. It is lined with the best Glenboig brick. These furnaces use forced draught with a small coal box for manufacturing gas. The gas passes over the bridge and is ignited with hot air which melts the metal; its capacity is one ton. Two heats are taken from this furnace in 4 hrs., which includes charging and pouring into ingot moulds. All manganese bronze alloys are made in these furnaces with very successful results. The coal consumption per heat figures out about 4 cwts. 1 qr. to 17.5 cwts. of metal melted. The fuel used for these furnaces is "Baird's best hard coke." It may be a little

Fig. 4.—Part of the Reverberatory Furnace Plant at the North British Locomotive Company, Limited, Glasgow.

dearer to begin with but is economical. There is no crusting or slagging round the bottom of the crucibles or furnaces as in the case of some brands of coke. Soft char is unsuitable for this class of work. Coal is used for the reverberatory furnace, and whilst splint is preferred, any class will do if carefully handled.

Quality of the Casting.

In every-day foundry practice castings are either rejected or accepted on the showing of the tensile strengths and elongations of definite test-pieces from the castings produced. While this may be a valuable check against the acceptance of faulty or inferior workmanship, yet the microscope reveals unmistakably that the cause of the trouble in many cases is entirely due to irregular sections in the casting. The evolution of the test-piece has been purely academic, and it can be demonstrated that in modern foundry practice no criterion exists of what a practical man would call a good job and suitable in every respect for their parts as engineering components.

Test results arrived at in laboratories from test-pieces cast in small sections, say 6 in. long by ⅝ in. square, and, according to specified tests, may, in every respect, be acceptable, but if a test-piece is cut from a section of the same cast of material out of a casting bearing from 1½ in. square to 8 in. square, it fails miserably under test without exception. These are the conditions modern foundrymen are subjected to. This is not quite in accordance with what metallurgists and consulting engineers would have us believe, although quite explainable by the foundryman.

If a sample of a gun-metal or high tin alloy consists of seven different sections, as detailed in Table I, A is in fine condition, the Alpha and Delta being very evenly distributed, and fairly homogeneous; B is also in fine condition, but a little coarser in structure, whilst C, D, and E are progressively still coarser, whilst F is very coarse in structure. In this type of structure there are local cavities. The seventh specimen G shows a 6 in. by 1½ in. piece, cast under chilled conditions from the same mix of metal, showing the most homogeneous structure.

The test results are as follow:—

TABLE I.—*Properties of Gun-metal Test-pieces of increasing Section—Casting Temperature of Samples,* 1,170 *deg. Cent.*

Section.	Sand Cast.	Dia.	M.S. tons per sq. in.	E. per cent.	R.A. per cent.
A	⅝″ sq. × 6″ long	0.564	17.0	5.2	4.96
B	1″ sq. × 6″ ,,	0.798	14.5	4.8	4.44
C	1¼″ sq. × 6″ ,,	0.798	13.8	3.5	3.2
D	2″ sq. × 6″ ,,	0.798	10.3	2.6	Nil
E	3″ sq. × 6″ ,,	0.798	9.0	2.0	Nil
F	4″ sq. × 6″ ,,	0.798	8.12	2.0	Nil
G	1¼″ sq. × Chilled	0.798	17.4	1.75	1.96

All made from Virgin Metal—Copper, 85.5; Tin, 13.25; Zinc, 1.25.

The specimens are not the finest one can produce, but just what any foundry foreman gets every day if he cares to examine his product of such dimensions. It is, therefore, up to the consulting engineer, the designer, and the metallurgist to consider this problem, for the foundryman can only chill his castings to a very limited extent if the heavy sections of casting have to be anything like the small sections in structure and test requirements.

TABLE II.—*Properties of Phosphor Bronze containing* 80 *Copper,* 10 *Tin,* 8.0 *Lead, and* 2° *Phos. Copper* (*Phos.* 15%).

Tests.	How Cast and dimensions.	Dia.	M.S. tons per sq. in.	E. per cent.	R.A. per cent.
1	Sand ⅝″ sq. by 6″ long	0.564	14.48	6.0	4.96
2	Sand 1¼″ sq. by 6″ long		12.8	5.5	4.44
3	Chills 1¼″ sq. by 6″ long ..		18.6	7.3	9.28
4	Chills* 1¼″ sq. by 6″ long ..		22.24	7.0	broke outside centres.

* Sample No. 4 was free from lead.

Table II relates to phosphor bronze for bearings and shows their properties, both sand and chilled cast.

In the consideration of these investigations the difficulties encountered in modern foundry practices are apparent in order to obtain the 100 per cent. results so much desired in modern marine and locomotive castings. As far as it is humanly possible a good sound job is assured by co-operation between the foundry and the laboratory, and the care exercised by the former finds confirmation in the results of tests carried out in the laboratories and test-rooms.

Many instances could be cited where demands are made on the material never contemplated from the foundry end, and sooner or later failure is reported. These failures, then, can hardly be attributed to the founder or the metallurgist.

London Branch.

STANDARDISATION IN MODERN FOUNDRY PRACTICE.

By M. J. Cooper, Member.

In introducing the subject of standardisation in modern foundry practice, the author realises he is speaking before, perhaps, the most critical audience in the foundry trade. Covering a number of years' experience at home and abroad, the author has observed the disregard in all foundries to standardise tools, appliances, methods, and materials in every-day use, not only in small foundries, but in comparatively large establishments. Take as an example two men working adjacent to one another occupied on the same class of work, or even on identical patterns, it is not an uncommon experience to find them using boxes of quite different size and shape, articles for ramming which have no resemblance, size, shape or weight, to the generally accepted tools for the purpose. Facing sand, the colour of which alone is positive proof that the constituent parts are not of the proportions ruling in other parts of the shop for the same class of work, apart from the more or less coal dust content or amount of moisture contained, and, most important of all in the author's opinion, the degree of density with which the moulds are rammed. Even the size, shape and position of the runner and gate employed so vary that it makes one realise the lack of system, method, or more correctly described orderliness of mind prevailing throughout the foundry world, and more surprising still that all these multifarious methods are expected to produce one result, they do, and mostly an indifferent one. Having completed the mould, again the same multiplicity of methods are employed throughout the same foundry for securing the boxes against ferro-static pressure. Weights of all irregular size and shape are employed, cramps with and without packing and wedges, slotted pins and the destructive method of wedging the pins from the side of the moulding box, all find favour within an arm's length of the point of observation. Runner bushes or cups, whose shape and dimensions seem to have been designed solely to discharge the contents of the ladle in the first stages of pouring, anywhere but down the runner, and later to convey slag and kish into the mould along with the metal. Again wrought iron gaggers or lifters, or cast-iron ones—an expensive abomination wherever they are in vogue—as is also the Scotch system of wooden sticks, or soldiers, all are often employed in conjunction in many foundries.

Many methods of time booking and time taking on jobs, mostly on the same scale of efficiency to the regular conduct of the shop, and in a charitable spirit, let us say well-meaning but unreliable. Even in many foundries that have modernised, the atmosphere of the old Bohemianism of the foundry prevails, as witnessed by the flotsam and jetsam of the engineers' scrap bin, which one finds general about the foundry. Realise, then, the difficulty of a man, either journeyman or foreman, coming from one foundry to another, each foundry having its half-hearted system, or perhaps no system at all, the difficulty to regulate his mind and his methods to the new surroundings.

It is advantageous to consider some of the many workmanlike methods and appliances in the light of standardisation. If the foundries are to standardise in their costing system, they must consequently standardise their methods and general routine, and although such standardisation of methods as applied in the motor and allied trades cannot, perhaps be accomplished in general foundry work, many branches of the trade, and many processes in the manufacture of castings and the appliances used, do adapt themselves, if not to universal standardisation, to standardisation in individual shops.

Sand Density.

The first operation calling for standardisation in foundry work is the density to which the sand comprising the mould face should be rammed, especially in green-sand work, and this is most readily accepted by the moulder who has served his apprenticeship in an almost exclusively green-sand foundry. In dry sand and loam sand the properties of the sand are ruled by the grain size and clay content, but in green-sand work executed by hand or machine it is essential to control the density in addition, to produce satisfactory results.

There is now on the market an instrument which will register the density of the mould face in a similar manner to the Brinell test. Now when some test of this nature is in general use foundrymen may begin to consider sand standards or the relative values of sands in general use with a standardised sand. It is now accepted that the most suitable sands for foundry use are those having a grain-size ranging between 60 to 100 mesh to the inch and a maximum clay-content of 12 per cent., and a density to which a sand may be rammed is governed by the percentage of grain content lower than 100 mesh and to the fineness of the clay content.

The Preparation of Facing Sand.

There is but a very small percentage of foundries, large or small, properly equipped for the proper preparation of facing sand or loam. The standard foundry or sand mill should be provided with mechanism for lifting the rollers off the bottom of the pan immediately the sand has received sufficient milling or kneading, and it is just as essential for economy in H.P. and economy in time that a variable speed gear should be fixed. The conduct of new sand when in contact with metal frequently depends on the treatment it has received before reaching the hands of the moulder. The usual sand preparing installation is in the form of a mortar grinding mill, and the choice seems to fall on the self-emptying variety, and the greater the amount of sand to be prepared, the larger the mill, and as though the strength of the material changed in proportion to the amount required, the weight of the rollers is increased with the size of the pan and vary from 5 to 25 cwts. per roller. Speeds vary from 10 revs. per minute for pans 3 ft. 6 in. dia. to 60 revs. on pans 9 ft. dia., and *vice-versa.*

Some mills are equipped with two plain-faced rollers or two cogged rollers, or, again, one plain and one cogged, and all this variation in speed, weight and design to accomplish simply the proper blending of the sand. Whether facing sand is being prepared or loam, on all these mills the speeds are constant, and with the self-emptying variety the mill goes on grinding the contents until the pan is emptied, and that operation is controlled by the condition of the scrapers which, following the low standard of foundry plant maintainance, is generally bad. Obviously part of the sand is properly mulled (or under-mulled) and the other part is overground, and unless later put through a disintegrator, the result is better imagined than described.

In the author's experience a roller with a 12 in. face, the weight should not exceed 10 cwt. and the surface speed of the pans or rollers should not exceed 150 ft. per minute, for facing sand. After passing under the rollers for a short time at full pressure the rollers should be raised and the speed accelerated just to give the mulling action without reducing the grain size, and in the case of loam, the speed may receive much greater acceleration. By this means the sand will be prepared much more quickly and with a very considerable saving in h.p. Regarding the merits of cogged and plain rollers, much will depend on the class of material being treated. For rotten rock undoubtedly the cogged roller is a great advantage for breaking down the lumps, where the sand cannot be procured in the disintegrated state. At the same time, immediately the breaking down operation is accomplished it is very obvious the surface of the roller which comes in contact with the sand is very small, and therefore has a greater crushing effect, considerably varying the grain size.

The Standardisation of Rammers.

The most important item of standardisation is the foundry rammer, the density to which sand is rammed depends entirely upon the sense of touch of the operator, and this can only be acquired when the medium used is fairly constant in dimensions and weight. In many shops balance and weight of the rammer receive no consideration whatever, any old piece of scrap iron on the end of a rod varying in diameter from ½ to ⅞ in. and in weight from 5 lbs. to 14 lbs., is allowed for the purpose of ramming, and to make it more awkward when it is not in use as a rammer it is the first article seized upon for a lever or as an adjunct in breaking up the foundry scrap. Pegging rammers for general floor work should be standard at 7 lbs., with a tolerance of 2lbs.; that is, + ¾ lbs. for heavy dry-sand work and – 1¼lbs. for light green sand, with a stale diameter of ¾ in. × 54 in. long. This is set out in Fig. 1. Flat rammers may have the same tolerance; the standard should be 9 lbs. + ¾ lbs. and – 1¼lb., the stale to be ¾ in. × 54 in. long. A rammer is much better on the light side, being more easily manipulated, and the density of ramming being accomplished by the variation in the length of the stroke, or the little extra force put into the downward blow. A flat rammer, upon which one might usefully standardise, is shown in Fig. 2.

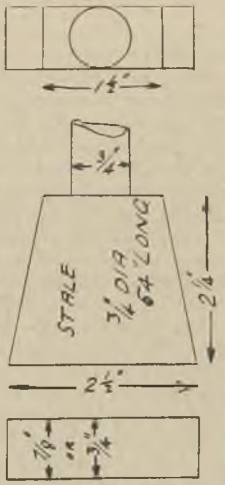


Fig. 1.—Peg Rammer.

The Design and Construction of Moulding Boxes.

There is urgent need for standardisation of moulding box equipment of all sizes, dimensions and thickness, weight for single-handed and double-handed operation, size of pins, snugs, handles and bar space.

It is quite common to see boxes 12 in. sq. × 4 in. deep and ⅝ in. and ¾ in. metal, and the author has seen boxes 4 ft. square, designed by

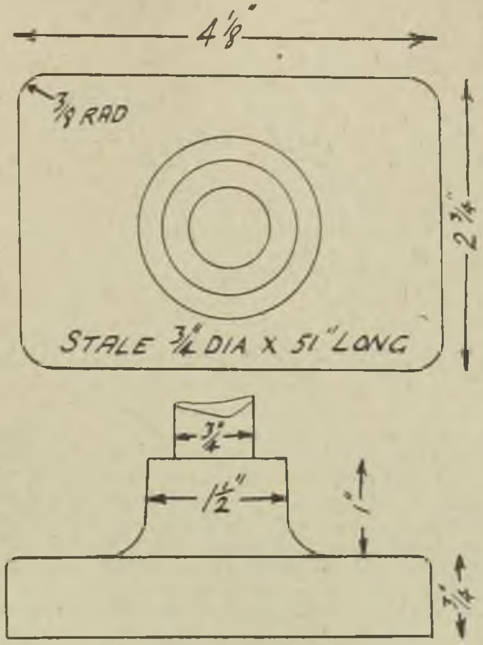


Fig. 2.—Flat Rammer.

a foreman pattern-maker in the dual capacity of foundry manager (within the last two years), for use with a jolter, with sides of 1¾-in. metal, and beyond the power of the machine to bump. It is suggested that for plate or machine work for maximum single-handed lift, the box and sand content should not exceed 1 cwt., and such boxes, say up to 20 in. × 12 in. × 4 in. deep. or 24 in.

× 10 in. × 4 in., or 16 in. × 16 in. × 4 in. deep, should not exceed $\frac{3}{16}$-in. metal with radiused corners giving equal metal throughout the box, and handles of mild steel not less than $\frac{3}{4}$ in. dia., and pins for plate work and general use, not less than $\frac{3}{4}$ in. dia. and $3\frac{1}{2}$ in. long from the shoulder, to be made of mild steel with 0.01-in. clearance on the diam. and tolerance on the lines of the "Newall" running fits, allowing a lead at the top of the pin of $\frac{1}{16}$-in. taper in $\frac{3}{4}$ in. All snug holes should be jig drilled and reamered to standard dimensions with snugs at least twice the thickness of the diam. of the pin.

For all double-handed boxes (two men) and crane boxes up to 6 ft. sq. it is advisable to have 1in. diam. register pins, with the same tolerance as the smaller pins, and on all crane boxes it is a considerable advantage to have the pins case-hardened. For deep lifts 9 in. and upwards, $\frac{1}{32}$ in. taper to 1 ft. should be allowed to within, say, $2\frac{1}{2}$ in. from the shoulder, which portion should then be parallel and have the usual 0.01-in. clearance. For double-hand boxes (two men) to be lifted about by hand when rammed, the handles should not be less than $1\frac{1}{4}$ in. diam. × 5 in. long; handles of less diameter cut into the hands at every lift and are the cause of great discomfort. Again, the handles for a double-handed lift shall be kept within reasonable limits of spread, and as near 21 in. as possible for comfortable working. On moulding boxes above the single-hand type and containing cross bars it is advisable to have four snugs, which may serve the dual purpose of taking the register pin and for clamping the box against ferro-static pressure. Cross bars should have a standard distance of 5 in. clear minimum, and may with advantage increase to 6 in. on large crane boxes, and on all composite boxes the bolt holes for securing all bars and group bars should be not less than 7-in. centres. A bar space of less than 5 in. will not allow the pegging rammer to work properly between the lifters, and flat ramming with a standard flat rammer is out of the question. Larger moulding boxes (top parts) of the crane type, in addition to having circular or radiused corners, should have the cross bars proportionately as near the same strength as the outside frame as far as possible to minimise contraction strains, and all lifting handles or lugs should pull longitudinally with the cross bars. For boxes above 6 ft. square it is desirable to have the outside frame channel section, for in addition to increasing the strength with a saving in weight, it is a great advantage when securing the boxes with cramps against ferro-static pressure.

All boxes above 6 ft. square should have the corners split with splitting plates and later fitted with another thicker plate to secure with suitable bolts.

In designing boxes of a heavier type the author favours the composite construction, that is an independent frame with bars cast in groups of three or four. This type of box possesses numerous advantages, a group of deep bars may be substituted for a group of shallow bars, or bars of special shape to suit the contour of the pattern, and wherever the class of work warrants it, provision should be made in the design of the boxes generally for bolting end and end, for instance, three 6-ft. square boxes would build a box 18 ft. × 6 ft., or two boxes would build a box 12 ft. × 6 ft., this, of course, necessitates all bolt-hole centres being made standard.

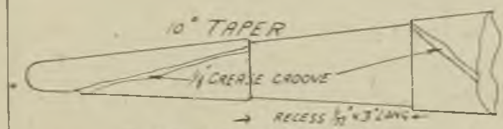


Fig. 3.—Spindle End.

Where trunnions or swivels are provided, and if cast as part of the box, these should have a suitable mild-steel chill cast through to make the metal homogeneous throughout.

Standardising the Equipment for Loam Moulding.

In the general run of spindle work, but three sizes of spindles are required, 2, 3, and 4 in. dia. These may vary in length according to the class of work produced, but the diameters cited should be strictly standard, and more important still is the adoption of a standard taper, say an included angle of approximately 10 deg. or 1 in. per ft., and the length of taper should be say 8 in., and a recess 1/32-in. deep and 3 in. long should be turned in the taper length to reduce the friction and the addition of a slightly spiral grease groove is a great advantage. This is shown in Fig. 3. Master spindles should be provided for the casting of crosses or spindle centres.

Speaking generally, very few foundries have adopted a standard taper for spindles, and the confusion and waste of time arising from this disorderly way of working is only known to those actually employed in matching a spindle and plate once they have been separated, and in the long run generally results in a new plate having to be cast. Again it is quite usual where a standard C.I. arm is not in use for spindles to vary in $\frac{1}{8}$-in. from any diameter to any diameter, consequently when the mould goes into the stove to dry, the board, the arm, and the spindle must be kept intact, otherwise the whole operation of setting the arm and the board has to be gone through again involving a considerable amount of extra work. There is almost as much variation in spindles and spindle arms as there is in rammers, and loam work, always an expensive and untidy process, is made doubly so.

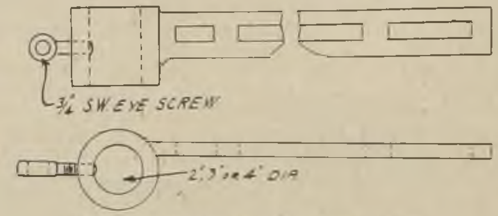


Fig. 4.—Standard Spindle Arm.

In Figs. 4 and 5 are shown varieties of spindle arms upon which standardisation is desirable.

Runner Plugs.

Runner plugs whose design promotes the very trouble for which they are employed to overcome, that is to prevent sand and dirt being carried down the runner with the first flush of metal, instead of which very frequently the face of the plug is so large that the power of suction disturbs the sand at the bottom of the runner basin upon which they repose and the displaced sand is carried down the runner and into the casting to be attributed to dirty metal, dirty moulds and eutectic excesses of all kinds. The general run of so-called runner plugs is an article of utility, they are invariably of a design like a flat rammer with a more or less flat surface 3 in. sq. or 3 in. dia. upwards. They act as occasion demands, as a runner plug, as a flat rammer, etc., but when doing its best service is used heated as a drier for redrying damp patches on cores after making up lifting hooks. The standard runner plug, submitted in Fig. 6, should follow the lines of the standard mushroom valve, but the seating should be deeper, and the included angle of the seating should be a little less than the plug.

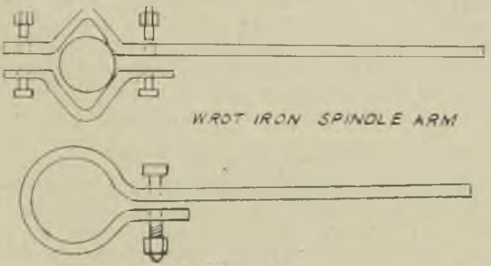


Fig. 5.

The seating may be made from a loose or separate core for a dry-sand mould, or in the case of a loam mould sufficient loam may be secured on the top plate and the seating pattern bedded in the loam and dried in position.

Skimmers.

Skimmers of all weights and sections of bar iron either too heavy comfortably to manipulate or too short and narrow to be effective are accepted as being good enough, and two or three bad castings of comparatively light weight will pay for all the new skimmer iron required in the average large shop in a year. For shank or light ladle work the most convenient section of merchant iron is 1¼ × ¼ in. and cut to 6-ft. lengths; this will allow ample to turn for the skimmer head, and a reasonable surplus for wear and tear. For skimming a crane ladle, when pouring, a ¾-in. dia. piece of rod or piping 6 ft. long to which has been welded a head in the form of a scimitar, say, 18 in. long and 3 in. deep in the blade, will trap a wide surface and adjust itself to varying sizes of ladles. Undoubtedly for skimming the slag and kish off a ladle at the cupola a standard boiler rake is difficult to improve upon.

Where individual attention cannot be given to casting small work which has to be machined and where metal is caught direct from the cupola a perforated skimming spoon is essential.

Runner Bushes or Cups.

For general jobbing, small work and plate and machine work requiring a head of metal the circular C.I. bush or cup, if properly lined or made upon a C.I. bush maker, is worth standardising, and if made in two sizes, will cover a big range of work. One, say, 4½ in. dia. × 3 in. deep, and another 5½ in. inside dia. and 4 in. deep, with a thickness of 3-16 in. to 5-16 in. taper metal, allowing a lining of ½ in. sand at the bottom and with ¼ in. at the top, and for heavier work a very useful size is rectangular shape 8 in. × 5 in. × 3½ in. deep, with a metal thickness of ¼ in. at the top and ⅜ in. at the bottom, made up on a bush maker to leave a sand lining of ¾ in. at the bottom and ½ in. at the top.

Dressing.

In very few foundries does the dresser receive any consideration in the provision of tools, generally improvising his own from anything likely lying around. The standard dresser's hammer is 1¼ lb. (a fitter's is 1½ lb.), but it must be remembered that with a lighter hammer the dresser does more than double the strokes to the minute than the fitter and maintains the speed continually throughout the day.

A dresser's standard chisel may be hexagon or oval in shape, but preferably oval, 10 in. in length and 1¾ lb. weight, hex HB across the flats and the oval ⅞ in. × 1 in.

Cupola Practice.

The standardisation of cupolas and their equipment is long overdue. There is waste of power due to high-pressure blast, small diameter supply pipes and small, badly-designed tuyeres, and ignorance in regard to volume of air passing through the cupola. Ample practical and laboratory data is available to demonstrate to the least observant what a wasteful factor in castings production the average cupola is, and in the provision of blast piping capacity it is obvious that there is not as

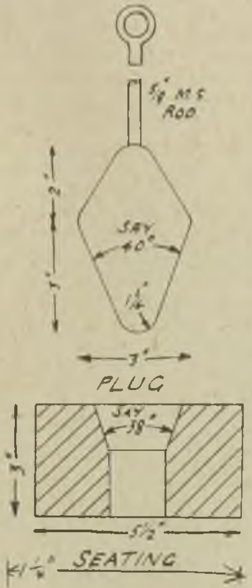


Fig. 6.—Runner Plug.

much consideration given to the matter as by the average plumber when providing rain-water pipes to house property. A deep crucible, a short body and a fan like somebody else's is the usual equipment. There is a greater leakage taking place in foundry work from careless cupola practice than in any other department of foundry work. It would be almost an utter impossibility for some foundries to produce reliable castings however high grade the materials used, and the cupola and equipment may have been quite an expensive item and supplied by firms whose name is a household word, as instance the number of years during which innumerable cupolas have been equipped with a blast-pressure gauge, an instrument which signifies nothing in regard to the essential requirements for melting, except to denote that the fan is still running. Only by the use of a volume gauge is it possible to control the standard of output. Foundries weighing coke and iron charges and measuring depth of bed before the first charge is put on and with proper supervision of backtenters, and a daily record of iron and coke consumption or castings produced per ton of metal melted are few and far between, and a few rough test pieces cast daily and observed for appearance of fracture would alone help to standardise production. Some foundries carefully weigh the iron, but not the coke; others the coke and neglect the iron, whilst still others only weigh the limestone because that is the capacity of the available scales. The author is convinced that a good material result in 75 per cent. of British foundries is the outcome of accident, and the comparisons of metal melted and castings produced would disclose the excessive amount of metal wasted in heads and runners.

The Standard Foundry Crane.

The type of electrical crane in use in the machine shops when placed in a foundry can only be described as a makeshift, and is as much a foundry tool as a mortar grinder is to a sandmill, and lacks many desirable features of the old hand jib crane. A creeping gear is an essential feature to every motion of a foundry crane, and unless possessing this feature, is a very destructive agent and a constant source of danger. The prevailing type of crane in foundry use, functions by a series of jumps and jerks at every operation, with the result that register pins are bent, snugs broken, and the time spent in many foundries in repairing broken moulds through bad lifts would alone pay for proper lifting equipment in a matter of months. At casting time the amount of scrap made about the floor through the difficulty of crane manipulation and castings spoiled through runnerbox displacement amounts to a considerable item in the course of a year.

Standardisation of Foundry Accessories and Materials.

Lack of proper standardisation in foundry practice is most keenly felt by the foundryman in the supply of raw materials and accessories. There is very urgent need for a standard to be established in the properties of coal dust, blacking, plumbago and coregum.

Quite a lot of the coal dust supplied is totally unsuitable for the purpose of mixing with moulding sand, and in many cases would be better left out—irregularity of grain size, amount of ash and sulphur content being some of the many bad qualities. Plumbago is so highly adulterated and of so coarse a texture that it just defeats the very purpose it is supposed to fulfil, and during recent years it is no uncommon thing to see the top surface of a casting grained like a cloud, the result of the plumbago having washed from the bottom surface and sides of the mould, while ordinary blacking is just a mass of volatile matter not having even the properties of common soot. The author has frequently used coregum that, when mixed with water, has immediately settled in the form of sand, and whose glueing properties were useless. All this sort of thing causes irregularity in consumption and introduces waste not only in materials, but is a very frequent source of continuous waster castings and serious worry to the user.

DISCUSSION.

Cast-Iron or Mild-Steel Gaggers.

The Branch-President, opening the discussion, said there was room for standardisation, and he was in agreement with Mr. Cooper on quite a number of the points. Without wishing to embark upon a course of destructive criticism, there were one or two points he wished to refer to. In the first place, he had had a fair experience of cast-iron gaggers, and was inclined to disagree with Mr. Cooper's contention that they were expensive. In the case of a fair-sized chill, for instance, anybody could put a spare drop of metal in as they were passing, in the form of a cast-iron gagger, and the cost was practically nil. Cast-iron hooks had a short life, due to breakages, but they all went back to the cupola without serious loss. If common iron or mild steel were used for making gaggers, there was the cost of bending. Certainly those gaggers had a much longer life than those made of cast iron, but, altogether, he believed that on balance the cast-iron gaggers would be the less expensive.

Testing Mould Hardness.

Referring to the instrument mentioned for testing the density of the mould face on the lines of the Brinell test, he said he had seen the instrument demonstrated, and could not agree that it would be very useful in a foundry. In the first place, with such an instrument one could not test the whole of an intricate mould. Obviously, the purpose of the instrument was to test the hardness of the mould, with a view to preventing scabbing, but in intricate moulds there were bound to be places which would easily scab, and which could not be tested with the instrument mentioned, although it could be used on square or cylindrical moulds, but in a well regulated shop one would hardly expect to see much scabbing in such moulds.

The Over-milling of Sand.

The Branch-President also disagreed with the author's remarks as to the effects of the over-milling of sand. Some time ago a paper had been read before the London Branch by Major Rhydderch, who was a prominent man so far as the investigation of sand was concerned. He himself had asked on that occasion what was the effect of over-milling the sand in a mould, how far it reduced the grain size and resulted in silt. The author of the paper had replied that he had tested sand which had been badly over-milled, and had been surprised to find that there was practically no reduction in grain size.

Standardising Rammers.

Another point on which the Branch-President differed with Mr. Cooper was that of the standardisation of rammers. It was his experience that, though rammers might be standardised, no two men used those rammers alike, and the human element was all-important. A man with a medium-sized rammer would do just as much work, and probably more, than a man with a large rammer. He did not mean that he would permit a man to use a small rammer with no head at all, but he did not consider that standardisation of rammers was essential, in view of the great extent to which the human element entered into the matter. One could ram quite well with the feet in some cases.

Moulding Boxes.

As to moulding boxes, and the author's recommendation for a thickness—he presumed he meant cast-iron boxes—of 5-16 in., up to the size of 20 in. × 12 in. × 4 in., he pointed out that the human element also entered into that question, and he would be very dubious as to the life of such boxes in the foundry to-day, particularly if they were put into the stove many times. In advocating the use of a thicker box, he did not suggest that it should be, say, 1 in. thick, but 5-16 in. did appear to be too thin. It was a very difficult matter to get what he called the old type of foundry labourer on whom one could depend to do his bit in the best possible manner. One had to put up with quite a mixed assortment, due to economic factors, and he would not care to trust a few of them to handle boxes 5-16 in. thick. He should think that a box of the size mentioned should be at least another $\frac{1}{4}$ in. thicker.

Mr. V. C. Faulkner thought that the Branch-President had failed to realise that the lecturer had put forward the statements in his paper in a tentative spirit. He did not think the author wished to be arbitrary, otherwise he would not have adopted the title he had, and his intention had been rather to establish a basis for discussion, in which particular he had succeeded. Referring to the machine for registering the density of the mould face, on the lines of the Brinell test, he said there were two such machines on the European market, one of which was capable of dealing with more or less restricted places.

Standardised Spindles.

He did not know whether the members were aware of the fact, but on the French market there were standardised spindles, though he had never heard of them on the English market. One must bear in mind that if some of these elementary things could be standardised, they could be turned out on a large scale by one foundry, and they would come into the moulder's hands at a price lower than that at which the moulder could make them himself. Home-made articles of this type were dearer than those bought outside, when one considered the time spent on them by the various foremen and managers. Foundry people often showed him with pride the articles they had made for themselves, but he had often wished that he could get hold of the true costs of those things. When speaking of blackings, the author had suggested that one might get an increased sulphur content in the finished casting. If one made a mathematical calculation, however, he believed it would be found that the sulphur increase would not be worth while worrying about. Before the war he had written to every manufacturer of graphites and blackings that he could find, and had analysed their products. Some of those products carried as much as 50 per cent. of ash, but since that time he was pleased to note real progress had been made, but there was room for standardisation.

Thin Boxes are Relatively Stronger.

With regard to the Branch-President's suggestion that the moulding boxes referred to by Mr. Cooper were too thin, he reminded him that, in the ordinary way, the thinner the cast iron the stronger it became, and increased weight did not always mean increased strength. In thanking Mr. Cooper for his paper, he said that he himself, as a metallurgist, had enjoyed it immensely.

Wastage in Gaggers.

Mr. Cooper, replying to the Branch-President, said his experience of cast-iron gaggers was that one was always out of the size required. The gaggers became broken, they were laid about in the sand and constantly dug up, and the life for a lifter was about three days. In his opinion it paid to use the best iron for making gaggers, and to have a standard size for the foot and a standard size for the top. Again, the cast iron deteriorated very much, and if it were thrown back into the cupola it could only be used for the roughest of work, as it was covered with sand, clay-wash and dirt. One foundry he knew of, in which there were eight jobbing moulders on the floor, used cast-iron gaggers, and every day two men were making gaggers from the time the cupola was started until it was stopped. Those gaggers were considered of so little importance, and so easily made, that they did not attempt to get them out of the boxes, but simply chopped them off and made fresh ones. He would not say they would not have lasted longer, however.

Mould Hardness Tester as Basis for Comparison.

Different foundries used different sands, and each sand called for a different degree of hardness in ramming. A man starting in a fresh foundry might point out that they were ramming too hard, or too soft, but if such a machine were in use it could be demonstrated that a certain registration was used throughout that foundry for moulds of certain depths, and it would settle the question at once.

Sand Mills as Power Wasters.

As to the milling of sand, he asserted that the sand could be destroyed, but what he had in mind was not so much the destruction of the sand, but the point that there was no necessity for driving big weights of rollers round. Since he had written the paper he had seen a catalogue, in which he had noticed that the surface speeds varied from 150 ft. up to 400 ft. for exactly the same size of mill. The heavier the roller the higher the surface speed, in some instances, whilst in other cases as the roller became heavier the surface speed decreased. It showed what a considerable amount of horse-power was being used in one instance as compared with another to accomplish the same object.

He did not agree that every man preferred his own weight of rammer, but it was far better to have a standard, and to use the same weight always for a particular class of work. He agreed with the Branch-President that one could ram with the feet, but when ramming with the feet one had a bigger surface contact than when using a rammer, and one did not ram so hard with the feet. As to the thickness of moulding boxes, he had seen boxes ¼ in. thick which had been used for twenty years, and were still being used. They were used by the old Brook's Sewing Machine Company. With such a light box one could get far more work done. The boxes he had referred to were never put into the stove.

Mr. J. Ellis (Past-President of the Institute), whilst agreeing as to the undoubted importance of standardisation, and thanking Mr. Cooper for his paper, with much of which he agreed, was disappointed that nothing had been said about the standardisation of the moulder, because very much that was in the paper was of no use until the moulder was standardised. As Mr. Cooper had said, one man could ram a large bed plate quite well with a shovel handle and a flat rammer, but another man with the same tackle, assuming that to be the standard, would make a waster. Standardisation of the moulder, however, was impossible. The quality of the metal used had a great bearing on the thickness of moulding boxes. With some metal one could make boxes 1½ in. thick, and they would not stand up to the work. Recently he had seen the stays of boxes 14 ft. long, 8 in. deep and ½ in. thick, and they had been used for many years, but were made of the very best cold blast iron. Speaking of gaggers, he said that cast-iron hooks had an advantage. For instance, they were far more rigid than in wrought iron, but the expense was greater.

Moulding Box Pins.

The moulding box pin question was a very vexed one. Some twenty years ago it was discussed, and all sorts of arguments were used. Some wanted square pins, some elliptical, others wanted cotter holes, others wanted screw pins. Whilst some said that the clamp was the best to hold the mould down others preferred weights. The human element entered into the question very largely, but he believed that the very best method to-day, especially for repetition work, was a standardised hole in both top and bottom, and a master pin. Perhaps one or two dozen pins would suffice for the needs of a foundry. The pins and holes were the same size, there were no lap joints, and there was no danger of the pins getting knocked, worn and broken. With regard to skimming with a piece of tubing, that could be extremely dangerous, and he had seen the metal shot right through the tube and out the other end. He liked the sketch of the runner plug in Fig. 6, because the ordinary type sometimes caused a great splash, and often somebody got burned. There were some things which could not be standardised, because of the human element, but there were many which could be standardised, and the members of the Branch would come to the conclusion that those matters were well worth considering.

Standardisation and Costing.

Mr. H. O. Slater (Past Branch-President) said he believed the day had arrived when even the employers were really interesting themselves, not only in the product of the foundry, but in the troubles connected with the design of tackle in the foundry—and quite rightly too. In many engineering concerns the equipment and design of the machine shops, pattern shops, and so on, were more than adequate, but the foundry was poked away in the most miserable corner of the whole concern. To-day, however, they were beginning to feel the necessity for proper production to meet the needs of the machine shops, and in that was largely bound up the question of cost. Some years ago the Institute had tackled the question of costs in the foundry, and the propaganda which had been carried on in that connection had had a great effect upon the trade. In the past the foundry had been regarded as almost a necessary evil. They had been asked to quote for castings per pound, and the employer, sometimes lacking the essential knowledge of costs in a foundry, had not known exactly what a particular casting would cost him. He would quote for an intricate casting at the same price as for a straightforward and easier job, and later the foreman would be blamed because costs were high. Costs and standardisation of equipment were largely bound up one with the other. In a foundry which he had visited he had noticed cupolas the workmanship in which was of the best that could have been put into the material, but the design, from a practical foundryman's point of view, was positively ridiculous, and manifested the danger of employing anybody other than a foundryman to design the most essential detail of the foundry. The foundry foreman was very often blamed for defective work, whereas it was due entirely to the bad design of the tools supplied by other people for his use. Speaking of gaggers of cast iron, he said that an arrangement consisting of a plate with two lugs at opposite corners and the trunnion in the centre, was very useful. It had eliminated a good deal of trouble during the war, and he had always had a good supply of hooks. He agreed that in a deep cod cast-iron gaggers were far superior to wrought iron, and in the case of steel work he very much favoured cast iron.

Jobbing Foundries Can Pay.

Mr. L. Tibbenham said that the standardisation of the moulder was hardly possible, but with the present moulding machines the founder did get standard moulds and standard castings. A few days ago he had been concerned with the making of two castings, one to fit inside the other, without any machining whatever. They had been made from a plate pattern, and they came together very well. Without thinking anything about it, he had put the plate on the moulding machine. Several hundreds of these castings were being made, and when they were fitted together it was found that they were very slack. That was a very serious thing, but if they had used the moulding machine from the beginning they would have had a standard casting. Mr. Cooper had rather frightened him when he had mentioned all the troubles that he had seen in the foundry, and he himself, as an employer, would be very embarrassed if he saw all those things happening in his own foundry. It would not be possible to allow such things to go on in a jobbing foundry. He had to quote competitive prices, and if he had no system of costing, as Mr. Slater appeared to think was the case, he would not make any profits, but, as a matter of fact, he did make profits as a jobbing founder.

Difficulties of Standardisation Stressed.

Mr. M. E. Gallon (Past-President of the Newcastle Branch of the Institute) said there could be no hard and fast rule with regard to the density of sand, and, no matter what instruments were used, one man would make a mould harder than another. There was a peculiar touch which had to be acquired in dealing with sand, and it was only acquired by long experience, and if the man who was ramming, whether he used a large or a small rammer, did not understand his job, there would be trouble sooner or later. There was a good deal of unnecessary milling of sand, and he had cast jobs weighing up to 24 cwts. in green sand, which had not been into the mill at all, but was just mixed up by shovel. Speaking of the standardisation of the central pin in the socket, he said that every foundry standardised in its own way to suit its requirements, and no hard and fast rule could be laid down. In his own foundry they had probably half a dozen or more centres, which could be used for any job, and they all fitted a certain size of pin, 2½ in., 2 in. or 1¾ in., as the case might be. No matter how far standardisation was carried, the same result could not be obtained every time in a foundry, because of the human element.

Can the Skilled Moulder be Replaced ?

The Branch-President, discussing the standardisation of the moulder, said the fact must not be lost sight of that distinct efforts were being made in that direction to-day, and a uniform system was being worked in the south-east of England for the training of apprentices to a definite standard. One recognised, of course, that the psychology of the moulder, and the human element as it was generally understood, could not be standardised. So far as he could see, those concerned were training a fair number of men for executive positions, but he was inclined to agree with Mr. Slater that, if there should be a trade boom, as we all hoped, there would be a deficiency of skilled men in the foundries. The standardisation of costing methods had its disadvantages as well as its advantages, and there was a danger of excessive standardisation. He had had experience of foundries, in which it had been the custom to ascertain the costs to within four points of a penny per lb. of castings, and, because of that detailed costing, the foundry was not allowed to have moulding boxes and other tackle, whereas, if those concerned had not been so fully aware of the cost involved, they would have provided for good tackle.

A Modern Conception of Industrial Needs.

Mr. J. W. Gardom pointed out that if there was no costing at all in foundries, however crude it might be, there would be no foundries. It was not necessary to go into minute details in foundry costing, and it was probable that the foundry management did not know the exact cost of certain small jobs, because it was not worth while going into it, but they knew the costs of the bigger jobs they turned out. With regard to the training of moulders, he was of opinion that the question was being discussed from the wrong point of view. It was advisable to grow with the times. To illustrate his point, he said that at one time Messrs. Lucas produced the best oil lamp for bicycles. If that firm had decided to make nothing but oil lamps, and to train men to make those lamps, they would not be in business to-day. If we could not produce sufficient skilled moulders, or could not interest sufficient men to become skilled moulders, was it not better to face the fact, and train men who did know something about the way the job should be done, so that when the boom came—and it was coming fast—their services could be augmented with those of unskilled men, whom they could train for the work? The same thing had happened in the Army, where the men who had enlisted during the war were trained by the N.C.O.'s.

Standardised Tackle Augments National Foundry Wealth.

Mr. V. C. Faulkner said that, generally speaking, he had been disappointed with the discussion, because it had been so destructive. Speakers had said that we could not do this and could not do that, and had drawn attention to the human element. but Mr. Gardom, in exhorting foundrymen to see what they could do under present conditions, had guided the discussion into the right lines. But for the fact that the Annual Conference was to be held in London, and the London Branch was very busy, a committee might usefully have been set up to deal with standardisation. If that committee did not agree with the rammer suggested by Mr. Cooper, let them suggest an alternative, or have three standard rammers if such could cover the ground. The same remarks applied to boxes. Although there were a large number of types of cast-iron boxes in use, he believed it was possible to produce a thoroughly good design which would cover the major requirements of the trade. There could be a standard drawing, and from it a standard box would be bought on the open market at a standard price, whereas at present, if one went to a foundry sale, one could not buy boxes, because they were not suitable for one's work. There was a great deal, therefore, in what Mr. Cooper had said.

Necessity of Skilled Men Emphasised.

Mr. H. O. Slater disagreed with the idea which Mr. Gardom had propounded with regard to the training of the moulder. What he himself wanted to point out was the necessity for having available really trained practical foundrymen, who could take over the management of the foundry, on the practical side and the commercial side. He himself had been trained as a soldier in a fortnight, but one could not train a moulder in a fortnight. It was necessary to have thoroughly trained men available, so that they could be employed at the right time, because if they were not available, national wealth was lost.

Cardinal Points Sought.

Mr. Gardom said Mr. Slater had missed the point that what the foundry had to do was to sell castings and make a profit. It did not matter whether the man who made those castings was a really trained man, or whether he was an unskilled man under the supervision of the technical man. Mr. Slater would say that the only factor in the making of a casting was the moulder, but as a fact he was only a part of it.

Mr. Slater said he was the most essential part.

Mr. Gardom disagreed, and said that the iron was the most important factor. (Laughter.)

Points Cleared Up.

The Branch-President was inclined to think that both Mr. Slater and Mr. Gallon had missed Mr. Gardom's point. All that Mr. Gardom was suggesting was that, if we could not get skilled men, we should adapt ourselves to the circumstances, and get over the difficulty by using machines, and in other ways. These difficulties had had to be overcome before. Whilst he agreed as to the necessity for skilled men, he wanted to point out—it was not a conclusion arrived at on the spur of the moment, but as the result of his experience over a period of years—that to-day, in spite of the slump in trade, there were more skilled men employed in the foundries than there were 25 years ago, although that period had seen the introduction of machines, and the various economic difficulties that had arisen had had to be overcome. The demand for skilled men could not be reduced with the introduction of better methods of production, because, with the march of progress, there arose a demand for other things which necessitated the employment of skilled men, and their number would increase rather than decrease.

Box Pins.

Mr. Cooper, replying to Mr. Tibbenham, said that, necessarily, all the faults he had referred to did not occur in the one foundry, but in a number of different foundries. He had no doubt, however, that if Mr. Tibbenham had several sizes of moulding boxes in operation in his foundry, 2 ft. sq., 1 ft. sq., and so on, they all required different sizes of pins. It would not be unusual to find that state of affairs in a foundry. There was no doubt that the use of loose pins, as suggested by Mr. Ellis, was the best system of all.

In reply to Mr. Gallon, he said he had not suggested that gaggers should be cut out altogether, but that the founder should have a standard, and use either all cast-iron or all wrought-iron gaggers. The question of whether or not a mould was hard enough was always a debatable point, but if the instrument for recording sand face hardness were used—and it would be adopted—it would do away with all the discussion and argument which now took place. He agreed with Mr. Gallon's remarks as to the milling of green sand. For the greater part of his early life in the foundry he had been concerned with green sand work for both heavy and light castings, and the sand was not milled because it did not need it. It was in its natural state as regards texture and grain size, and only required milling when used for bench work.

Splitting Up the Moulder's Trade.

On the controversial subject of the standardisation of moulders, his idea would be to train rammers, finishers and closers in all foundries. There was nothing new in that principle. As the engineering trade had developed the workers had split up into fitters, millers, drillers, and so on. The glass bottle trade had been split up years ago. The foundry trade would have to come to that, and there were men in the foundries at present who did nothing but finish and close. When he had spoken of the training of the moulders and the standardisation of the rammers, the idea he had had at the back of his mind was that the wage earner to-day was not taking any interest in the business; it was not his life-work, in the sense that it was in earlier times, but was merely a means of earning a living. No man to-day made it his life's work, as did the craftsman of earlier days, who was not content to finish at 5.30 p.m. The same remarks applied to the employer. There were very few men like Henry Ford, and the employer looked forward to finishing his work and leaving himself free for his golf, his evenings out, and so on. After all, that was quite natural.

Mr. R. J. Shaw, proposing a vote of thanks to Mr. Cooper for his paper, said that he had not discussed the paper because in his own foundry 75 per cent. of the suggestions made by Mr. Cooper were carried out. A question which had not been mentioned, however, was that of the splitting of boxes at the corners. Heavy boxes, when they had been used about twice, split at the corners, and it was difficult to patch them up sufficiently strong to be quite safe, but he thought the method indicated by the lecturer an excellent way of getting over the contraction strains which caused the fracture. He understood that what was done was to core a slot out of the corner forming a flange on the inside of the side of the box, and afterwards fill the slot with packing and bolt the side flange and the end of the box up. He himself put a round core in the boxes, but he had known heavy boxes, with a great many bars in the top part, and which one could not prevent cracking.

Mr. J. W. Dunn, who seconded, pointed out that standardisation was very difficult in a jobbing foundry, where in one day one had to cast a hydraulic cylinder, a few machinery castings, then fire-bars and buffer plates, and finally bed blocks. In such a foundry, running 20 tons of metal a day, with instructions from the management that nobody was to be in the shop after 5 o'clock, standardisation was difficult.

The vote of thanks was accorded with acclamation.

Mr. Cooper, responding, said that many people had not even thought about many of the things referred to in the paper, and much could be done in the direction of standardisation. One could not have standardisation, however, unless one was prepared to pay for it. In his view there was more room for standardisation in the jobbing foundry than in any other, because it was the lack of standardisation in the jobbing foundry which was responsible for the ridiculous prices quoted to-day. There was no system in such foundries, and the purpose of his paper was to urge the trade to get down to some standard system of working.

Birmingham, Coventry and West Midlands Branch.

RECURRING FOUNDRY PROBLEMS.

By D. Wilkinson, Member.

The art of founding has been described as making a hole in sand and filling it with molten metal. For brevity, this definition has much to commend it; and if its accuracy were commensurate with its brevity, the title of this Paper would never have arisen.

The object of the founder is to produce a metal article of a predetermined shape which shall be of a uniform composition and solidity. His difficulties and problems arise from the high temperatures at which he has to manipulate the metal he uses. In preparing the metal, transferring it to the mould, and cooling it to the normal temperature, many conditions arise which militate against uniformity of composition and solidity; and to control these conditions adequately requires a care and forethought that can only be realised by daily contact with them.

It may be well to commence by defining the qualities required in the castings produced. It is desired to produce castings which shall be uniform in composition and solidity. By a casting of uniform solidity is meant one which is definitely free from internal voids. To define uniform composition is not quite so easy. It can hardly be said that every part of a casting shall consist of the same material, since cast iron is made up of constituents which vary widely in their composition and properties. So it may be said that every part of the casting should consist of the same proportions of the various constituents which make up the cast iron in use.

It is quite safe to say that with the present foundry and metallurgical knowledge it is not possible to take a pattern, and from it to produce one hundred castings which shall be identical in every respect. If anyone thinks differently, let him try the experiment, and at the end he will be a wiser man. The conditions of success are so elusive that, despite the closest control, variations will slip in. Not all the variations that occur destroy the utility of a casting; but we are all too well acquainted with undesired results that prevent a casting fulfilling the purpose for which it was made.

When variations arising from carelessness or from want of skill arise the remedy is obvious and needs no discussion. But when defects of this class are completely eliminated, there remains an irregular proportion of variations which constitute a problem taxing the highest skill and knowledge. The present Paper is a contribution to the study of this problem.

It will be noticed the word variation is used rather than defect. The reason for this is that any departure from a complete uniformity is to be avoided as far as possible. The aim of the founder should be to secure a product which can be relied upon to function in an entirely satisfactory manner. It should not be considered sufficient to produce a casting which is just sufficiently good for its purpose. It is desirable to produce castings which will function, not up to their own limiting strength, but up to the limiting strength of the material from which they are made. As foundry craftsmanship, metallurgical knowledge and designing ability develop, so will the reliability of castings increase, and foundrymen must always keep before them the ideal of reproducing in their work all the best qualities of the material they use. Only along this line can real advance be made.

As it is an open question where foundry troubles, and the resulting problems, really commence, we will begin by considering the pouring of the metal into the mould. It is not proposed to take account of evils arising from the entrainment of air, carrying of slag into the casting, or the partial breaking of the mould by the weight of the iron, as these things can readily be prevented. But when good iron is properly cast into a sound mould, actions and reactions occur which are not yet fully under the control of the founder.

Typical Reactions.

In a green sand mould there is always a certain amount of surface erosion due to the heat and motion of the molten iron. If the mould is carefully made, the amount of material abraded as a fine dust may be small, but it will certainly be present. As the surface of the mould is dried by the molten metal, the generated steam is decomposed by the iron, forming hydrogen gas and magnetic oxide of iron.

$$4H_2O + 3Fe = Fe_3O_4 + 4H_2.$$

The gas burns at the joints and vents of the mould, but the oxide remains behind in the metal. As the oxide is carried up by the iron there is the possibility of further reaction between it and silicon and carbide of iron, forming in the one case silica or ferrous silicate and in the other carbon dioxide, or probably a mixture of oxides of carbon.

$$Si_2 + Fe_3O_4 = 2SiO_2 + 3Fe.$$

The reaction will most probably go further and ferrous silicate will be formed:—

$$2Si_2 + 3Fe_3O_4 = 4FeSiO_3 + 5Fe.$$

Occasionally, ferrous silicate formed in this manner may be mistaken for slag carried by the metal from the ladle.

In a small mould these reactions may be so limited that they can be ignored with safety; but their effect in a medium or heavy casting may be attended with serious results. As these lighter bodies float on the rising surface of the iron they agglomerate into large masses which, by design or by good fortune, may be carried into the risers; or they may adhere to the side of the mould, or be caught under a core or a projection of the mould, or come to rest in some eddy of the liquid metal and be covered and remain hidden as the mould fills.

Flat upper surfaces of heavy castings frequently show traces of this scum or scoria. Irregularities in the skin of the upper surface are seen; and if these parts are machined, patches of so-called "dirt" are revealed, which even when they are not directly harmful, detract from the appearance of the casting.

Troubles from Scum Inclusions.

Most foundrymen are able to recall some large and expensive casting which, when taken from the mould, appeared to be perfect; so much so that it was a pleasure to look over it; but which upon machining was found to contain in some unexpected place a patch or mass of scoria which completely ruined it. In the writer's opinion quite a number of defects which have been ascribed to liquid contraction or to gas action, would be found, upon careful examination, to be due to this cause.

There is no difficulty in observing the formation of this scoria or scum. Most open sand castings will provide very good examples. In engineering establishments use is frequently made of bars of cast iron of various diameters. The writer has regularly been called upon to supply these articles in all diameters up to eight or ten inches. The larger sizes are usually cast in green sand, with a bottom runner, cut tangentially. The riser used is about 75 per cent. of the diameter of the bar and about 25 per cent. of its depth. Invariably, as these bars are cast, a mass of scum may be seen to form in the centre of the whirling metal, finally coming up the riser right out of the casting. It would be cheaper to make these bars with an open top and pour the metal directly into them; and when this is done, a bar may frequently be made which shows no trace of scum on its surface. But metal cut from these bars sometimes has expensive machining operations done upon it; and it is the writer's experience that a bar cast with a bottom tangential runner, and a riser that will allow the scum to be floated right out of the casting, yields an article which gives greater satisfaction to the machinist and reduces trouble to a minimum.

To remove these scoria-forming materials from the casting, or to prevent their agglomeration into masses of serious dimensions is sometimes very difficult. As in the bars just instanced, it may be possible by a definite arrangement of runners and risers to lift or wash out of the casting either the whole or a portion of the scoria. Or, again, it may be possible to arrange the gates so that the scoria may be broken up and its collection into dangerous masses or places prevented.

But it is hardly possible, in a casting of more than a small size, entirely to prevent its formation. As a last resort it may be necessary to dry the mould to minimise the trouble; as in a well-blacked and thoroughly-dried mould the abrasion of the mould by the metal, and the reactions between the metal and steam and its products will be reduced to a minimum.

When the mould is filled with metal, other agencies begin their work. Again, all defects arising from irregular ramming, imperfect venting, or over-damp sand, are omitted, as these are easily preventible, and should not occur.

Blow-hole Defects.

On machining the upper surface of a casting one sometimes finds a number of small rounded holes which are quite smooth and which seem to have resulted from bubbles of gas in the metal. Frequently traces of scoria are intermingled with these bubble-holes. Badly-melted, oxidised metal is a prolific source of this trouble; but cases frequently occur in which this explanation does not satisfy a thoughtful founder, anxious to arrive at a correct understanding of the cause of the defect. When a number of castings are poured from one ladle, and some are found to contain this defect while others are free from it, to look for the cause in the cupola practice does not seem quite the proper action to take.

Sulphur is frequently selected as the culprit; but this explanation can hardly be considered satisfactory. Well-made malleable castings may contain up to 0.4 per cent. of sulphur and yet be quite sound and free from this defect; so it is difficult to see how, say, 0.15 per cent. sulphur should cause it when 0.4 per cent. does not. Moreover, no reaction between ferrous or manganese sulphides and the usual constituents of molten iron can be conceived which will liberate a gas as one of its products.

Entrained-air may be one of the causes. If the runner bush is allowed to empty itself when the mould is nearly filled, it is quite possible the injector action of the metal falling down the partially uncovered gate may draw in a quantity of air, some of which will be retained unless the metal is fluid enough to allow it to escape.

But there is no doubt in the writer's mind that the reaction between the oxide of iron formed during casting and carbide of iron present is the usual cause of this trouble. It is difficult to see how this reaction and consequent liberation of gas can be avoided in any casting of medium weight which takes more than a few seconds to pour. The gases burning at the vents is complete evidence of the formation of oxide in the casting; and the secondary reducing reaction can hardly be prevented. It is safe to assume that when the mould is filled with metal, any further oxide formed will remain in contact with the mould and will not enter into the casting. Oxide already in the metal, if reduced by carbide of iron will liberate oxides of carbon, which will rise through the molten metal. Provided the metal is hot enough to prevent the immediate formation of a skin where it lies against the top of the mould, these gases will escape and all will be well. But if the metal happens to be cool, a skin may form before the reaction is completed, and then the gases will be retained immediately under the surface of the casting to be exposed on machining.

Importance of Magnetic Oxide Reaction.

It is on account of the formation within the mould of magnetic oxide of iron (Fe_3O_4) and its subsequent reduction, partially by carbide of iron with the liberation of oxides of carbon, that the foundry axiom of pouring hot to secure a clean casting has arisen. With hot metal, the secondary reaction is completed before the skin of the casting is frozen against the mould and so the gas bubbles escape. Also, with a highly heated iron, although more oxide may be initially formed, its reduction will be more complete; and its complete removal and the escape of the resulting gases yields a sounder casting.

It will be noticed that the defects arising from these reactions are similar to the defects arising from metal oxidised during melting. This metal will contain ferrous oxide, FeO; and its reaction with carbide of iron will yield gaseous oxides of carbon exactly as the Fe_3O_4 does. But the two causes are quite distinct; and it is certainly unwise not to differentiate between the causes, even if the results are identical.

After the mould has been successfully filled with clean, hot iron, some of the more recondite foundry troubles begin. It is not an easy matter correctly to visualise the behaviour of cast iron during solidification. Considering the variety of castings made in the average foundry, the variables introduced into the problem of solidification approach infinity. But certain broad principles are recognisable, and if these can be grasped and the variables grouped around them, the problem will be simplified.

Solidification Voids.

Interesting though the subject is, it is not proposed in this Paper to deal with the metallography of cooling cast iron, but space will be occupied in considering the foundry, rather than the laboratory, aspect of the matter. The formation of voids in the metal during solidification, is the chief concern.

Internal voids, or cavities, which are not due to mould or core disturbances, are usually called "draws" by most founders, and are considered due to contraction. A distinction is frequently drawn between liquid and solid contraction. While it is convenient to assume this distinction, it does not indicate a difference. The action is the same; but in the one case it concerns molten, and in the other frozen metal. Of recent years the action of occluded and dissolved gases in the formation of internal cavities has been studied; and much evidence of the action of these gases has been adduced. The opinion seems to be gaining ground that they are responsible for most, if not all, the internal cavities not due to cores or moulds.

It has for some time been the writer's opinion that the effect of occluded and dissolved gases in cast iron has been considerably over-rated. If, in properly melted metal, occluded and dissolved gases can give rise to serious defects, it would appear impossible to make sound castings from cupola metal. It is sometimes said that perfectly sound castings do not exist; but the writer cannot agree to this. Castings are made in large numbers which are so thin in section, so extensively machined and so carefully tested, that it is impossible any internal unsoundness should escape detection. It is not claimed that 100 per cent. of the castings made are perfectly sound; but it is definitely stated that the machining, testing, and inspection to which many types of castings are subjected, is so extensive and severe, that those which survive and go into service can be guaranteed free from internal unsoundness.

If, then, it is possible to produce castings free from internal unsoundness, the action of gases in properly melted cast iron must either be negligible or very easily controlled. Which of these alternatives is correct?

Occluded Gas Unimportant.

Occluded gases as a direct cause of cavities may be dismissed. An occluded gas is one which is dissolved by a metal on melting and retained on solidification. If the definition is correct, this part of the question settles itself. The metal contains the gases when molten; but it also contains them when solid. They may be extracted from the cold metal in considerable volume by suitable treatment; but they are not liberated by solidification.

A metal, however, may hold gases in solution while molten and eject them upon cooling. If a small piece of silver is melted, withdrawn from the furnace and allowed to cool in air, as the surface solidifies the gases dissolved in the metal will break through the skin, carrying a portion of the still liquid interior with them. Usually this ejected metal adheres to the button of silver: but sometimes the evolution of gas is so violent that a portion of silver will be thrown some little distance.

Nothing like this ever occurs during the solidification of good cast iron when poured into a good mould. The writer has fed, and watched the feeding, of so many castings that he can categorically state that well-melted cast iron does not normally eject gases upon solidification. If there is any gas ebullition from a feeder, a riser or a runner, it can invariably be traced to cause other than the metal.

An easy experiment will prove this, if proof be needed. Let a clean, thoroughly-heated shank be taken, filled with molten iron and set down to cool. The closest observation will not perceive any liberation of gas during the whole time of freezing.

The cavity-forming action of gases initially present in the iron is secondary, not primary; and if the primary actions are prevented secondary gas action cannot occur. The action of occluded gases is not negligible, but is easily controlled. The primary cause of cooling voids is inefficient feeding during contraction.

Solidification Action Analysed.

Consider the solidification of two plain castings: one an open sand plate, 2 ft. sq. and 1 in. thick, and the other a block 2 ft. cube. It is common knowledge that the plate will contract much more than the cube. The reason for the reduced contraction in the cube is also common knowledge. Assuming the larger casting loses heat uniformly, there will be a time in its solidification when a skin some inches in thickness will enclose a still liquid interior. This liquid interior will evidently exert a tremendous opposition to the contraction of the skin, and this opposition will be reinforced by the expansion which occurs as the metal steadily freezes. The opposition of these forces having prevented the normal contraction of the skin of the casting, it is evident that as the liquid interior freezes and is reduced in volume the skin will not be able to follow it up, and so a void or voids will inevitably occur. As these voids form out of contact with the atmosphere, a vacuum would exist in them were it not that occluded gases are liberated under the influence of heat and reduced pressure. So that as the voids form they are filled with gases liberated from occlusion in the solidified skin or solution in the liquid interior.

It has been assumed that the cube of iron measuring 2 ft. each way has been cooling uniformly on each surface, but it is known that in a casting of this size cooling cannot be uniform. The plate, 1 in. thick, will be still liquid in the middle when the corners and edges are frozen, and when these have cooled to a black heat the middle will still retain its redness. There will be a somewhat similar want of uniformity in the cooling of the cube. The edges and corners will cool more rapidly than the sides, and owing to the upward flow of heat the top will cool more slowly than the sides. If the mould is filled with uniformly heated metal—that is, so filled that no "hot spots" are formed, and no riser is provided—one will inevitably find a large depression on the upper surface sloping down to an internal cavity. The contraction voids will have been partly filled up by molten metal from the middle of the top surface.

If the metal is poured through a single large side-runner, still without providing a riser, the resulting cavity will take a different form. The passage of the whole of the metal over one part of the mould will superheat that part, and this superheat, added to the actual heat of the metal in the heavy runner, will form a "hot spot" that will take part in the feeding of the contraction void. It may probably be found that the top of the casting is flat and apparently solid; but there will be an internal cavity directly communicating with the gate. The contraction void will have been partially filled up with metal from the "hot spot."

In each case it is probable that during the formation and partial feeding of the voids reduced pressures will have liberated gases from the metal, and these gases may have left traces of their passages out of the casting. But the point to be borne in mind is that it is not the gases that have made the void, but the void that has liberated the gases.

Again, if the casting is poured in such a manner that the formation of a "hot spot" is prevented, it is provided with an efficient feeding head, and the contraction is followed up with an adequate supply of hot metal. If this is done no argument is needed to prove that a sound casting, free from contraction voids, will be secured. Moreover, during the whole period of solidification, there will not have occurred the slightest evidence of gas ejectment from the metal. The difference in texture between the middle and the outside of castings of this nature is not concerned with the formation of cooling voids, but with grain growth and graphite formation.

Hot Spots.

The term "hot spot" has been mentioned as bearing upon the question of solidity. By a "hot spot" is meant a part of a casting which does not cool at the same rate as the adjoining parts. This retarded cooling may be due to several causes. Where a large quantity of metal flows over one place, as in a single gate on a large casting, the heating of the sand may retard the cooling of the metal and form a hot spot. By dividing up the gate, or by locating it on a thin part of the casting, the extra heat given up to the sand can usually be dissipated before the casting solidifies. Frequently, especially in castings of medium weight and varying section, hot spots are found to develop not so much by the flow of metal as by obstructed radiation during solidification.

Before putting a pattern into work it is a good thing to consider how the flow of metal in the mould will affect its cooling and which parts are likely to retain the heat longest, since these parts will give most trouble. The drawing of isothermal lines will greatly assist in settling the relative speeds of solidification, but the accurate drawing of these lines on any but the simplest forms of casting is a matter of some little difficulty. It is much easier to draw radiation lines. These lines will show with certainty the relative speed of solidification, and much information can often be obtained from them.

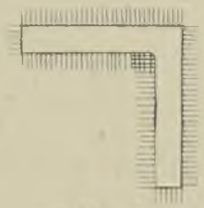


FIG. 1.

Take the end elevation of an ordinary angle plate (Fig. 1) as an easy example, and draw short lines at right angles to its surfaces. Wherever these lines are open, cooling will be rapid. Where they cross, cooling will be retarded and the metal will remain liquid for a longer period than in the other parts of the casting. It will be noticed they cross at the re-entrant angle on the underside of the angle plate, and here, retarded cooling will form a hot spot as the casting solidifies. These lines may be considered to represent the paths along which heat will be radiated from the casting.

Drawing radiation lines of this character and from them locating hot spots not due to gate action, has provided for the writer an adequate explanation of a type of drawhole for which, for a long time, he could not satisfactorily account. In small- and medium-sized castings of irregular shape one sometimes finds drawholes running upward into the heavier parts. The point in question was why a drawhole should form against the force of gravity. It is easy to understand that metal may feed downwards from a hot spot, or riser, into a contraction void, but it is not so easy to understand why a drawhole should form upwards into the casting. The angle-plate just mentioned will sometimes provide cavities of this nature in the re-entrant angle.

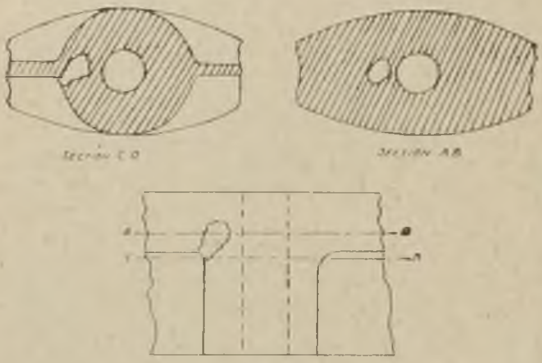


Fig. 2.

The question arose with the writer during the early days of his apprenticeship. A considerable number of castings weighing about 10 lbs. each were on order, and the trial castings all contained a drawhole on the lower side of a flange. The part of the casting affected is shown in the sketches (Fig. 2). The defect was easily removed by increasing the fillets in the angles and altering the shape and location of the gate. But the question why the void should form against gravity remained, and occasionally cropped up again with other castings, and it was some years before an explanation was arrived at that satisfied every point.

The defect under consideration could not be due to a badly-vented core, since it did not communicate with the cored hole; and many other instances were noted in castings which were not cored. Blowing from the mould did not satisfy the objection that the hole was evidently formed when the casting was on the point of complete solidification, as otherwise it would have gone right through to the top. If the hole was formed by mould gases when the casting was almost solid, what had become of the metal which originally filled the hole? That defects of this character are formed while the metal is freezing is proved by the presence of dendrites, or fir-tree crystallites, which can usually be found in their interior.

Diagnosis by Isothermal Lines.

While studying the cooling of masses of metal it occurred to the writer to draw heat radiation lines from the surfaces of the masses being studied, to assist in drawing isothermal lines of correct contour. Afterwards applying these lines to a casting in which a drawhole similar to the one under discussion had occurred, showed that three sets of radiation lines met in the angle. Evidently there would be considerable interference with the radiation of heat during cooling, and a hot spot would be formed as the metal began to solidify. A little further thought provided a solution which completely satisfied every objection. The metal in the casting under examination, as was also the case in the casting shown in Fig. 2, was a common phosphoric iron with a rather lengthy freezing range. Without doubt, a contraction void had formed in the top flange near the hot spot, and into the vacuum thus made occluded gases had been liberated. The high temperature at which these gases existed had given them considerable pressure, and they were able to force their way downward through the semi-molten metal in the hot spot, driving the still molten portion behind them into the void, where it solidified, while they escaped into the mould. In this way a "draw hole" is formed against the force of gravity.

In defects of this character it is not a case of mould gases blowing into the metal, but of occluded gases, liberated into a contraction void, blowing through the semi-molten metal of a hot spot into the mould.

Hot spots formed by retarded cooling during solidification are sometimes partly responsible for a very different form of defect. An example will assist us in forming an opinion. The sectional sketch of a monobloc shows a fault which it is thought is not entirely unknown to makers of these castings.

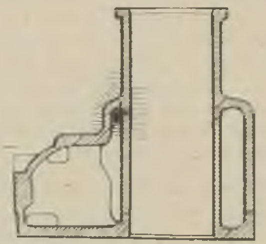


Fig. 3.

A sectional casting (Fig. 3) containing this fault was here exhibited. The defect which varies in extent in different castings occurs about half-way down the barrel near the junction of the water jacket. At times it is revealed as a distinct hole after machining. Occasionally it forms a slightly porous place which leaks under water test. Sometimes the casting may pass the water test without a trace of a leak, but examination under a strong light shows a small discoloured patch on the machined surface. The sectioned casting did not leak when water-tested, but the discoloration was visible when it was examined under an electric light.

It is the writer's experience that this defect, however slight it may be, always leads to the immediate rejection of the casting, and the inspection staff seems to be very well acquainted with the place at which it occurs.

The defect has been ascribed to blowing from the core, due to imperfect venting. It has also been ascribed to segregation resulting from the increased section at the junction of the jacket and barrel. These explanations never satisfied the writer, as they did not account for the fact that when the defect was slight it always occurred below the thickest part of the junction and immediately below the top of the jacket. It would appear that if the defect were due to segregation it should be located in the thicker section instead of below it. If due to blowing from the core, again it would appear the defect should show in the thicker section, or even in the jacket itself.

Segregation as Cause Discounted.

Once more the drawing of radiation lines led the way to a solution which satisfied the objections to previous reasons. Examination of the radiation lines shows that in the upper thin part of the jacket core they converge and cross to an extent that indicates the formation of a hot spot as the casting solidifies. It will also be seen that this hot spot will be located, not where the jacket joins the barrel, but immediately below it, exactly where the defect occurs. Evidently there is a connection between the defect and the hot spot.

Granting the existence of a hot spot, where the metal will remain semi-liquid for a few moments after the adjoining parts have solidified, why should it be defective? A careful examination brings the conviction that segregation is not the cause. Even when the defect is so slight that no leak will occur, the action of gas can hardly be doubted; and when the defect is large enough to show up clearly, the passage of gas is obvious. Why should the core—which is an oil-sand one—give off gas into the metal when the temperature had fallen so much that the greater part of the casting had solidified, if it did not do this while all the metal was molten and at a higher temperature? It is quite evident the defect did not form until the jacket and its junction with the barrel were solid, as these parts are quite sound;

and had they been still liquid the gas would have passed into them.

The main vent of the jacket core passes within about 1¼ in. of this defect; and as the main vent in a core of this description is usually made as large as possible, it is not entirely a question of venting. It can be seen that it is rather difficult thoroughly to evaporate and oxidise the binder in the thicker sections of the core without burning the thinner sections; and if the oxidation is not complete, in every part, the heating up of the core by the metal on casting will give rise to an excessive internal gas pressure as the oxidation of the binder is completed. It will also be seen the pressure will not be greatest immediately on casting, but will increase as the heat penetrates into the thicker sections where the binder is still partially unoxidised. As the casting solidifies, the ferrostatic pressure on the hot spot will be reduced; and if the pressure at this point falls below the pressure of gas in the body of the core, then gases, in addition to passing out of the vent, will also pass into the part of the metal which is still liquid.

This, the writer considers, is the explanation of the defect under consideration; and it suggests its own remedy; a thorough oxidation of the binder used in the core.

A hot spot, we may safely conclude, is always a potential source of trouble; and so should be carefully watched. It is not always easy to locate these points and to prevent them giving rise to defects, but a few general principles may assist in minimising their effects.

The gate should be located as far away as possible from any place where retarded radiation can occur. Gas pressures should always be prevented in these places. The grade of sand and the ramming of the mould should be carefully watched; remembering that the denser the mould the more difficult it will be for heat to radiate.

Chills Suggested as Remedy.

An alteration to the contour of the pattern, where possible, will often remove the difficulty; not merely covering it, but curing it completely. Thorough venting frequently provides a remedy. In this case the venting serves a double purpose.

Not only does it relieve gas pressure, but it provides an easier path along which heat can radiate. Take the case of the angle plate mentioned above. (Fig. 1.) If a slot could be made through the bottom of the mould to within a quarter of an inch of the re-entrant angle, it is evident the cooling of this part would be hastened considerably. In a minor degree, venting on to a hot spot acts in the same way as a slot. Failing other measures, a chill, or densener, will provide an effective remedy.

Needless to say no claim is made that foundry problems have been dealt with in an exhaustive manner. The subject is already vast in extent: and as research opens up new fields it continually extends. But it was considered better to confine the scope of the Paper and handle a few of the problems at some little length rather than discursively touch upon many. Foundry practice is filled with problems of the deepest interest: and when the worrying side of these problems can be overcome, thought expended on their solution is abundantly repaid by the satisfaction that accrues from a consciousness of work well done.

DISCUSSION.

Mr. F. H. Hurren, referring to cooling, asked Mr. Wilkinson if he had ever had a similar experience to the following. "You cast," said Mr. Hurren, "say a dozen or eighteen castings of a particular pattern on a day. They are all machine-moulded, the cores, as far as one can tell are made by similar methods, the coring-up is similar so far as humanly possible, the temperature of the metal which is poured into the mould is the same, and yet one is porous and the others are all sound. The porosity is not in the ordinary nature of a draw; it is simply a patch of black and spongy metal which will not stand up to the water test."

Mr. J. V. Murray thanked Mr. Wilkinson for his practical Paper, and said that although he did not quite agree with some of his conclusions a strong case had been made out which might prove to be correct. Mr. Wilkinson had gone a long way towards proving the connection between the defect and the hot spot. It was his (the speaker's) opinion that as the metal froze it pushed certain impurities towards the centre. Although Mr. Wilkinson ruled out segregation there was no doubt it was occurring between the crystals.

The Chairman (Mr. A. Harley) said the Paper illustrated the fact that foundrymen nowadays had to exercise very minute observation of defects and scientific theories had to be found to account for them. The more numerous such papers were, and the more information was available, the more certain they were to arrive at the real cause of defects. If the constitution of cast iron were simplified they would avoid most of the troubles in cooling down, as well as contraction difficulties and draws. When they considered the structure of cast iron and its many constituents, all with different melting points, it was easy to understand why they experienced so many difficulties with castings. With regard to phosphorus it was the pretty general practice to keep the phosphorus very low. By keeping down the phosphorus in cylinders they practically eliminated all troubles from draws occurring through inequalities of section.

Mr. Wilkinson, in replying to the discussion, said he would be the last man in the world to say that sand did not cause defects, because he knew to his sorrow that it did. But in the case mentioned in the Paper he did not think it was so. It was not the case of the gas flowing up to the spot exactly, because the pressure was even throughout the whole body except in the immediate vicinity of the vents. He was glad to know that on the whole his hearers thought the theories he had advanced were tenable.

On the motion of Mr. Hurren, seconded by the Chairman, a hearty vote of thanks was accorded to Mr. Wilkinson.

Mr. D. H. Wood, in proposing a vote of thanks to the Chairman for presiding, expressed regret that there were not more Birmingham members present and also that Coventry was not better represented.

Mr. Lane seconded the motion, which was endorsed by the meeting.

Sheffield and East Midlands Branches

(JOINT MEETING).

LIFTING AND SHIFTING APPLIANCES IN FOUNDRIES.

By H. H. Moore, Member.

The wise man, long ago, said, "*Where there is no vision the people perish,*" and this wisdom applies to the foundry industry as well as to more general forms of activity, so, in planning new foundries, or making changes in old ones, let us look ahead, and see where economies can be effected and production increased. Of course, the old plant in some of our foundries works, but it is slow and inefficient; it eats up the cost of itself year after year, because somebody will not see the losses or will not have the courage to consign it to the scrap heap.

It has been stated in recently published reports by prominent foundry engineers in the United States of America that in one automobile foundry some 69 tons of material are moved once for each ton of castings produced. In another automobile foundry 55 tons of material and equipment are moved to each ton of finished castings—and that in a bath-tub foundry 137 tons of material are handled for each ton of castings produced. A large jobbing foundry in the U.S.A., it is stated, handles 200 tons of material for each ton of castings that get to the despatch department.

The Foundry Trade Journal of January 22, 1925, in a leader on the same subject, entitled "Where Can the Maximum Economy in Foundry Practice be Effected?" mentions "that the manufacture of one ton of grey iron castings involves handling 168 tons of material, and that probably in a malleable ironfoundry this figure would reach well over 200 tons," and it is rightly suggested that "the efficient and economical handling of these materials offers a very profitable field of investigation for every foundryman."

A very interesting analysis covering the handling of castings in a brass foundry, given in the form of a Paper presented to the American Foundrymen's Association by Mr. T. C. Flinn, was published in THE FOUNDRY TRADE JOURNAL of October 27, 1925, and is well worth careful perusal, as it shows that in a brass foundry having a total output of some 2,500 lbs. of castings per day, 152 tons of material are handled to produce 1 ton of castings.

There appears to be a considerable discrepancy in the figures mentioned, but, again, Mr. J. M. Primrose, of Falkirk, a valued member of the Institute, reading a Paper† some time last year on "The Conveyance of Material in the Foundry" (with special reference to the production of light castings), stated that in a light castings foundry melting 30 tons per day the material handled is, in round figures, 255 tons, made up of:—5 tons coke; 30 tons pig and scrap; 10 tons new milled facing sand; 30 tons of molten metal; about 10 tons gates and runners, and 20 tons of castings.

And allowing 1 ton of sand per moulder (which he says is understated), say some 70 tons of sand, handled twice, the total stated is reached. Mr. Primrose says "eliminate some of the time in handling parts of this bulk, and a rise in the output of castings should soon be observed; the work done by the unskilled man in this foundry (if there is such a person) means 105 tons, comprising coke, pig-iron and scrap, milled sand, molten metal, gates and castings, and it should not be difficult to invent some system which will at least materially reduce the non-productive labour."

The whole subject warrants careful attention and serious consideration, for while some foundries in this country are well equipped for the handling of materials, yet the majority have yet much to do in the way of necessary labour saving, speeding up, and cost cutting appliances.

For any operation in handling of materials several methods of performance are sure to be found, and one will be found better than another for certain reasons, and less desirable for certain other reasons. At this point then the mind must

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† FOUNDRY TRADE JOURNAL, February 26, 1925, page 188.

consider other things than the operation itself, such as its relation to previous and subsequent operations, and its suitability for the particular requirements of the work, its period of usefulness, and so on, and, what is very important, the financial return on the investment.

The tendency of the age is towards the conservation of the natural resources of the world, and in handling of materials to the conservation of labour effort.

When labour is high priced the necessity for apparatus is increased, and decides that machinery is necessary, where, if suitable labour can be secured, the operation would be performed by hand more cheaply than by plant adopted.

Frequently it will be found in the handling of material that the advantage of reducing the physical effort is not only an economic advantage in that it directly reduces costs, but also that it reduces the number of men needed, and brings their work within the physical power for human effort. A man may lift 100 lbs., but he cannot do it all day long.

Work must be really interesting before men will continue to do it well, so in securing handling economies the wise will avoid the necessity of handling operations wherever possible, and solve the individual cases thus reduced in number by the means that will keep down the labour effort and save the money in operating costs.

The way to handle material cheaply is to avoid handling it at all, if such a state of things were possible.

Whatever device is used in the foundry for lifting and shifting, the following two elementary principles should be borne in mind:—(1) In handling material carry out only the operations that are absolutely necessary; and (2) perform these operations in the way that secures the lowest cost.

A large dredging contract in a harbour in China, let us say Hong Kong, was to be let some years ago. As hydraulic dredges are most economical, and usually do such work for the lowest cost, a representative of a large dredging company, realising there were very few, if any, large dredgers in China, thought that he could underbid, and secure a valuable contract. On arrival at Hong Kong, however, he found that he was right, for there were no hydraulic dredges to bid against him. He had a fine one available, but he found also, to his chagrin, that coolie labour was so cheap that a coolie could carry the earth out of the excavation in baskets on his head at so low a cost per yard that it was more economical to drive piles around the earth, pump out the water, and carry the mud by coolie labour.

It is needless to say that the work was done by coolie labour, and that was the most economical method under the existing conditions, but such a state of things hardly exists to-day; this illustration will force on one's mind the fact that the device that is most economical in handling material at one place, and under one sort of condition of labour and environment, may not be the most economical in another place. This fact should always be borne in mind, for it is of vital importance.

But under any set of circumstances there is a rule that applies to all handling problems, and one that can be depended on to aid the mind in selecting a good workable plan. It is in general terms nevertheless of great value, as all plans can be tested by applying its principles. This rule can be stated as follows:—The material under operation should follow a direct route, from receipt or start on to final shipment or despatch, with as few retrograde movements as possible, and the articles being made or manufactured should go directly from operation to operation, or stage to stage, without rehandling.

Commencing with the cupola, pig-iron and coke are mainly man-handled, first from the truck, finally on to the charging platform, and thence to the cupola. There are many methods of charging in use, but worthy of note is a method originated in the U.S.A. in which the stockyard overhead travelling crane links up with an inside overhead traveller running over the charging platform, the yard crane and the charging platform crane, both travelling for their respective work on their respective gantries, but both being of the transporter type, namely, each carrying a single joist, so that by means of a system of automatic stops the cranes

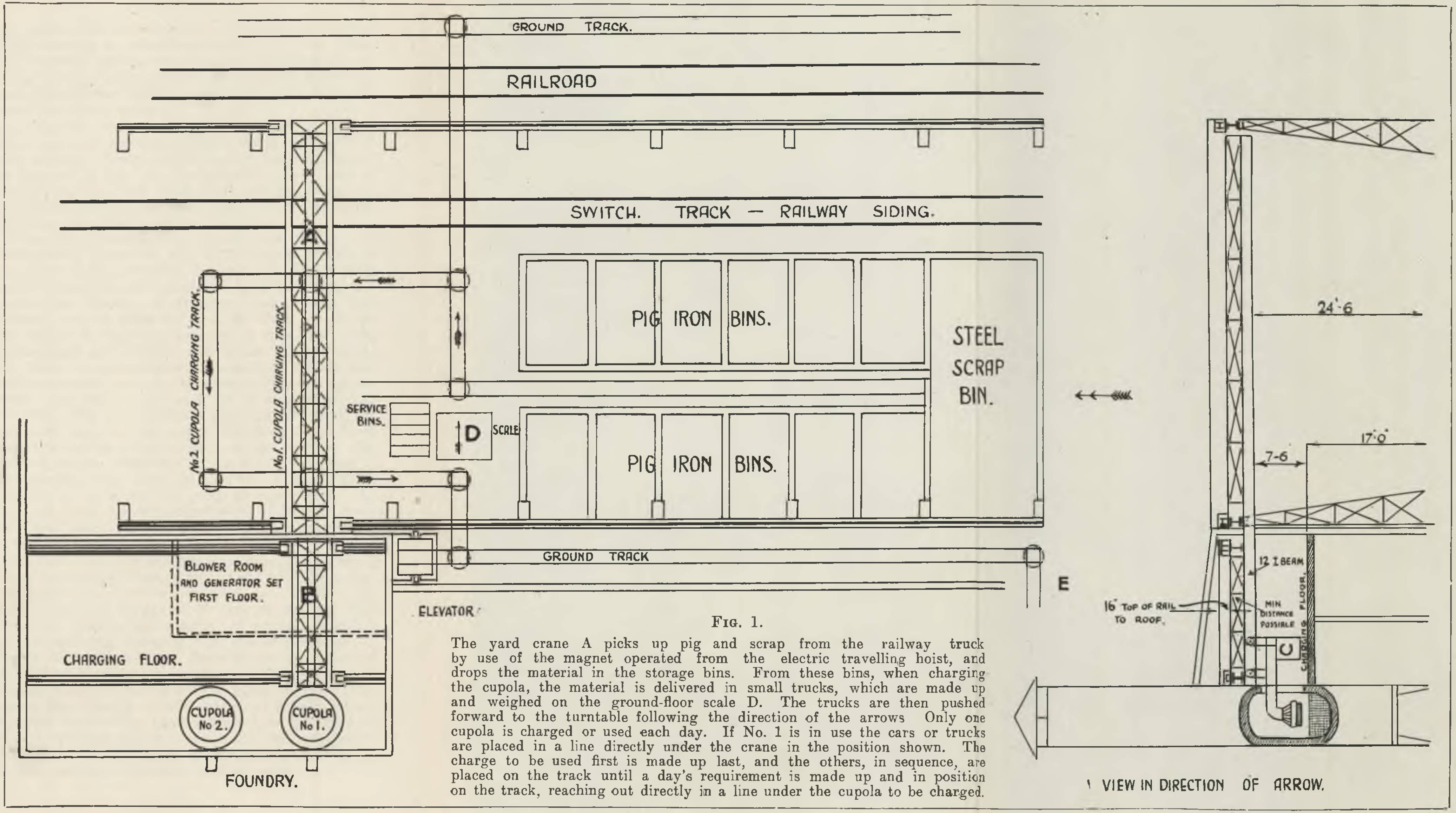


Fig. 1.

The yard crane A picks up pig and scrap from the railway truck by use of the magnet operated from the electric travelling hoist, and drops the material in the storage bins. From these bins, when charging the cupola, the material is delivered in small trucks, which are made up and weighed on the ground-floor scale D. The trucks are then pushed forward to the turntable following the direction of the arrows Only one cupola is charged or used each day. If No. 1 is in use the cars or trucks are placed in a line directly under the crane in the position shown. The charge to be used first is made up last, and the others, in sequence, are placed on the track until a day's requirement is made up and in position on the track, reaching out directly in a line under the cupola to be charged.

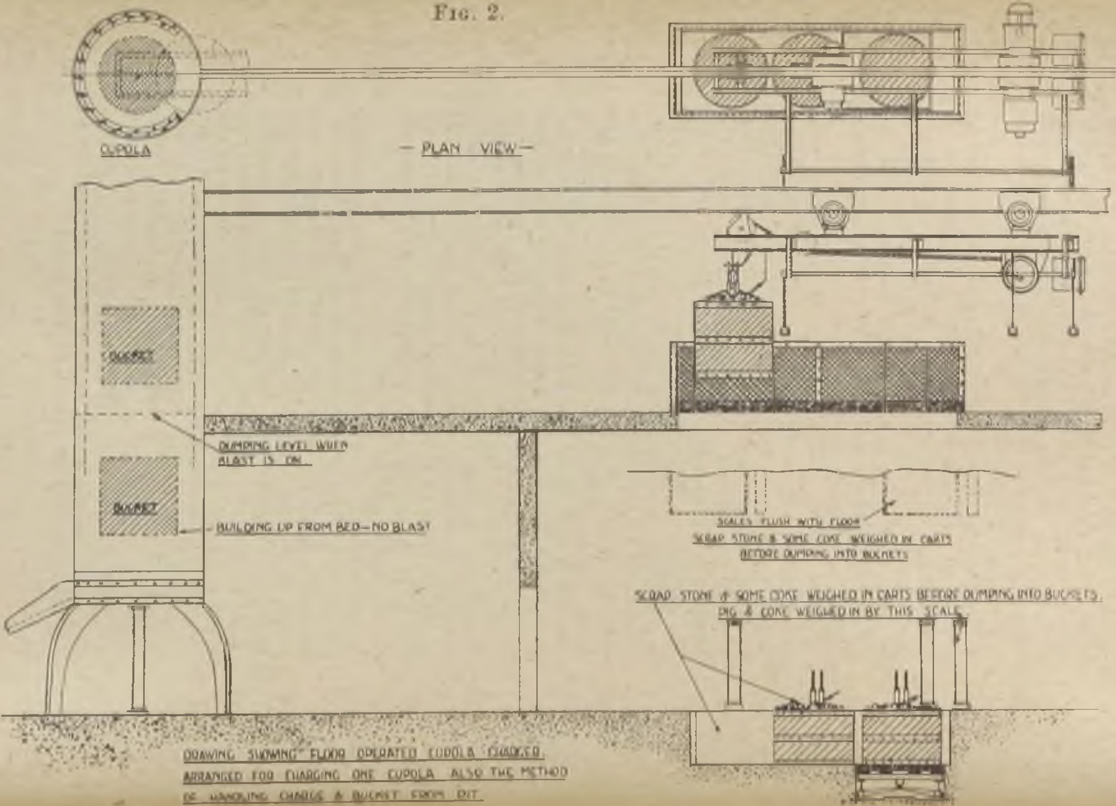
can lock up in one line, and an electric travelling hoist running on the bottom flange of the joists can be used right across the two, or separately on either crane, for the efficient handling of materials from the railway truck to the yard, and from the yard into the cupola.

The outside crane in Fig. 1 (see folder) is used to unload all raw materials, either with a magnet or grab bucket. It serves also to make up the charges on suitable trucks on the ground track, and is used in conjunction with the inside crane to deliver the material directly from the ground track trucks to the inside of the cupola.

When the ground-track trucks are filled, and arranged as shown in Fig. 1, the cycle of charging operations is started by running the electric hoist or charger out along the outside crane, the magnet or bucket is dropped down, and the material, either coke or iron, is lifted up to its full height, so that the suspending rope and cable is sheathed well within the frame of the hoist. The hook on the magnet is sheathed within the cantilever arm, so that swinging or damage to the hoist rope whilst the arm is in the cupola is avoided. The E.T. hoist is then run forward off the yard crane to the inside charging crane, and along until the coke bucket, or the iron on the magnet, as the case may be, is inside the cupola. The charge is then dropped, and the charging hoist returns to complete the cycle of operations. It is stated that by this method some 15 tons of iron, etc., per hour is easily handled from the ground to the inside of the furnace.

The labour-saving feature of this arrangement is shown by a comparison with the old hand practice, formerly 24 men were required to handle the material for an output of 80 tons of iron per day from one cupola, this number of course, covering all the yard and charging floor labour necessary to handle all material from the railway truck to the storage piles, from the piles, or storage, to the ground track trucks, and from these trucks to the cupola (not merely cupola charging) making three separate lifts of the same material, or 240 tons in all. At present six men can make up and charge the required material to obtain the production of 80 tons per day of metal at the spout.

FIG. 2.


CUPOLA
— PLAN VIEW —
BUCKET
BUCKET
DUMPING LEVEL WHEN BLAST IS ON.
BUILDING UP FROM BED—NO BLAST
SCALES FLUSH WITH FLOOR
SCRAP STONE & SOME COKE WEIGHED IN CARTS BEFORE DUMPING INTO BUCKETS
SCRAP STONE & SOME COKE WEIGHED IN CARTS BEFORE DUMPING INTO BUCKETS. PIG & COKE WEIGHED IN BY THIS SCALE.
DRAWING SHOWING FLOOR OPERATED CUPOLA CHARGER ARRANGED FOR CHARGING ONE CUPOLA ALSO THE METHOD OF HANDLING CHARGE & BUCKET FROM PIT

Coke is handled from the charging floor, or from the ground, as may be desired; a novel bucket, with a holding capacity of 400 to 600 pounds of coke, is set down by the coke storage, and filled by forking the coke into it. This coke bucket is transferred to the cupola by use of the magnet which is dropped over the bucket, and depresses the hinged lid, this throws the hooks forward, which engage the top of the magnet, and the bucket can be lifted without fear of its being disengaged until the hoist runs it into the cupola, when a pull of a hook disengages a latch, which allows the bottom of the bucket to drop ten inches on a central rod, and distribute the coke evenly; the bucket is then run out and put to work again, the action of the bottom touching the floor or ground being sufficient to close it up again. Now this system may seem only suitable for large outputs, but it certainly opens one's eyes to what might be done on a smaller scale for even medium size foundries, with very economical results.

Another system, somewhat similar to the one just mentioned, and shown on Figs. 2 and 3, which describe even simpler schemes than the one outlined in Fig. 1. Of course the electric hoist can in either case be used also with the skull-cracker for breaking up scrap.

Self-acting chargers, operating from the ground floor are now more in evidence, and take the filled trucks, carry them up an inclined conveyor, and deliver the charges directly into the cupola, and they seem to have much greater possibilities for the smaller foundry.

The fourth scheme, Fig. 4, is one used to advantage in this country, and is, in the author's opinion, a very good one where melting is going on practically continuously, and overcomes the rehandling to a good extent. It uses two overhead runways, the lower one being operated either by hand, or an electric hoist, and the upper one being preferably of the electric type, but in this scheme, charges can be pre-arranged on the ground, or on the charging platform, as best suits the conditions obtaining; in either case tipping skips are used, charges made up on the ground, or ground floor, weighed in the skip, and transferred by the electric hoist from the lower runway to the upper runway, where the charging can be done direct into the cupola in a very simple manner.

(Here some 40 views were shown of cranes and lifting gear of interest to the foundry trade.)

Electric Cranes.

Electric cranes are so well known that little need be said, but a Paper* recently read by Mr. Daniel Adamson is well worth perusal. Electric cranes are indispensable, and a foundry not properly equipped with its full quota cannot be efficient. Foundrymen buying cranes should be most careful to get "foundry cranes" with proper creeping control, or otherwise they will lose a great advantage.

With regard to the type of hand-pulley blocks, and ruling out the type of block coming under the heading of differential in its varieties, it can be said that the geared self-sustaining hoist, or pulley block, operated by hand, still holds the field as the most economical device up to about 50 ft. of lifting and lowering per hour, above this amount an electric or other power-driven hoist is the more economical.

Fig. 5 shows the total operating cost of various types of lifting machinery, in pence, per hour, for a given number of feet of lifting and lowering per hour accomplished. The example is taken for 1-ton loads, and includes interest and depreciation. This diagram has been plotted for a hoisting mechanism pure and simple.

In the case of cranes where the proportional costs of hand and power cranes is less, the power crane becomes economical much sooner, and it may be taken as a rough and ready rule that where the amount of lifting and lowering per hour exceeds 10 to 15 ft., it is wise to compare total operating costs with a view to deciding the most economical type to be employed. The greater the tonnage to be lifted, the sooner does a power crane become the best investment.

Fig. 6 illustrates the range of economy of various types of lifting mechanism under various conditions. In general, while a plant is being served by a lifting gear, the plant is at rest or partially so. Consequently, standing charges of many kinds are proceeding without useful work being done to pay

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* Manchester Association of Engineers.

these charges. The spaces between the curves show the range of economy of the several types for various values of standing charges proceeding. It will be seen that as the standing charges increase the range of economy for the less speedy lifting mechanism decreases.

One dominant fact is brought out by these curves, and that is:—*It is the very worst possible policy, particularly in hand-lifting machinery, to instal any other than a high-efficiency machine.* These curves compare normal working costs only, and do not make allowance for the decreased safety and liability to breakdown, so very often found in the less efficient and badly made cheap type of lifting gear.

Sand Handling.

In general foundries where no automatic sand preparing and conveying system is in use, the electric overhead runway (or when suitable the hand overhead runway) can be arranged to good advantage for delivering new milled sand, or taking out shaken out sand by means of electric travelling hoists, and automatically-operated grab, or tip-buckets, and some foundry managers of high repute rely upon this system. Many good examples of this method of sand transportation from the sand plant to any point required in the foundry, as also to feed special storage hoppers serving the core departments and light foundry, using in conjunction with electric travelling hoist a grab of the combined hand and self dumping type arranged for discharge when suspended by means of hand operation, or cord, or automatically, can be found in use in this country.

Battery Trucks.

The electric battery truck, as a locomotive alone, for hauling trailers, with fixed or lifting platform. is a good distance-hauling medium for the periodic movement of unit loads, and serves its purpose well for traffic between buildings some distance apart, and when moving material of a character not adapted to the fixed conveyor economies, its use is dictated for widespread distribution to many points, great variety of materials, or where the movement is too light to support the larger fixed equipment. For comparatively long movements,

FOUNDRY COSTS FOR ONE MONTH, 1925.

Weight of good castings made.				Metal cost.						Direct wages.				Oncosts.				Total cost.
T.	C.	Q.	Lbs.	T.	C.	Q.	£	s.	d.	Class.	£	s.	d.		£	s.	d.	
93	2	1	20	130	12	1	580	15	3	Moulding	310	9	7	Melting	119	3	3	
				Less shop Scrap						Coremaking	58	11	1½	Dressing	82	4	5½	
				30	2	2	124	5	3									
93	2	1	20				456	10	0		369	0	8½		201	7	8½	

ONCOSTS.

A.—Indirect Labour.

	£	s.	d.
(1) Supervision in Foundry	16	16	0
(2) General labouring in foundry			
(3) Sand preparation for moulders	57	5	10
(4) Pouring labourers			
(5) Shop cleaning			
(6) Test bar experiments			
(7) Pattern store keeper	14	14	3
(8) Maintenance—plant and patterns	8	14	0

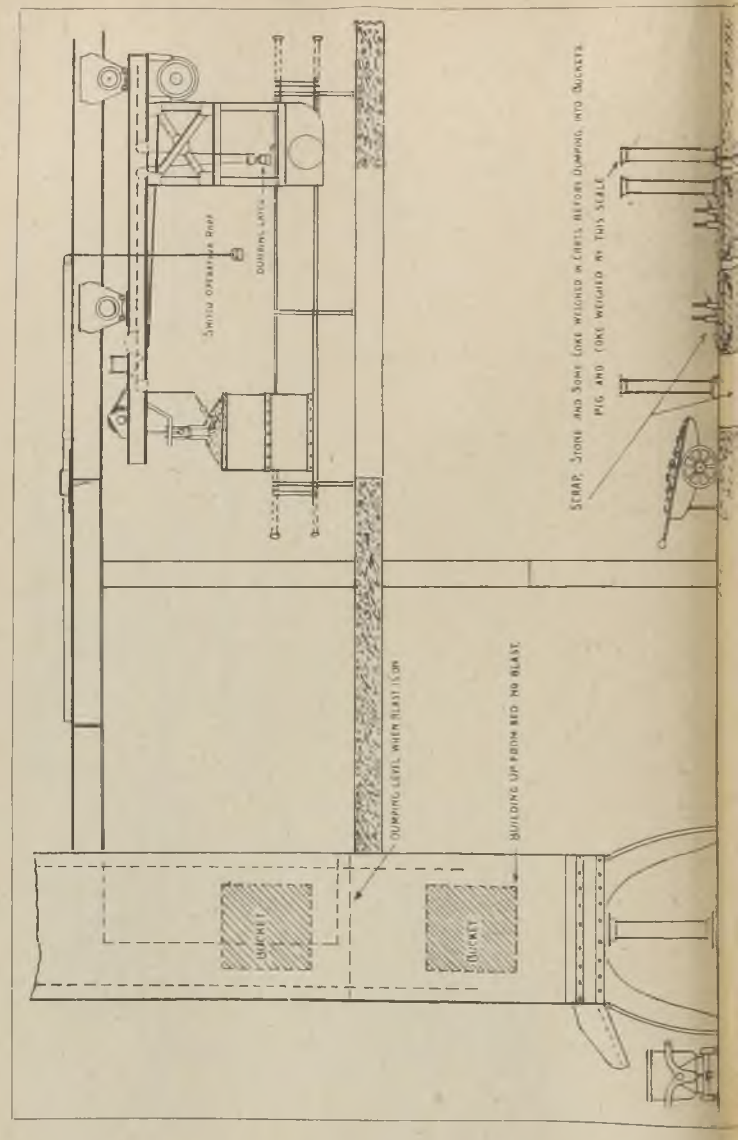
B.—GENERAL STORES, ETC.		
(9) Stores supplies—Core shop	5 17 0	
(10) ,, ,, —Foundry	8 9	
(11) Coal dust, blacking, etc.	13 6 10	
(12) Shop heating		
(13) Core stove fuel	11 8 4	
(14) Sands	15 19 9	
C.—POWER COSTS	8 2 6	
D.—WATER COST	1 2 0	
E.—REPAIRS, RENEWALS AND MAINTENANCE		
F.—LOOSE TOOLS	3 7 7	
G.—STAFF AND MANAGEMENT	29 13 0	

Weight of good castings made.				Metal cost.	Direct wages.		
T.	C.	Q.	Lbs.	£ s. d.	£ s. d.		£ s. d.
93	2	1	20	456 10 0	369 0 8½	388 3 6½	1,213 14 3

PERCENTAGE OF TOTAL COST.

Metal cost	37.6%
Direct wages	30.4%
Total indirect wages	16.5%
All other expenditure	15.5%

COST OF GOOD CASTINGS=£13 5s. per ton.


Switch Operating Rod
Dumping Latch
Scrap, Stone and Some Coke Weighed in Carts Before Dumping into Buckets
Pig and Coke Weighed by this Scale
Dumping Level when Blast is On
Building up from Bed No Blast
Bucket
Bucket

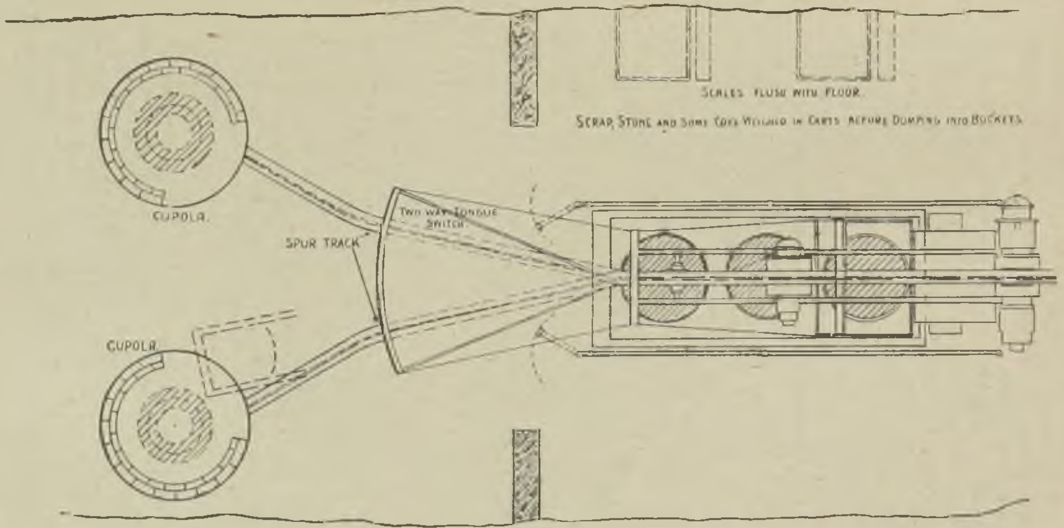

SCALES FLUSH WITH FLOOR.
SCRAP, STONE AND SOME COKE WEIGHED IN CARTS BEFORE DUMPING INTO BUCKETS
CUPOLA.
TWO WAY TONGUE SWITCH
SPUR TRACK
CUPOLA.

FIG. 3.

and those which must traverse variable routes the battery truck is finding a continually widening field of application.

The effect of good internal transport in the foundry is very pronounced, eliminating delay, removing strenuous operations, and allowing moulders to devote more time to actual production, and to expend their energy in the most economical manner. Sand and molten metal are handled with facility, charging is reduced to a science, castings are removed to the dressing or fettling shops, and sand blast, with ease and facility, and moulding boxes and tackle are brought into use, and also rapidly removed, and properly stored when out of use. A foundry equipped with labour-saving devices for conveying materials can command the best class of labour, as moulders, and others, are able to earn a better wage with less fatigue. The facility with which all waste material can be removed means cleaner foundries, and reduces waste to a minimum.

Something more must be done in Great Britain to cut down productive costs, and it is the duty of all foundrymen to look closely and quickly into the means of securing a greater output at a less cost. Everything required for economical lifting and shifting can be bought in Great Britain; so buy British.

The examination, as detailed above, of a monthly cost sheet of a small or medium-size general foundry engaged on light and medium work, with some repetition moulding machine work, having an output of some 93 tons of good castings per month approximately, at a shop-door cost of £13 5s. per ton, covering all internal cost, but no establishment charges, is, to be brief, on the usual lines of a foundry being part of an engineering business producing castings for its own consumption.

Under the heading of indirect labour there are "general labouring," "sand preparation," "pouring labourers," "shop cleaning," etc. These items figure out at £57 5s. 10d, or 12s. 4d. per ton of good output. It is apparent serious economies have still to be effected here by the introduction of improved and additional material handling appliances.

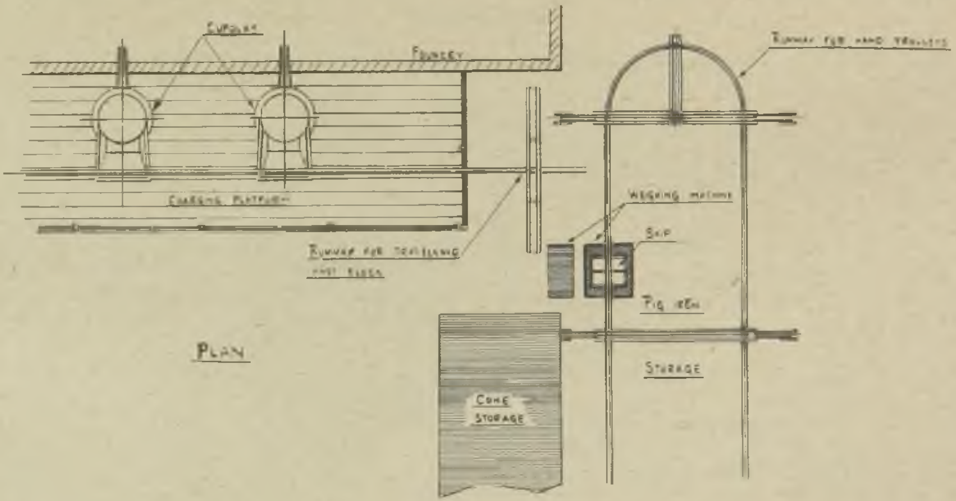
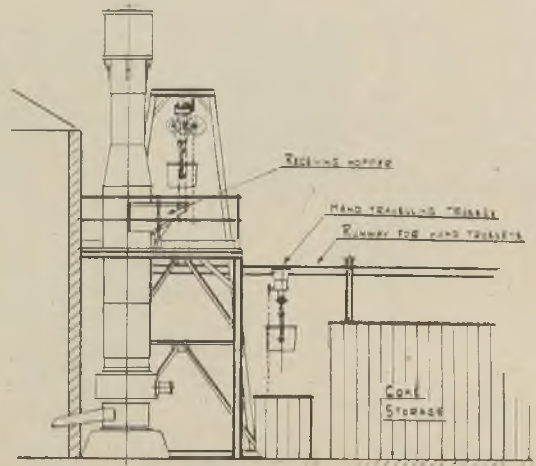
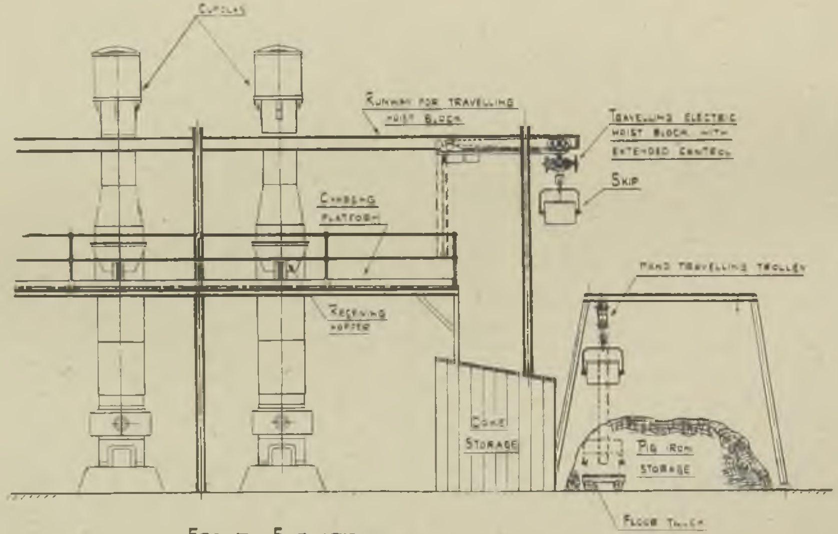

Cupolas
Foundry
Runway for hand trolleys
Charging platform
Runway for travelling
hoist block
Weighing machine
Skip
Pig iron
Storage
Coke
Storage
Plan

Fig. 4.



End Elevation

Fig. 4.



FRONT ELEVATION.

FIG. 4.

Now, take the melting cost, which also forms part of the oncost, this item figures at £119 3s. 3d., or 25s. 7d. per ton of good castings, in this is found £41 3s. 11d. for cupola attendance, or 8s. 10d. per ton of good castings, so that there is a total labour oncost of £98 9s. 9d., made up as follows:—

	£	s.	d.
General labouring	57	5	10
Sand preparation			
Pouring labourers			
Shop cleaning			
Cupola attendance	41	3	11
	£98	9	9

or 21s. 2d. per ton in bare figures.

These items really can be improved considerably, as also can the direct labour for moulding, which stands at £310 9s. 7d., or £3 6s. 9d. per ton, by the installation of more jib cranes of various types for the individual use of the moulders, together with a sand preparing plant, and in one section, a system of light transporter cranes to allow of the whole floor area being used to better advantage.

The most serious obstacle to progress in this particular foundry is floor area, and it is realised that by allowing the moulders twice the working area they now have, so that the previous day's work could be shaken out and cleared without interfering in any way with a full day's moulding, this would allow of a greatly increased turnover, with very little additional operating expense.

Moulding appliances are not in the scope of this Paper, but if a portable auto sand cutter is to be used on the foundry floor it must have adequate crane service, as also must the portable type sand slinger, which also requires proper sand feeding, or it cannot be used to the best advantage; but foundrymen who have read the articles in the Press, and also the Papers read by Mr. Lane and others on "The Mechanical Handling and Preparation of Sands," have some idea of the importance of the various lifting and shifting devices involved in a proper sand system.

[Here were shown some 30 more views of lifting and shifting appliances interesting to foundrymen.]

Mass Production in the Foundry.

Now with regard to the strictly repetition foundry, things are very much different here from those prevailing in the general and jobbing foundry, and the system employed needs to be more or less continuous. In the foundry equipped for rock-bottom cost repetition-production the moulds are usually poured as they move along a continuous conveyor; the men who pour devote their entire time and attention to the work.

As the flasks are poured they move along the conveyor to a shake-out or knock-out grating. Here they are knocked out by hand, a vibrating appliance, or a mechanical jar knock-out machine.

DETAILS OF METAL COST.

Pig-Irons						Per ton.					
	T.	C.	Q.	Lbs.		£	s.	d.	£	s.	d.
No. 3 ..	25	13	3	14	at	5	15	6	148	18	0
No. 3 ..	27	4	2	14	at	4	1	0	110	5	9
No. 4 ..	10	15	2	0	at	4	2	6	44	8	11½
No. 1 ..	2	0	0	0	at	4	13	9	9	7	6
Own Scrap ..	31	11	0	0	at	4	2	6	130	2	9½
Bought Scrap	33	7	1	0	at	4	2	6	137	12	3
	130	12	1	0					£580	15	3
Less Shop Scrap	30	2	2	0	at	4	2	6	124	5	3
	100	9	3	0					£456	10	0

DETAILS OF MELTING COST.

	£	s.	d.
Labour—Cupola attendants	41	3	11
Fuel	55	2	0
Stores, Refractories, Limestone, etc. ..	13	7	4
Re-Lining Cupola and Plant Upkeep ..	2	10	0
Power	7	0	0
	£119	3	3

DETAILS OF DRESSING COST.

	£	s.	d.
Labour—Fettlers and Sand Blast Operator	61	10	5½
General Stores and Supplies	1	9	0
Power Cost	19	5	0
	£82	4	5½

The flasks are immediately available, and are used several times each day. Due to this rapid handling, less flasks are necessary. It has been said that sometimes the saving in flask equipment is enough to pay for the continuous equipment. From the knock-out grating the sand drops into a hopper; from this hopper it goes on to a conveyor that carries it to a screen. The screen takes out all hard lumps, sprues, gaggers, rods and nails, and ensures sand of uniform size for moulding. It "fluffs up" and cools the hot sand. Below the screen the sand passes over a magnetic separator, which removes all remaining metal.

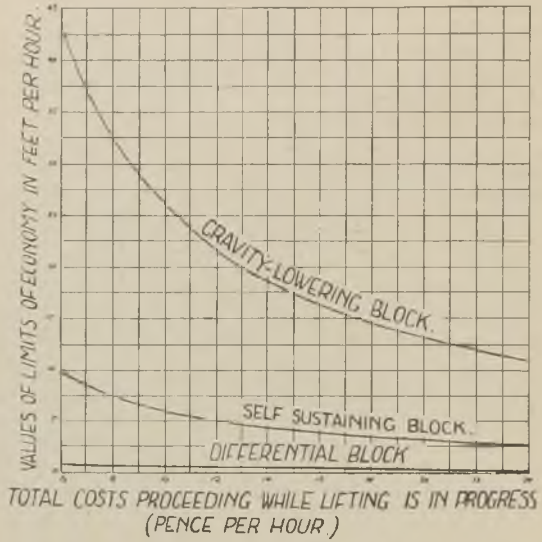


FIG. 5.

The sand now passes over a tempering belt, where it is wetted down, and then into a conditioning machine. This machine aerates, blends, and tempers the sand, and puts it into proper condition for moulding. The working part of the machine is a simple revolving cage. Sand is fed into this cage, and is thrown between the pins to break up all lumps, and give the sand a uniform consistency. The conditioned sand now goes to a central overhead storage bin. This bin has sufficient capacity so that the sand becomes properly seasoned before it is used. From this bin a uniform flow of sand is delivered by an automatic cutting feeder to a conveyor that distributes the sand to the bins above the moulding machines. This continuous process is in use for not only light, but also medium size work, and it is claimed in America as an example of its efficiency that 23 men easily do the work of 65 men in two-fifths of the space previously employed.

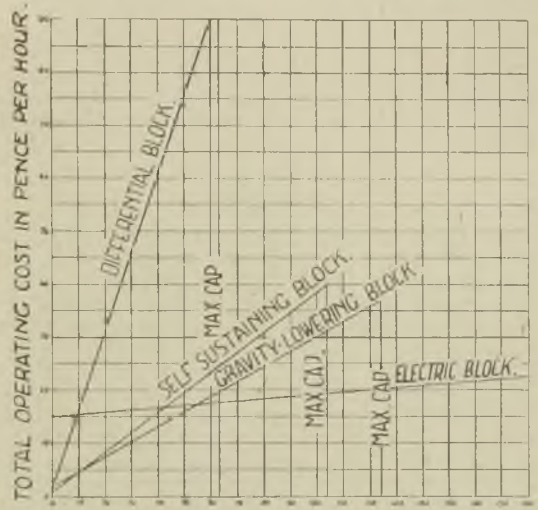


Fig. 6.

Conveyors.

Much progress has been made by the use of conveyors in this country during the last few years, the gravity conveyor by itself having come into use by leaps and bounds, and great economies and increased output have been effected by their use. Finally, reference should be made to the continuous core-drying stove, several examples being in use in this country. Conveyors set a pace of working that ensures a uniform rate of production, and as is well known have helped much in reducing the cost of production in many lines of repetition foundry work.

Conclusion.

The author desires to express his gratitude to his friends Mr. John Lucas and Mr. Clarke for their great help to him, and the team spirit shown in connection with this Paper during a period of great pressure, and also to acknowledge his references to the Paper read by Mr. Primrose, of Falkirk, and also for useful extracts from The Foundry Trade Journal, and also to his colleague, directors of Messrs. Herbert Morris, Limited, for placing at his disposal much information of interest.

DISCUSSION.

Mr. Russell believed the audience was considerably bewildered at the ground the Paper covered and the number and variety of appliances nowadays available. He was particularly interested in the cupola charger, this being one of the foundryman's crucial problems to-day; the cupola charger tended to a better control, as under the old style of things the man was out of sight on the cupola stage. He was quite sure it would be a boon if the charges could actually be weighed on the ground. He would have liked Mr. Moore to have enlarged on the two runway system of cupola charging. A point that always reacted against the use of the average pulley block in the foundry was that (if the job was a fairly large one) the chains had the action of damaging the moulds.

He was sorry that the lifting gear manufacturers had not yet originated a crane whereby the gears were all in, or controlled from a gangway. Personally speaking, when this proposition had been mentioned to the crane manufacturers, he had always been informed that the loss of efficiency when the chains were all in a gangway was very serious. The two-speed block referred to by the author was an interesting device. He would like to be assured of its safety. An electric block, shown on a slide, was, from his own experience, a most efficient tool. He had one at work in his fettling shop for 5¼ years, and it was surprising how little trouble it gave. For handling foundry loads up to 2 tons he had not the slightest hesitation in endorsing the claims made for the electric pulley block.

The figures given relating to the weight of materials handled per ton of castings produced were astounding, but they were obtained from so many sources that their accuracy could not be doubted.

Respecting the particulars given of foundry costs, he was not quite sure what these covered without personal reference to the figures, and, although they were extremely interesting, it was quite possible they were taken out in a different manner from what he was used to.

In reply, **Mr. Moore** said he agreed that with regard to travelling gear in the foundry there was something yet to be done, but very much progress had already been made in this direction, and foundrymen's views as to what was best for their own specific cases varied greatly. He assured Mr. Russell with regard to the two-speed lifting block that there was no doubt whatever with regard to its safety. (Mr. Moore enlarged on the design of the block.) With regard to the oncost figures mentioned, various foundries made up their figures in different ways, but the same facts had to be faced. He was pleased to hear of Mr. Russell's experience with the electric pulley block. He (the author) was sure that it had a greater future than any other lifting gear, and in these days when production costs must be lowered, the great aid would be found to be the electric pulley block.

Mr. Pemberton said that he had been very interested in what had been shown. It had taken them from coolie labour to shipbuilding cranes. The cost of wages undoubtedly played a big part in present-day costs. Mr. Moore had raised one point with regard to cupola charging apparatus, *i.e.*, "15 tons per hour, the charging now being done by six men, which was previously done by 24 men." That meant that each man would be handling about 2½ tons per hour, which did not seem a great advantage. Mr. Pemberton had in mind his own cupola, doing 10 tons per hour, handled by two men, charged from the floor, and he would like a private discussion with Mr. Moore as to what would be saved by charging up with an overhead runway.

All data to be made available.

He (Mr. Pemberton) advised foundrymen that if they were installing overhead appliances to discuss the matter only with the experts, and to remember that it was in the mutual interest of the supplier of the plant and the user that the user should put all his cards on the table when putting his proposition up to the supplier. He thought that the author should have dissected his Paper, and given it to them over a series of Papers.

Mr. Moore, in reply, pointed out that with regard to the use of cupola charging apparatus and the 15 tons per hour now being charged by six men, and which was previously handled by 24 men, that Mr. Pemberton had perhaps not realised that the figures mentioned covered not only charging, but all the actual work done from the removal of the material from the railway trucks, staging it, weighing, and the whole of the work up to the actual charging into the cupola.

Pulley Block Chains.

Mr. Cox said that what appealed to him most in lifting gears for foundries was not so much as the utilitarian point of view but the safety factor. He thought that if cranes could be operated with the chains at the side it would be much better—that is, if the control could be removed further away from the molten metal it would be a distinct advantage, and, furthermore, the blocks should be guarded so that they were not subject to heat.

Mr. Bunting thought that the manufacturers who specialised in hand-hoisting tackle should be able to provide a device which would allow the men to stand further away from the molten metal.

Mr. Moore said he was not clear as to whether Mr. Cox was referring to hand or electric lifting gears, but in any case he (the author) was sure the requirements of the case could be met without difficulty; but it was a question of the manufacturer having a proper knowledge of the conditions to be met, and the same remarks answered the question of Mr. Bunting.

Mr. Stevenson asked the author for advice on the lubrication of foundry machinery generally. It was known throughout the trade that the foundry machinery was the most neglected of any section. There was no doubt that when new machines were supplied to the foundry they were fitted with oil holes, but these very soon became blocked up, and he wondered if the author could give them any information on the best method of providing lubrication of foundry machinery.

Mr. Evans said that the productive moulding costs were nowadays so low that little further could be done in this direction, and the foundryman was now forced to tackle this handling proposition. It had been forced on him that the highest costs were those entailed in handling material. The moulding costs were satisfactory, but many had fallen behind in their methods of handling. He had found the electric battery truck almost invaluable in solving some of his material handling problems. Finally, he asked if there was yet a magnet crane available which could work on an A.C. circuit.

A hearty vote of thanks was accorded the lecturer.

Lancashire Branch.

ALUMINIUM FOUNDRY PRACTICE.

By G. Mortimer.

INTRODUCTION.

With the growing necessity for cutting working costs in our industries to-day, there may be traced a tendency to investigate new and more rapid methods of production, closer and more scientific control of processes, materials which will do the work and cost less.

The founding of metals is one of the few skilled trades left: one of the few where personal experience cannot entirely be replaced by ingenious mechanism. Machine moulding, pyrometric control, automatic transport, the scientific handling of sands, all the varied paraphernalia that go to the making of a modern foundry, merely assist that experience: they do not supplant it. It is difficult to think that they ever will.

Since foundrymen deal, then, not with an exact science, but with a subject complicated with all the variables of human experience, it is possible only to generalise. But if one foundryman's meat is another foundryman's poison, there is common ground in this: that all foundrymen who are successful in the casting of aluminium follow, whether they know it or not, certain fundamental principles. There are one or two peculiarities in the light metal as compared with brass or iron. Where these are recognised and met in a simple and logical manner, there will be found the most consistent success with aluminium.

These differences are set out in the following paper indicating their effect on choice of alloy or method or plant. Should questions arise at any time on the better method of meeting certain special circumstances, the author will always be pleased to augment these notes with more specific information.

Modern developments have produced a confusing array of light casting alloys, the possible combinations being in point of fact unlimited. To clear the ground it is only necessary to remember that the permissible range of physical properties is not unlimited. This range may be obtained, for all practical purposes, as readily by the manipulation of one or two simple and cheap components, as it can be by ringing the changes on half a dozen of the more costly of the rarer metals.

Since this is the case, it is wise to confine attention to a few alloys which call for no specialised foundry knowledge or subsequent treatment, which have been tried out for years under varied conditions of service and climate, and which may be regarded generally as sound substitutes for commercial brass and bronze.

"L5."

The best known of these in this country is "L5." Some thirty years ago, when aluminium casting was in its infancy, it was found that the pure metal could be cast. It is still being cast to-day in quantities, for chemical plant and similar work. It was found further that the pure metal gave poor engineering properties in the cast state, and was difficult to machine. The addition of zinc improved matters considerably, and zinc alloys became popular here and on the Continent, the proportion varying between 8 and 20 per cent., and settling gradually in this country to a compromise of 15 per cent.

Zinc is one of the cheapest hardeners of aluminium, easy to mix, tough and reliable in service, readily machinable. In the foundry, however, it has one real drawback, in that for a considerable range of temperature after freezing all zinc alloys are excessively weak. They are tender in the mould, and this at a time when a lot of the contraction is taking place. In foundry terms, the zinc alloys are "hot-short," and this hot-shortness is a prolific source of cracked castings.

Value of Adding Copper.

Substituting some 3 per cent. of copper for the same amount of zinc materially helps matters, with no loss of strength or machining qualities. Such an alloy, consisting of 12 per cent. of zinc, 3 per cent. of copper, balance commercial aluminium, has been in use for some twenty years, on such parts as gear-boxes, crankcases and other highly stressed units on automobiles and aircraft engines. For years it was known to the trade as "No. 6" alloy of the British Aluminium Company, but during the war all available data on light alloys was collected and tested out, and definite specifications were issued for all of proved merit. The specification number of this particular alloy became "L5." Minor modifications in the wording and terms of the specification from time to time have resulted in the name "2L5," the properties of which are summarised at the end of this section.

From the foundry point of view 2L5 is an easy alloy to work with, and it is suitable for a vast range of parts made in brass, in comparison with which it is one third the weight, more rapidly machined, and cheap.

The Disability of Zinc.

From the engineering point of view the material is stiff, strong and stable in all climates, and its long record of reliable service in so great a range of applications tends to give confidence to designers. In applying it to engineering parts, however, one point should be kept in mind. All the zinc alloys are weak at high temperatures. 2L5 is never used for automobile pistons, and should not be used for any job required to withstand a similar range of temperature. Castings required to withstand high temperatures are better cast in a straight copper alloy, the best known of which in this country is 3L11.

The Value of a Straight Copper Alloy.

At the time when founders in this country were discovering the utility of zinc as a hardener in aluminium castings, America was passing through a similar teething stage in regard to copper. From that day to this American founders have continued to use copper for all purposes where the British use zinc, and popular opinion has gradually settled down to an accepted standard alloy containing from 7.5 to 8.5 per cent. copper, balance commercial aluminium. This alloy, under the name of "No. 12," is used to this day in the States for about 90 per cent. of their vast output and range of aluminium castings, whether for general work or for special aircraft castings, whether cast in sand or in dies. This is in itself a sufficient testimony to the reliability of a simple copper alloy.

"3L11."

Soon after the war commenced, efforts were made in this country to find a more satisfactory alloy for aircraft pistons than was afforded by the zinc group. One of the more successful was an alloy consisting of 7 per cent. copper, 1 per cent. zinc, 1 per cent. tin and the balance being commercial aluminium. This was given the title "L11." Later it was found that even this small percentage of zinc was detrimental at high temperatures, and so it was omitted, and in place was 2L11. Later still, the tin content was made optional: it is difficult to see quite why it was ever included, except possibly on the grounds of a slightly lower crystallisation shrinkage. The final specification, since one never uses the tin, is a straight alloy containing 7 per cent. copper and known as 3L11. For all practical purposes, therefore, it is now identical with the well-known and deservedly popular "No. 12" of America. As such, it is a safe and reliable alloy to use as a substitute for brass, and has an advantage over L5 in being better able to withstand high temperatures.

Increasing the Copper Content.

Now, for various reasons it is often of advantage to increase the copper content. For instance, the higher the copper content, the lower the total shrinkage, and this may help on the production of one or two obstinate castings. Again, within limits the more copper used the less the tendency to general porosity, which point is of value in connection with castings designed to withstand hydraulic pressures. Finally, a higher copper content gives a hard, well-finished machined surface, eminently suitable for such wearing surfaces as automobile pistons.

The indiscriminate addition of copper, however, brings its own penalties in a rapidly increasing brittleness in the casting, and in an increase in weight disproportionate to any gain in strength.

Use of Manganese.

To guide founders and designers alike in the matter, a specification was issued for a 12 per cent. copper alloy, now known as L8. This alloy is the one used for the great majority of motor pistons cast in this country, whether cast in sand or in dies. The copper may be increased another couple of points without undue detriment, and if to this is added from 1 to 2 per cent. of manganese a useful alloy is obtained, having the property of *increasing* in tensile strength with rise of temperature up to about 250 deg. C. The alloy L8, however, holds its own in popular esteem on account of its greater ease of casting and its higher thermal conductivity.

The above alloys represent the repertory of the majority of aluminium founders in this country, and the brass foundry need go no further to meet the requirements of 90 per cent. of the cases where brass or iron is normally used now. They are recommended by this company on account of their facility of working, and their long record of reliable service under extremely varied conditions of design, duty and climate.

For comparative purposes, their specified physical properties may be tabulated alongside those of ordinary grades of commercial brass and iron.

*Material.	Tensile strength. Tons per sq. in.	Elongation on 2 in.	Specific tenacity.
2L5	11/13	3/5	115
3L11	9/12	3/4	87
L8	9/12	1	86
Brass	18	40	59
Bronze	18	40	57
Grey Iron	12	—	47

* Minimum results called for on a standard test bar.

Specific Tenacity.—In the last column for the sake of comparison is given an arbitrary figure obtained by dividing the tensile strength in tons per sq. in. by the weight of a cubic inch of the material in pounds. This factor was introduced by Dr. Rosenhain some years ago in a praiseworthy attempt to convey comparatively the effect of low specific gravity as a factor in design of any parts subjected to inertia stresses.

Such cases are innumerable in practice, and a few typical instances are cited in a later section. The specific tenacity factor is of comparative value only, and obviously cannot be used very freely for absolute calculations in design. It does serve to explain, however, why in certain applications a relatively weak material like aluminium can give greater reliability in service even than cast steel.

In further regard to the above table, it is fully understood that results on all the materials may, under controlled conditions, exceed the figures given. It is also understood that many special brasses and bronzes are available, giving physical properties in one way or another far in excess of those averaged by the common materials cited. It is merely a question of choice of an alloy for some particular duty, and a decision as to whether the circumstances warrant the extra cost of raw materials, special foundry practice, or subsequent heat-treatment.

Similarly there are special alloys of aluminium, for such special cases as justify their study and extra cost. There are alloys of nickel and magnesium, of silicon, manganese and lithium: alloys which give the strength of mild steel at a third of the weight, or which may be bent double with a hammer in the cast state without fracture, or which are relatively free from corrosion by sea-water, or possess a high electrical resistance or a low coefficient of expansion.

The British Aluminium Company, Limited, will always be pleased to advise on the choice of an alloy for any special duty, give hints on any modifications in design needed, and any special treatment needed at various stages of manufacture.

Simple copper-zinc and straight copper alloys as given above, however, will be found to cover most of the requirements of general brass foundry work. They are relatively simple to work in the foundry, and they are well understood by designers. By a logical variation of the proportion of the constituents it is possible to co-relate the tensile strength and ductility factors in a convenient manner, and obtain the whole of that permissible range of physical properties which is compatible with simplicity and low cost.

Making the Alloys.

The author's firm is prepared to supply the above alloys and many special ones ready for use in ingot form, melted and alloyed under ideal conditions. Many founders prefer, however, to mix their own melts, and to these are offered the following hints.

The technical success of aluminium founding begins with the purchase of materials, for the word "aluminium" in the open market still covers a multitude of sins. "Clean aluminium scrap" may mean anything; the best available analysis does not tell the whole story. "Remelted ingot" is a pitfall, unless the history of the metal is known. Indifferent zinc and copper can ruin the best workmanship.

Virgin aluminium should be purchased in the first place. It will be found subsequently that, firstly, a certain addition of "scrap" definitely improves castings as in the case of iron, and, secondly, that sufficient scrap is forthcoming from normal foundry operations to eliminate any necessity for purchasing from outside. If it should become necessary to buy scrap, two points should be watched; the scrap should be in large lumps, and it should come from a known and approved source. One reason is sufficient for both precautions, and that is the well-known affinity of aluminium for oxygen. Aluminium invariably has a coating of oxide on its surface; excess of oxide is detrimental, therefore limit the superficial area of added scrap. This automatically eliminates machine swarf, the treatment of which will be dealt with later. Again, if oxide forms instantaneously on solid aluminium, it obviously forms even more readily on molten metal. It is therefore advisable to purchase scrap, if it ever becomes necessary, from some concern which understands the melting of the metal and has a name for a high-grade product.

The specifications outlined insist very wisely on maker's own scrap being used, and the best castings will not contain gates and risers from previous casts.

Copper and zinc must be of the best electrolytic ingot available wherever high class, reliable work is contemplated. In the case of second grade castings, where only a stiff, cheap structure is required, the founder will use his own discretion. Bus-bar clippings, and a cheaper spelter are quite good material where it is not necessary to guarantee physical properties to strict specification. The saving, however, is generally small because of the relatively small proportion of these metals used, and there is another economic factor which should be kept in mind even on the cheapest grade of work. That factor is the percentage of foundry wasters. A run of obscure trouble in the foundry is so often run finally to earth in the quality of the spelter and copper used that, generally speaking, it pays on a running job to pay more for these materials and cut out this potential source of trouble and loss from the start.

Alloying.

Zinc is simple enough to handle, being added direct to the melt. It should be added last and stirred in, care being taken to avoid undue turbulence at the surface of the melt. Add about 2 per cent. more than is required in the final analysis, to allow for oxidation and volatilisation losses.

Copper is best added in the form of a rich alloy previously made up, and there are two good ways of doing this. In the first a known quantity of copper is melted, and aluminium is added to it a little at a time until a 50/50 alloy is obtained. Stir thoroughly and pour into chill moulds. The resulting ingot may be added direct to the melt in the correct proportion, without raising the temperature of same to the high figure reached when copper is added direct.

In the second method aluminium and copper are melted in separate crucibles in the proportion of two to one by weight. When molten the copper is poured into the aluminium, stirred in, and poured off into chill ingots. This gives an alloy with a copper content of approximately 33 per cent. The eutectic point of the copper-aluminium system is approximately 32.5 per cent., and this composition has the lowest melting point. As this is about 535 deg. C., this rich alloy will dissolve away almost immediately on being introduced into the melt, which is normally at about 700 deg. C.

Comparing the two methods, the latter is probably a needless refinement. The 50/50 hardener functions admirably in practice, is brittle and easily broken up, is easier on the whole to calculate for varying melts, and does not need the melting of so much aluminium in its preparation. This latter is quite a point, because of the high latent heat of fusion of aluminium: it takes a lot of fuel to melt a pound of aluminium, and one therefore tends to avoid remelting that pound.

Melting Practice.

This is the crux of the matter, and if furnace hands are trained to follow a few first principles right from the start, it will mean materially less uphill work later on. It is now generally recognised that aluminium cannot readily be "burned" in the accepted sense of the term. This may also be accepted in regard to the common alloys of the metal: the only damage likely to occur in the case of the alloys mentioned being loss of zinc through volatilisation. The mere raising of temperature does not appear to affect the metal or its alloys permanently to any appreciable extent. What does damage the melt is the extent to which it absorbs gases, which largely hangs on the temperature attained and the period during which it is maintained in a molten condition.

There is this fundamental fact to bear in mind in connection with aluminium melting. The metal absorbs gases like a sponge at high temperatures: hydrogen, nitrogen and oxygen; and the worst of them is oxygen. The affinity of aluminium for this gas is well known; it was this factor that caused the abrupt removal of the Messines Ridge from the path of British troops during the war. It is the chief factor in most industrial thermit reactions, and the chief obstacle to be overcome in welding and soldering the metal. In foundry work it is handy to remember one small fact. If the film of oxide that instantly forms on all aluminium were not a simple and effective check to further action, there would not be an ounce of the metal in the world to-day.

The great difficulty about alumina, or oxide of aluminium, is that it has much the same specific gravity as the melt: once stirred in there is no very effective method of getting it out again. On routine production, therefore, oxide with its detrimental effects on castings tends to accumulate. It cannot entirely be excluded, but it can be kept within non-detrimental limits by following three simple rules.

Avoid Overheating and Overstewing.

The melting point of these alloys ranges about 650 deg. C. For general purposes it is seldom necessary to go beyond 700 deg. C. This latter may be exceeded by at least another 100 deg., provided attention is given to stewing.

Aluminium should not be kept in a molten condition too long. Even at low temperatures oxidation is proceeding steadily, but at a steadily decreasing rate if the surface is left undisturbed. The scum of oxide and dross is the simplest and one of the soundest checks to further action, and continual skimming merely doubles or trebles dross losses. When the mould is ready for the metal, skim the pot thoroughly and stir for a short time, taking care to disturb the surface as little as possible. Pour with the shortest stream and the least possible turbulence. Do not quite empty the pot: minor foreign inclulsions, iron complexes, slight scalings from the sides of the pot, tend to collect at the bottom. If they go into a good casting they may cause a weakness or a hard-spot on machining. It is better to ingot the last inch or so of metal at the end of the day, and use it for low grade work. Obviously also it is better to allow such inclusions to sink than to keep them up in the melt by continual stirring; an additional reason for leaving the melt undisturbed until just before ladling.

Temperature Control.

It will be seen from the above that success hangs on rather keener control of temperatures than is normal or necessary with brass. For this reason it is strongly recommended that melting should be under pyrometric control, for there are few metals so difficult as aluminium to gauge in matters of temperature. The most experienced furnace hand will make a mistake on the first sunny day after a dull spell, and it is wise to eliminate as many potential sources of trouble as possible from the start.

The necessity for close control of temperature influences the choice of melting plant. There is no standard furnace for the melting of aluminium. Ordinary brass furnace house equipment produces thoroughly good castings, but control being cumbersome, most founders sooner or later evolve a more readily handled type for the lighter metal.

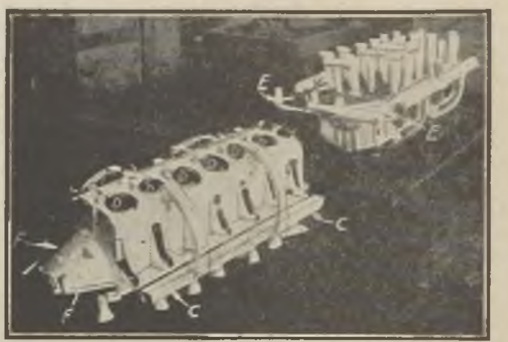


Fig. 1.—Liberty Crank Case showing the Forest of Risers used and the Horn Gates.

Whether these are fixed or tilting, employ pots of iron or plumbago, are fired with gas, fuel oil or electricity, does not greatly matter here. The importance of these points lies in the direction of economy rather than technical preference, and they are largely settled by local conditions, personal prejudice, or convenience of supply. The main essentials are cleanliness, ease of control and reasonably rapid melting.

Plumbago Crucibles.

Aluminium is perhaps preferably melted in plumbago crucibles because of their great cleanliness It is very difficult to contaminate the melt from the walls of plumbago crucibles, and for this reason they are used for very special work in connection with air-craft castings and similar high-grade products, such as are shown in Figs. 1 and 2.

The useful life of plumbago crucibles is short, however, and their initial cost is high. The thermal conductivity, and therefore the rate of melting, falls off rapidly after a couple of weeks' work. This happens long before the crucible is mechanically worn out, and it introduces two factors; firstly, either a sound pot must be replaced, or a heavy fuel-bill faced; secondly, the time taken to effect melting becomes equivalent to stewing. Although a new plumbago crucible does not contaminate the metal, therefore, it is within ordinary experience that after a few weeks' service it can, in effect, contaminate the melt through undue time in melting and consequent absorption of gases.

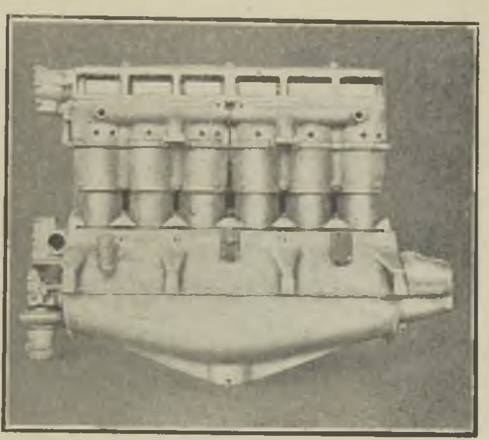


FIG. 2.—ALUMINIUM CASTINGS FOR THE SIDDELEY-PUMA AERO ENGINE MADE FROM 3L11 ALLOY.

By far the greatest proportion of the world's aluminium castings is melted in iron pots. These are relatively inexpensive, give a longer, useful life, and melt at a reasonable and consistent rate throughout,

Iron Pots.

From the economical standpoint iron pots are immeasurably superior to graphite crucibles; from the technical point of view they have the advantage of melting more rapidly throughout their useful life, and so cutting the time factor in the matter of stewing. This advantage is, however, offset by the basic drawback of iron in contact with molten metal, the risk of taking up iron in the melt.

Fig. 3.—Tilting Furnace for Gas or Oil Fuel, using Plumbago Crucibles (Monometer).

Iron forms with aluminium and its alloys hard complexes which crystallise out in the form of needles and plates, causing drawn and cracked castings, local weaknesses, and "hard spots" on machining, where the compounds have chipped off the sides of pots and gone into the castings. It is therefore essential to keep the iron content low in the purchase of the ingot, and to add as little as possible in the normal routine of the foundry.

This, fortunately, is readily managed by the coating of the pots with some neutral wash, of which there are many available. Probably the most convenient is a thin dressing of graphite wash, followed by a thin coat of whiting and water glass. The pots should be thoroughly scaled at least three times a week, and given a lighter coating on the above lines. Do not make either wash too thick, or apply too freely, as this increases the risk of chipping off into the melt. Needless to say, this precaution applies equally to all iron ladles, stirrers and skimmers used in contact with the metal, and in connection with these it is well to remember to coat them well up the handle.

Given the above precautions, applied rigidly and periodically, there is little danger of any iron of practical import being taken into the melt. Apart from the showing of daily analyses, this is proved by the life of such a pot set against the great tonnage of metal melted during that life; iron pots practically always fail from the exterior, through the action of furnace gases. One further point is to eschew the practice of skimming crucibles, before pouring into moulds, with a bent strip of iron. It is often the handiest thing, and may undo all the precautions taken in the furnace house. A chip of wood is as effective, and does no harm.

The Reverberatory Type.

A third basic type of furnace, deserving mention because of its growing popularity in regard to aluminium melting, is the reverberatory. In this type (Fig. 4) the flames impinge direct on the metal, and melting is very rapid. Since the furnace consists mainly of a cast-iron container lined with firebrick, it is obviously cheap. The linings last about a year, and are easily renewed at low cost; the type is, therefore, economical in upkeep. Melting is more rapid than by any other method, and heat losses are at a minimum, so that running costs are low. Given a slight increase in dross losses over the types previously described, the reverberatory still remains the most economical in fuel labour and upkeep charges of any of those in common use, and, in addition, it takes up the least floor space for a given melting capacity.

The reason the reverberatory has not superseded others entirely, is simply the fact that the furnace gases are in direct contact with the melt. In the light of previous remarks any hesitancy to adopt the type would appear pardonable. That the principle is not necessarily detrimental, however, is indicated by the fact that many thousands of tons of aluminium and its alloys are melted annually in reverberatory furnaces of all capacities, and that as far as tensile and elongation tests carry one, little difference is noted either way between metal melted thus or in plumbago crucibles.

Fig. 4.—Melting Furnace of the Open Flame Tilting Type (Selas Turner).

It is but fair to bear in mind, when criticising this type on theoretical grounds, that all aluminium is melted in the presence of some sort of atmosphere, and that the reverberatory alone offers a convenient and reasonably precise control over the composition of that atmosphere.

The type is not fool-proof. It will be seen that by mal-adjustment of the burners it is quite an easy matter to produce an oxidising flame, to reach high temperatures very rapidly, and to soak the melt for some time under these highly detrimental conditions. Given that this is duly recognised, however, and that there is intelligent supervision and good furnace discipline, the reverberatory can give excellent and consistent technical results on routine general work, and there is no doubt as to its economy.

The Importance of Pouring Temperature.

Whilst emphasising the importance of pyrometric control of melting, it will not be out of place to refer to the still more important question of pouring temperature. If a casting is melted and poured at a high temperature it will probably turn out porous under hydraulic test, or even cracked. It will certainly be "drawn" where sections of different thickness meet, and it will certainly have a dull finish. Test bar results will be below par, and the average verdict would be that the metal had been "burnt" in melting.

This verdict would be wrong, and it can be proved by remelting that casting under controlled conditions and pouring it again at the lowest temperature at which it can be successfully run.

If the metal has been correct from the start it will then be found that the casting is neither cracked nor drawn, and that it will stand a reasonable hydraulic test and possess its specified physical properties. Finally, it will have recovered that best practical sign of a well-run casting, a bright silvery lustre as it comes from the mould, all of which suggests thoughts which are usefully followed up. There are three main reasons for keeping the pouring temperature as low as possible.

Effect of Occluded Gases.

Firstly.—The metal absorbs gases. These gases have a tendency to leave the metal as it cools. The lower the temperature, therefore, at which pouring occurs, the lower the volume of gas likely to be frozen into the casting when it sets.

Effect of Total Shrinkage.

Secondly.—The total shrinkage in the mould is a function of the pouring temperature. If, for instance, a casting were poured at 1,000 deg. C., it would have to contract some 3½ per cent. *before* it reached 700 deg. C., which is a fair average temperature for pouring aluminium castings. This means feeding of an order which is seldom

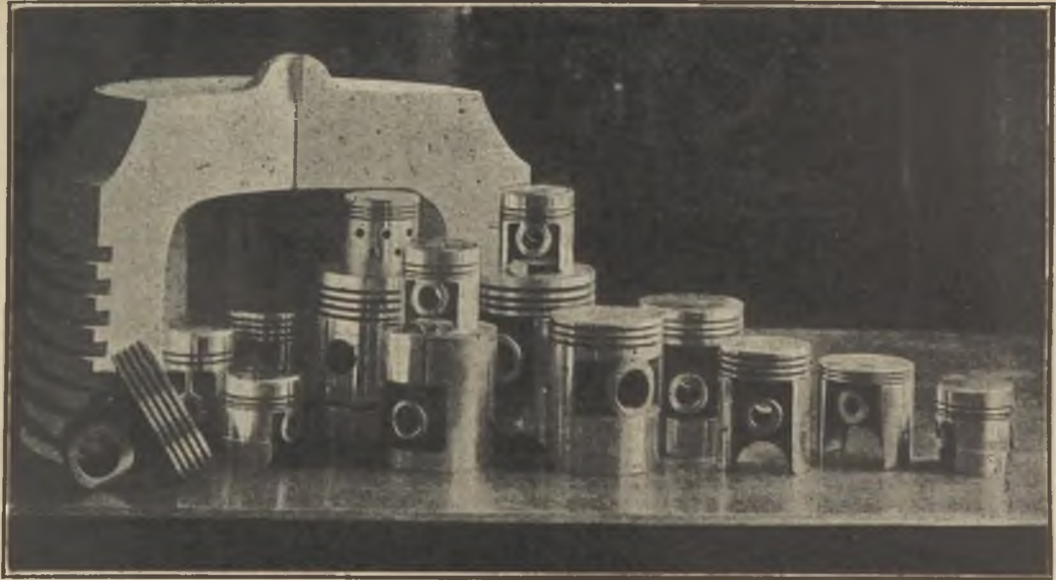


Fig. 5.—Heat Treated "Y" Alloy Pistons from a few Ounces to 2½ cwts. for Diesel Engines.

attained in practice, and so one would get a casting either cracked and drawn here and there, and/or with an open grained and porous structure. In a metal like aluminium, where the total shrinkage is on the high side, the more one can shave off it before it enters the mould the better.

Effect of Slow Cooling.

Thirdly.—The hotter the metal, the more it will heat up the surrounding sand before setting. Thus the casting will set more slowly than it need; it will take some time passing through its solidification range, and this has a two-fold effect. In the first place, the gases referred to above tend to come out of solution just in time to be frozen into the casting in the form of minute pinholes—the "speckey metal" so familiar to aluminium founders, and the subject of many quite unjust accusations in regard to lack of cleanliness in melting or the use of second-rate material. In the second place, metal which freezes slowly through its solidification range has a tendency to form larger crystals than metal abruptly chilled. Both effects make for a more porous casting than would be obtained by pouring at a lower temperature, which would allow solidification to occur very soon after the metal had reached its appointed place.

For the above reasons the pouring temperature becomes a matter of first importance, and on intricate and important work it is recommended that the best pouring temperature be found by experiment, fixed for that job, and checked every time by a pyrometer. The effect of this on foundry routine means a definite saving in wasters.

The usual type of iron-constantan pyrometer, enclosed in an iron tube, is best for the rough handling of a furnace house. For gauging pouring temperature, however, this type is too slow reading, and an ordinary iron-constantan couple works more satisfactorily, given reasonably careful handling. The two wires are used bare, and they may be used throughout their length if welded together from time to time as the junction burns away. With this type one precaution is necessary. The couple must not be immersed in the metal to any depth, or the current is short-circuited by the molten metal and a false reading results. Carefully separate the wires for four or five inches above the junction, and dip only the welded tip into the melt.

The substitution of scientific control for the personal factor wherever possible certainly lightens the task of the management, but is a fool's paradise unless the scientific apparatus employed is kept up to the mark. Pyrometers are notoriously fragile and capricious instruments, and in the foundry they receive more than the average rough handling. They should therefore be periodically checked against a " master," and a wise organisation will see that this " master " is also checked for accuracy from time to time, against some useful fixed standard such as the freezing point of pure aluminium (658 deg. C.), and that of fused common salt (801 deg. C.).

SAND CASTING.

Moulding Practice.

Any good brass moulder can mould for aluminium with complete success, and without special knowledge of the metal, provided that the castings are of relatively simple design. As the work becomes more intricate, however, he will necessarily meet with problems which follow naturally from four characteristics of the metal. They are:—(*a*) The solid contraction of the light alloys; (*b*) their weakness at high temperatures; (*c*) their high crystallisation shrinkage, and (*d*) their low specific gravity.

Shrinkage and contraction have been deliberately separated in the above, for greater simplicity in explaining their effect on moulding practice.

Solid Contraction.

The pattern scale for 3L11 is one in eighty-four, that for 2L5 one in seventy-eight. In practice a scale of one in eighty meets the case for all the alloys referred to. The solid contraction, then, is on the high side, though in itself insufficient to cause much trouble were it not for the

Weakness at High Temperatures.

The combination of the two factors at once suggests the most obvious cause for cracked castings. Equally obvious, also, is the remedy. All cores and all sand retained by projections of a casting must be rammed lightly; as lightly and evenly as they can be rammed without collapse on handling, or when the molten metal rushes in. Cores particularly must crush easily. Wherever possible they are made of green-sand, not only because of the great economy of this medium, but also because a green-sand core is less rigid than any other. To enable them to be handled without fracture they are sprayed with treacle and water and skin dried with a floor torch.

Dry-Sand Cores.

Where delicate cores must be made and green sand is found too fragile, they may be either dry sand or oil sand. Dry-sand cores should be used with reserve; they do not " give " easily, and may cause cracked castings; they are, however, economical and practical in many applications, provided this point is borne in mind. Sea sand with a binder which collapses easily when heated up is generally the better, if the more expensive proposition. There are innumerable core binders on the market suitable for aluminium, and the main point to watch is relative cost. A binder which is cheaper in first cost than another, may be more costly in the end if the second can be used with the addition of fifteen parts of water. A resin binder is often advocated, because it softens under heat. It is not popular with moulders, however, on account of the choking fumes set up; and it has a further drawback in the great difficulty of removing cores should the casting happen to cool down before they are knocked out.

Probably the best all-round base for a core binder is linseed oil, and a good mix is made as follows:—Equal parts of linseed oil and molasses, to be used as to one part of this mixture to 25 parts of dry sea sand.

Vital Importance of Light Ramming.

To meet points (*a*) and (*b*), therefore, all that is needed is the use of good, well-tempered green sand, lightly and evenly rammed, together with cores which, whatever their design and their composition, crush under heat with the minimum of

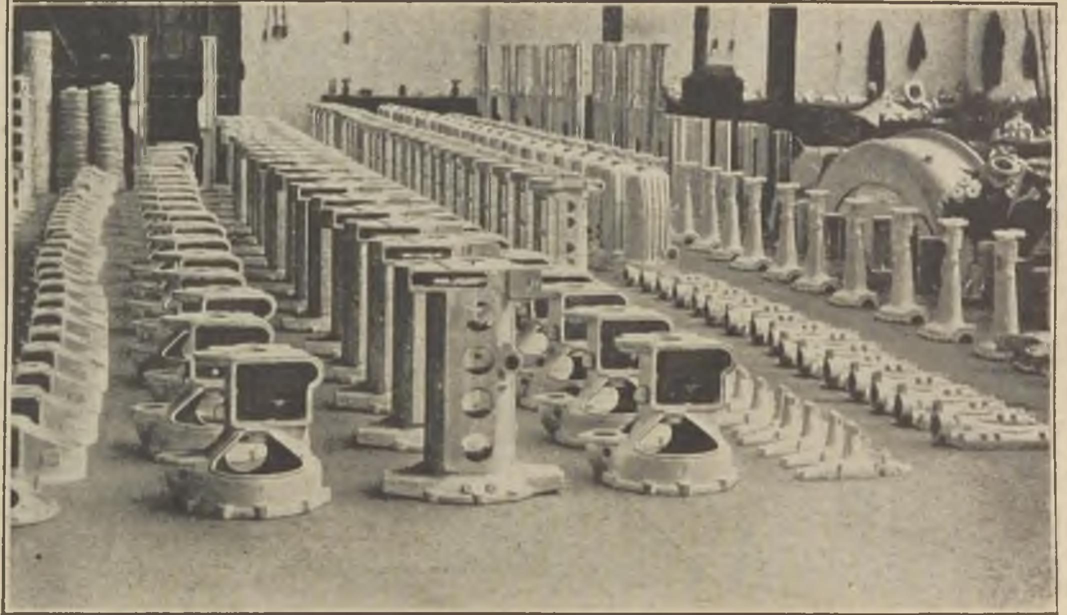


FIG. 6.—A SELECTION OF MACHINE MOULDED CASTINGS MADE BY MESSRS. WILLIAM MILLS, LIMITED, BIRMINGHAM

effort. All this seems very simple, but one cannot lay too much stress on this necessity for light ramming.

One of the more useful points in regard to machine moulding is just this possibility of consistent ramming. The extent of ramming necessary for any particular job may be found by experiment and fixed for that job, and maintained thereafter with a reasonable consistency. Every founder knows the economic advantages of machine moulding. This particular aspect of machine moulding, as applied to aluminium, and as a useful factor in reducing wasters, is however worth emphasising. It is one of the useful points about aluminium that ordinary green sand, with its natural clay binder is the best of possible materials to use, and that it can be used almost indefinitely. Very gradually, the natural binding effect of the clay content wears off, and this is best met by occasional additions of new sand to the old. The binding action is, of course, brought about by the addition of water. However, the addition of water must not be overdone, or blown castings will result every time. The water is best added with a good sprinkler to the heap of sand hot from the mould, for the finest "tempering" is effected by steam, not by drops of water.

Crystallisation Shrinkage.

This is the shrinkage which takes place when the metal passes from the liquid to the solid state, and should be distinguished from the solid contraction which takes place subsequently in the mould. For the alloys discussed, this shrinkage is in the neighbourhood of 7 per cent., and since, of course, it takes place fairly abruptly, it indicates the necessity for providing ample means of feeding thick sections, or alternatively of forcing them to cool at the same rate as the lighter sections. The use of chills and risers is therefore more pronounced than in brass practice, and both are of heavier section.

It would be trite to observe that neither would be necessary given perfect gating, since perfect gating is seldom or never possible of attainment in practice. Because a careful study of gating, however, can result in cutting the 50 per cent. of chills and risers, the following hints are submitted.

Gating.

Since it is advisable to fill the mould with metal at the lowest temperature at which the casting can be poured, it seems reasonable to fill it quickly, and this calls for gates of large capacity. By doing this a pouring temperature may be used many degrees lower than by filling the mould slowly through a small gate. By a large gate however, we do not necessarily mean one runner of large capacity; it is better practice to use many of small capacity and distribute them logically throughout the mould.

If the mould is poured rapidly at a low temperature, there is risk of entrapping air which has no time to escape before the metal freezes. Hence a common source of blowholes, and hence, also, the necessity for so designing runners that the minimum of turbulence is set up in the incoming metal. For this reason many castings of relatively flat design are best gated from the bottom, so that the rising metal will carry up all air before it. Bottom pouring, however, should be used with discretion; for it is clear that in the case of fairly tall castings the rising metal gives up a good deal of its heat to the surrounding walls. The top of the casting, therefore, is not only cooler than the bottom, but it is also in contact with cooler walls. Thus it must set at the top some time before the bottom freezes, conditions which are exactly what one sets out to avoid in studying gating at all. Such a casting will tend to "hang" in the mould, and will turn out porous, and/or cracked. Gating from the bottom in such a case is also extravagant in waste metal in the gate.

The section of the gate, where it joins the casting, should be so adjusted that it invariably freezes after the adjacent metal in the casting has set. This, of course, varies with every casting, like most other conditions of gating, and it does not necessarily mean that the section of the gate must be larger than the section it is joined to; the sand in the gate is generally hotter than that in the mould. It means that the section must be adjusted until there is no draw, or porosity in the casting at the point where it enters, and often enough any such defect is at once remedied by allowing a liberal fillet at that point.

Finally, as with all metals, the ideal to aim at in gating is so to arrange its design and disposition that the casting cools at the same rate all over. This means so guiding the path of the metal that heavy sections are filled with cooler metal than thin sections, and needless to say this is seldom attained in practice. It is because it is so difficult to approach with a metal like aluminium that resort is made to the makeshift compromises of chills and risers.

Chills.

Chills are primarily used to ensure reasonably even cooling throughout a casting of varied section. They are unnecessary in a casting of substantially the same section throughout, provided attention is given to logical gating, and to the provision of fillets at sharp corners.

Chills are useful for varied purposes distinct from the above, such as the rapid freezing of a machining strip to obtain a close-grained, hard-wearing surface; or the similar treatment of some local area which must withstand hydraulic tests without leaking.

They may be of iron or brass or aluminium. The most satisfactory are of brass, discounting two minor disadvantages: slight discoloration of the chilled area, and a tendency on the part of the chill to disappear. The use of cast iron overcomes both objections, the metal functioning quite well.

A tendency is noted to place a chill promptly on some area of a casting which shows a crack; this point should be watched, because it is not always obvious to a moulder that the right spot to chill, if any, is some thick section in the neighbourhood which is the prime cause of that crack. To chill the affected area often cures it, but almost invariably sets up some stress or other which results in other cracks elsewhere, and gradually 100 per cent. more chills come into commission.

The use of chills should be avoided wherever possible, if only because of their habit of " sweating,"

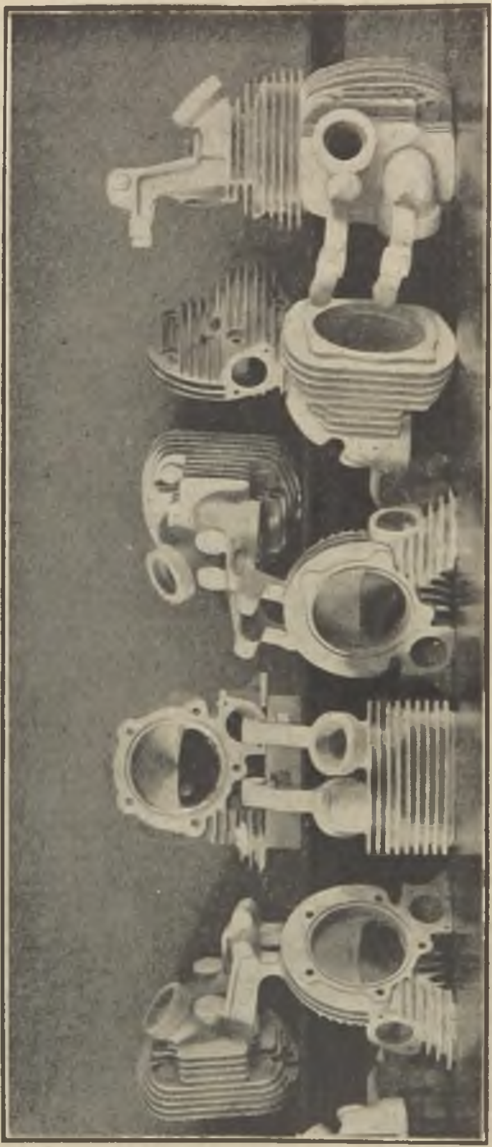


Fig. 7.—Light Aero Engine Cylinder Heads

and causing blowholes and "flutters." Molten aluminium reacts strongly to moisture condensed out on the surface of chills, and there is always a tendency to this in a green-sand mould. It is a common slogan in aluminium practice that the moulds should wait for the metal, not the metal for the moulds; and this is sound enough advice. But if the moulds contain many chills and have to wait for long, they should not be closed up until the metal is ready. There are many practical dodges for checking the tendency for chills to sweat, smoking them with a taper, dusting them with French chalk, sand-blasting them, and so on. The best remedy is to leave out the chills, if good castings can be obtained by attention to gating.

Risers.

Risers are used primarily to feed thick sections, such as bosses, etc., which tend to solidify after the surrounding portions of the casting, thus setting up draws, local sponginess, and contraction stresses.

Risers serve also to give free exit to the air from a rapidly filled mould, to bring up oxide and any other dross collected by the metal. Occasionally they are used to keep an isolated thin section in an otherwise thick casting "live," until the remainder sets; a function which is the exact reverse of chilling.

Because of the high crystallisation shrinkage of these alloys, risers are used more freely, and of heavier section than is normal in brass practice. As in the case of chills, however, their employment can be overdone. The use of risers, their design and placing, deserves more logical consideration than can be the case if this is left entirely to the moulder.

The best gating being admittedly imperfect, a heavy section takes longer to set than an adjacent light section. The light section in freezing draws metal from the still molten heavy section; the latter sets in its turn, and must be fed by artificial means, not only against its own shrinkage, but also to make up for the metal taken from it by the light section. The necessity is shown in the casting by a "draw," or local sinking of the surface, and to cure this one "feeds" that section with a riser or a shrinkage ball.

Alternatively one may chill the section, and so force it to cool at the same rate as the thinner one; but for the moment we are considering those cases where, for one reason or another, a riser is preferred to a chill.

Now, the presence of a heavy riser, properly designed and placed, will feed that section or boss very efficiently. It introduces one further complication, however, in the fact that it tends to keep the section molten for a longer time than previously. It will not give a draw, because the section is properly fed; what it may give, in some instances, is a state of stress in the surrounding part of the casting, due to the solid contraction of the thick section taking place after the thin section has already contracted through much of its range. In a metal so "hot-short" as aluminium this often leads to cracks. The remedy in nine cases out of ten is to use the riser, but to chill the section it is feeding, and to chill it heavily to

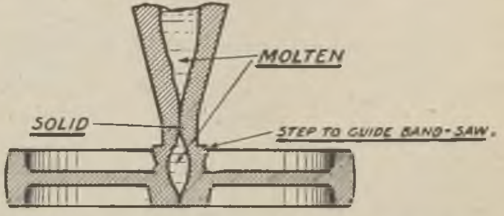


FIG. 8.—BRIDGING IN RISER AND ITS EFFECT.

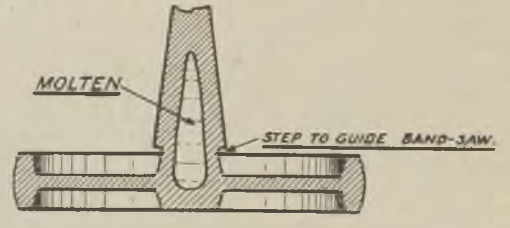


FIG. 9.—INVERTING THE RISER TO ENSURE THOROUGH FEEDING.

allow for the extra heat communicated by the riser.

The reason this point is brought forward is because it is often overlooked in practice that two distinct factors have to be faced; the crystallisation shrinkage, and the subsequent solid contraction. A due appreciation of this will save much disappointment to those who, having duly placed a riser to meet a local draw, run into troubles with cracks, the origin of which is not very obvious.

Its common sense is indicated by other considerations. Metal which comes up risers has generally passed over much cold sand, giving up its heat *en route*. It is often, therefore, of lower temperature than the section it is designed to feed; it may freeze before that section, and if this occurs the trouble is accentuated rather than met. The riser draws metal from the section; it does not feed it.

This, in fact, occurs more in practice than would appear probable, and it is due to the form of riser commonly used, which may be described as cone-shaped, with the apex of the cone resting on the section to be fed. There is no objection to such a form beyond this; that it is obviously possible for the metal at the wide upper end to be " live," and to sink as though it were feeding the casting, an appreciable time after the narrow neck near the casting has set. The tendency for the neck to set and to cut off any feeding action, has an analogy in the " bridging " seen in steel ingot practice; both have the same effect in an entire absence of feeding at a time when external appearances give the impression that matters are proceeding according to plan. (See Fig. 8.)

There are two sound methods and one bad one of ensuring that a riser is doing its work as indicated by the molten metal above. The first is to chill the section to be fed, and so force it to set before the riser. The second is to invert the riser, so that the base of the cone rests on the job, not the small end; this gives sure feeding, checks any tendency for the riser to " hang " in the mould, and means less metal melted for a given casting. (See Fig. 9.) It is not always practicable, but where practicable is worth trying.

A Detrimental Practice.

The bad method is to pour "live" metal down the riser as soon as the mould is full. This practice is fairly common, and follows on an observed inefficiency of the riser due to the above causes. It should be thoroughly discouraged as far as aluminium is concerned. Risers bring up with them, in addition to dirt and dross collected by the metal, a fairly tough skin of oxide. Pouring metal down the riser carries this skin, practically unbroken, down into an otherwise sound casting. The presence of the "seam" thus formed is difficult to trace, until some more or less important boss quietly parts company with the casting.

The fact that this does not always, or even very often occur, is one of the worst features about this type of defect and its cause. If a casting broke every time a moulder poured metal down a riser, few moulders who did this would retain their jobs. When a casting does break on service owing to a skin of oxide across a section, however, the fracture looks thoroughly bad, the stress required to break the casting can be almost nil, and "aluminium" is written down as a treacherous material. The method of its manipulation is seldom brought in question.

"Blind" risers have their distinct technical advantages in regard to some aluminium castings, besides the economical one of taking less metal. Such risers are blanked off a few inches above the section they feed, and a vent only is carried on to atmosphere.

Porosity.

It is sometimes found in practice on certain designs of casting, that with the use of the best available materials, careful melting and logically considered feeding of thick sections, an otherwise sound casting will not withstand hydraulic pressure tests. Such a casting could, of course, be doped.

Since doping is at best only patchwork, however, it seems worth while to investigate this tendency to porosity, and given that the above points are in order, in nine cases out of ten the cause will be too slow cooling through the solidification range.

This is best demonstrated by casting a brick of the metal in sand. If it is sliced up and one of the slices is used for a water-tight door, it will be seen at once just how water-tight it is. If those same slices are melted up and the metal poured out in a thin sheet on the floor, using the same pouring temperature as before, the casting should now hold a considerable pressure without sweating. The metal is the same, and the melting and pouring temperatures the same; but it has cooled rapidly through the freezing range.

The moral is that the mould must not be heated up locally to the extent of losing its chilling properties. Where there is a casting, such as a thin sump designed to withstand pressure, and of a section which in any case calls for high temperatures for successful running, it will lead to porosity if much metal is passed over the surfaces of the mould to fill heavy and tall risers. It is better to blank them off at the lowest point at which efficient feeding can be accomplished.

Using the Inertia of Incoming Metal.

Incidentally, the blanking off of risers introduces one useful factor in the production of solid, clean-cut castings. For the momentum of the column of metal in the gates, brought abruptly to a standstill, introduces a momentary pressure of very salutary effect in the forcing out of occluded gases, and in pressing an already sluggish material into the finer corners of an intricate mould. Here again, blind risers are not the panacea of all evils; they are not even best practice in a great number of castings. The above remarks are hints, not rules, and a good founder will know how to interpret them.

Low Specific Gravity.

This final point of differentiation between aluminium and the heavier casting materials has as much influence on methods used as any of the others.

The specific gravity of the light casting alloys dealt with varies between 2.85 and 3.0, or roughly one-third that of brass or iron. From this two points at least arise

The first is that with metal of so light a weight, venting must be carefully considered and thoroughly carried out. If there is any appreciable back pressure on the escaping gases they will tend to make their way to atmosphere via the molten metal rather than via the vents. This gives rise to blowholes, and/or to a loose, porous, structure at some points, owing to the metal in the vicinity being kept in continual agitation whilst passing through the freezing range. Metal which cannot solidify quietly is spongy when cold.

Effect of the Air Content in the Sand.

This factor is aggravated in connection with aluminium by the necessity for light ramming.

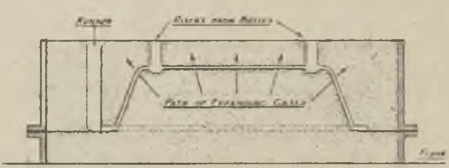


Fig. 10.

Light ramming means a porous mould and core, and it follows that the interstices between sand particles contain in the aggregate much air. Drying the mould helps only to the extent of obviating any action of expanding steam; it does nothing to meet the necessity for the large air content in the sand to expand as it warms up. That expanding air must go somewhere; the point about working with aluminium is that there is much air to deal with, and that owing to the light weight of the metal, the natural tendency is for air to escape through the still molten casting.

The simplest illustration of this is given in a casting such as an aeroplane engine sump, on which the standard of inspection is high, and which is polished all over the exterior. The obvious method to mould this is upside down, since the pattern leaves its own core, which may therefore be of green sand. (See Fig. 10.) To avoid sagging of the core and distortion of the casting, the flask would be firmly bedded on the floor. The effect would be an economical way of moulding an extremely costly casting; costly, because of the high percentage of rejects for minute blowholes and other surface defects, showing up after polishing.

It will be clear that in such a case a very large volume of lightly rammed sand is enclosed on five sides by a thin sheet of molten metal, and that the sixth side is practically blanked off by the floor. Unless unusual precautions are taken in regard to ample vents, the casting would be blown in nine cases out of ten under such conditions. In nine cases out of ten one would get a sound casting if pouring brass.

FIG. 11.

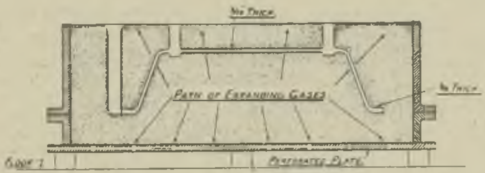


FIG. 12.

Two Alternatives.

If this casting were moulded with the open side up (Fig. 11), it would mean a more costly job in the foundry because of the necessity of hanging the core in the mould, and providing one which would hang without sagging or fracture. Yet the author would prefer this method to the alternative remedy (Fig. 12), supporting the first mould on a perforated plate clear of the floor, for two reasons.

It is possible to guarantee a sound casting. because it is known that any dust and loose sand collected by the metal could not float up to the exterior and spoil a highly polished surface with minor specks and blemishes. Because there are many similar jobs met with in practice, meter cases, fuse-boxes, automatic machine parts and so on, this one instance has been dealt with rather fully. Due recognition of the principle will save much trouble where thin, box-like castings are being made, requiring a high finish on the exterior.

Pressure in the Mould.

One further point in dealing with a metal one-third the weight of brass is that logically runners and risers should be three times the usual height to obtain an equivalent pressure in the mould. This is almost always impracticable, but a thick cope should be provided wherever economically possible.

The practice of pouring from a height to obtain an artificial pressure in the mould is not one to be encouraged with aluminium. Its effect is best seen in pouring a glass of beer from a height. One certainly gets a head on it. If not one takes vast care in relative manipulation of bottle and glass. The same care in regard to aluminium is notably absent. In no case is this sort of head wanted in aluminium, since it leads to blowholes, porosity and excessive dross. If extra pressure is wanted in any given casting, there is only one way of getting it in normal foundry routine, by increasing the height of the runners, and either by bringing the risers up to that height or blanking them off as previously described.

Fixing Height of Pouring.

This point has received far closer attention in the States than in this country, and there are at least two methods in fairly extensive use, aiming at ensuring a reasonably equal rate of pouring throughout a contract and so cutting out this much at least of the prevalent personal element. The first is to fix the pouring height by mechanical means, or by resting moulds on girders, etc., at the natural height a moulder will pour from. The second method lies in using a simple oil-sand strainer in the gate, pierced with four or five holes about the size of an ordinary pencil. The primary use of such a strainer is its surprising capacity for holding up dross and air bubbles which would otherwise be injected into the mould. It serves a second useful purpose, however, in regulating the flow of metal into the mould over a great number of similar castings, even though the moulder may tend to vary pouring height and rate from casting to casting. If such variable factors as these are fixed as far as possible in advance, much time is saved in exploring an unnecessarily wide field when troubles occur.

Use of Snap-flasks.

The above paragraphs indicate the main difficulties arising out of the low weight of aluminium; before closing this section we would mention one advantage. Because the metal exerts so little pressure on the mould, a great range of parts can economically be moulded in snap-flasks. This method economises in moulding boxes and labour of handling, and provides almost ideal natural venting.

Aluminium Moulding Boxes.

Moulding boxes are practically always made of aluminium re-melted skimmings and swarf in aluminium foundries; they are light to handle, cheap to machine, practically unbreakable; whilst in emergency they can always be melted down and run into low-grade castings.

Clean Finish.

For a clean white finish, the moulds and cores are dusted over with either French chalk, or a mixture of this with graphite. Lycopodium is also extensively used. Graphite by itself tends to give a dull finish.

Knocking out, and when to do it, is a question for individual experience on particular castings. The contraction and hot-shortness of the light alloys suggest the desirability of releasing cores as soon as possible. The hot-shortness, plus average foundry handling, suggest leaving well alone.

It is so easy to damage castings slightly when they are at a high temperature, that one should modify the accepted rule, that they should be removed from the sand as early as possible. It is suggested that where castings show cracks, however rapidly the cores are released, it might be a good plan to leave them in the mould over-night. It is possible that the cracks might then be conspicuous by their absence.

Dressing.

Dressing, in the case of aluminium, is a matter of peculiar ease. Gates and risers are quickly cut off by a band saw, and if they are so placed that a band saw can cut them close to the casting, there only remain the usual thin flashes, chill marks, and so on, to be dressed by an emery wheel, or by chisel, hammer and file.

Where a particularly well-finished job is required, either sand-blasting or bobbing with a wire brush are recommended. A white matt surface is obtained by dipping in hot caustic soda, neutralising by a dip in weak nitric acid, washing thoroughly and drying. Sand-blasting by itself gives a fine grey matt finish, and if ribs and lettering are then highly polished a very good effect is obtained by the contrast of the silver against the grey. The polishing of numerous small castings is readily accomplished by tumbling with steel balls, at some slight cost of clean definition.

Salvage, Reclamation and Repair.

Many otherwise clean and sound castings are marred by some small blowhole or crack, or locally fail to withstand hydraulic pressure tests without sweating. In most cases such work can be made perfectly good by soldering, welding, doping or caulking.

Soldering.

This is in no case recommended except where the defect does not in any case affect the serviceability of the casting, and where the cavity can be so undercut that the solder will not tend to come out whether there is an actual "joint" between it and the casting or not.

There are now solders on the market for aluminium which can be guaranteed to give a good, strong joint, given attention to directions for use. There is none in which a permanent joint can be guaranteed, under all conditions of service. Most available solders for aluminium part company with the job they are used on in a very short time, hence the need for undercutting. Soldering of aluminium should be regarded in the light of a dental operation only; a filling for appearance's sake, not an engineering job.

Welding.

All the alloys dealt with may be welded with an oxy-acetylene apparatus in the normal manner, with or without a flux. It is safer to pre-heat the casting before welding, or contraction stresses may be set up and result in serious cracks. Intricate and highly stressed castings are best annealed afterwards for a couple of hours at about 350 to 460 deg. C., and allowed to cool off in air, but this is a needless refinement in the great majority of castings in general routine production.

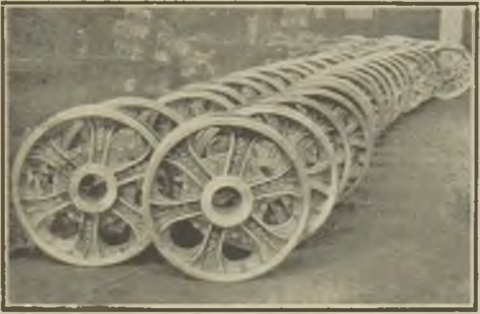


Fig. 13.—London General Omnibus Wheels made from Aluminium Alloy.

A flux is useful for dissolving the inevitable oxide film, the main obstacle to the flowing together of the casting and welding stick. In normal practice, however, a flux is seldom necessary, the film being removed by puddling with the welding stick. The latter should be of the same composition as the casting, and if casting and stick are brought together in the flame so that they are locally at the point of fusion, the oxide film may be scooped off by the stick in the presence of a reducing flame, and a good weld obtained. In some respects welds obtained thus are preferable to those obtained with a flux, for if the latter is used too copiously and left in the weld it can cause trouble later on.

FIG. 14.—LARGE JACKETTED CHEMICAL PANS CAST IN PURE ALUMINIUM.

Cracks are often superficial only, and may be deeply grooved along the line of the crack and welded up in a couple of minutes. If they go right through the casting, the latter is best scraped. If a crack right through the casting, however, does not necessarily affect its utility for the job, drill a ¼ in. hole at each end, groove deeply on both sides of the casting, and weld up the whole. Blowholes, draws, cracks, insufficient machining allowances and so on, can all be dealt with rapidly on these lines. Welding sticks are available in which no flux is found necessary, and which produce a weld rather stronger than the rest of the casting.

Plugging.

Plugging is resorted to on machined castings, etc., on which it is not desirable to risk welding, with its possibility of distortion or contraction stresses. Blowholes are permanently filled by drilling, tapping and plugging. Cracks may also be similarly dealt with; a hole is drilled at one end, tapped and plugged; the centre of the next hole is on the line of the crack at the circumference of the first plug, and so on, progressively to the end of the crack. Such a repair takes less time than would be imagined; it prevents the crack developing further, sets up no stresses in the casting, and is strong as regards internal pressures. It is, in fact, used to a considerable extent in the repairs of cracks in steam boilers.

Caulking and Peening.

A light planishing of surface defects, superficial cracks, draws, local sponginess, sand and chill marks, etc., is readily carried out with a round-nosed hammer or caulking tool. As long as the defects so treated are relatively simple, defects of appearance rather than of strength, this is a rapid and useful method of dealing with them. The extent to which caulking is carried out, however, should be under control; it is possible to introduce incalculable stresses in a casting by "drawing up" cracks or sand holes by heavily spreading the neighbouring metal.

Doping.

Slightly porous castings can be made to withstand hydraulic pressure without leaking by doping with water glass under pressure, preferably hot. The casting is then washed out and dried.

The use of water glass (sodium silicate) is liable to set up slight internal corrosion of the material; it is on this fact, indeed, that its action in closing the pores of a casting depends. Whether such corrosive action matters or not in practice has yet to be decided. In the meantime a very excellent substitute is ordinary linseed oil, introduced under pressure, drained thoroughly out of the casting, and stoved for an hour or two. This dope is as effective as water glass, and has no sort of corrosive action; it tends, in fact, to protect the casting against corrosive action. It tends to slog the ordinary hydraulic testing pumps, and for this reason the cleaner water glass is preferred. If the casting is filled with the oil, however, and air pressure applied, or the ordinary water pump connected up, this objection will largely be met. There is no need actually to pump the oil.

Some industrial waters appear to have much the same effect as water glass, in setting up just sufficient corrosion to close up a porous structure. Where this is the case, testing with tap water and setting aside wet for the night may do as much good as a deliberate doping operation, or as much harm.

If a casting requires doping more than once before it will stand up to the required pressure without leaking, it is advisable to scrap it. Such porosity carries with it poor physical properties, and the necessity for much doping or otherwise is a sound indication of the strength of the casting.

Fusion Welding.

Much subsequent patching and welding is avoided if a close scrutiny is kept on castings as they are knocked out. Whilst the casting is still at a high temperature, slight mis-runs, malformations, sand-holes, cracked ribs, etc., may be made good by so-called "burning on." Sand is rapidly built up around the defect, and a channel for overflowing metal provided. Metal is poured in until partial fusion of the affected area takes place, when the oxide film is puddled off and a sound weld is obtained. Excess metal is quickly scraped off, and finishing left to the dresser.

Fusion welding is much practised in this country, not only in salvage of slightly affected castings, but for major repairs on large crankcases, replacement of broken bosses, and so on. For the process it may be said that the operation is rapid and cheap, that it introduces no factor like dissolved gases in the weld as is the case with oxy-acetylene, and that a weld made thus by an expert is difficult to distinguish from the remainder of the casting on micro-examination. As carried out by a man who understands the problems involved, using the same metal as that in the casting, and keeping a good flow of it over the defect until all traces of oxide are washed away, such welds are entirely reliable. Where they are carried out haphazard, on a nearly cold casting, with too little puddling or too great an economy in the metal poured, they can be a source of weakness which is difficult to trace until the casting breaks on service.

Recovery of Waste Material.

All foundries inevitably produce a certain percentage of by-products or scrap material, and aluminium foundries are no exception. It is the aim of good foundry management, of course, to keep that percentage as low as possible, and also to extract the utmost useful yield from such waste material as is found unavoidable. This material may be roughly classed as under:—

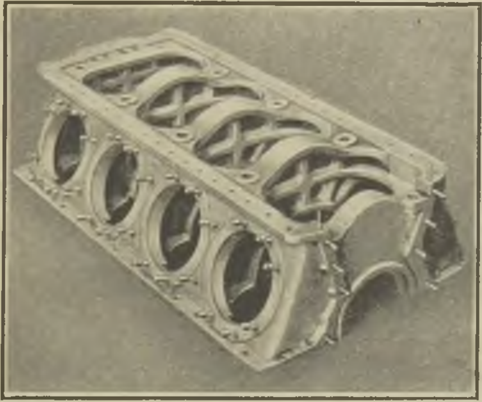


Fig. 15.—Bottom Half Crankcase of "Cub" Napier.

(*a*) *Large Scrap.*—Mis-run or cracked castings, runners and risers, clearance strips, etc., heels from pots.

(*b*) *Spillings and Splashings.*—The inevitable result of much ladling from melting pots to crucibles, and of carrying the latter through a crowded foundry.

(*c*) *Skimmings.*—The dross and scum removed from the surface of metal just before ladling from pots or pouring from crucibles into the mould.

(*d*) *Sawings.*—The heap of particles which collects beneath the band-saws.

(*e*) *Grindings.*—The fine dust from emery bobs which collects in the dust extractors.

With regard to (*a*) and (*b*), these may be returned to the pots in current use for castings of the second grade, relatively unstressed work. The only precaution obviously necessary is the separation of any dirt, sprigs, or other foreign material taken up from the floor by spillings. Lack of care in this respect is one of the causes of "hard spots" encountered during machining castings.

Skimmings consist largely of metallic alloy containing much entrained oxide, forming a stiff lace network or spongy mass, and preventing ready fusion of the metallic content. The introduction of about ½ per cent. by weight of zinc chloride liberates the metal, enabling the oxide to rise, if somewhat unwillingly, to the surface as a fine dusty powder.

In large plants skimmings are treated in an iron pot by themselves. As each charge of newly melted alloy reaches its teeming temperature, the skimmings from all pots in turn are deposited in one adjacent melting pot. Here, on attaining the right temperature, flux is added and stirred in, the pot temporarily closed, and the dross allowed to rise for skimming off. Almost the whole of the metallic content is recoverable by this method.

Machine Swarf, Sawings and Other Fines.

These are the *bete noir* of the foundryman, and if not logically treated they may be a continual source of loss. The extent of this loss may not be appreciated in many cases, since it is not very widely known how, with a little thought and trouble, this class of material may be made to yield a high percentage of reclaimed metal.

Some foundries sell all fines to metal merchants, a method of disposal which for simplicity cannot well be improved upon. The market rates obtainable are, however, low, and it is largely on this account that attempts are made to reclaim sawings, etc., which tend to run into large figures on a heavy weekly output.

Any attempt to melt down fines direct in bulk is doomed to failure at the outset from the point of view of economy. A moment's consideration of the conditions will indicate this. Each and every particle in the mass of sawings is coated with a thin but tough skin of oxide. By raising the temperature of the mass sufficiently, the metal within that oxide skin may well be brought to a molten condition. That, however, is a matter of time and of high temperature, because of the essentially low thermal conductivity of such a mass; and both time and temperature are all that are needed to thicken that oxide skin, and to make it increasingly difficult for the extremely light drop of molten alloy to break through it and fuse with the next. At a temperature of 850 deg. C. the finer sawings begin to burn actively, as seen by the brilliant glow which starts in patches here and there. If this action is allowed to continue the whole mass is quickly converted to oxide. Yet in the direct melting of fines it is difficult to get any change in the charge at all unless this temperature is approached.

The addition of large percentages of zinc chloride assists matters, but whatever flux is used the tendency to oxidation in this process is extremely marked. In other words, time, labour and melting charges are largely expended in converting a potentially valuable material into one which can be dug up in any back garden.

For this reason it is more general practice to provide a good heel of already molten alloy in the pots, into which the lower layers of fines are forced by the weight of the charge above. The insidious danger of this method lies in the very fact that it is such an improvement on the first method and that the value of the metal recovered generally exceeds the sum obtainable for the swarf itself. Thus the system appears economical enough: there is a tendency to take what the gods provide and to rest on one's oars.

Yet the total yield against that theoretically possible is invariably low: there are indeed cases

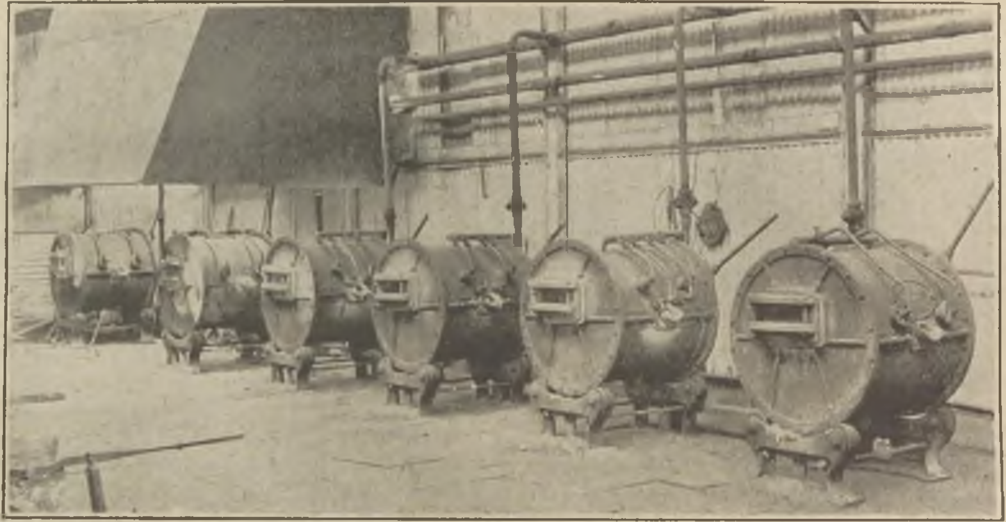


FIG. 16.—A BATTERY OF SELAS TURNER FURNACES.

on record where the total weight of metal recovered has been no more and no less than that of the original heel with which the long and costly operation was started. It cannot be too strongly emphasised how readily fines are converted to oxide, and how easy it is to reach temperatures at the bottom of the pot which will tend also to oxidise the heel. If this same heel were systematically weighed before each reclaim melt were started, the net effect would often be found disappointingly low after "running down" a large quantity of sawings.

In foundries having a keen and intelligent executive this factor has received due recognition for some time, and as a result of much patient experimental work in this country and in America, a method of dealing with sawings and similar swarf has been developed which does reclaim a high percentage of the metallic content.

Briefly, that method consists in providing a molten heel as usual, but in adding the fines only in small quantities at a time, and puddling each quantity thoroughly into the heel before adding more.

Now, to rabble these sawings into a molten heel of metal may be compared with pushing cork packing into a bowl of mercury with a pencil: an intriguing proceeding, but very unproductive of useful result. For this reason the heel is kept at round about 670 deg. C., or in a pasty condition. The particles are brought to this pasty condition by intimate contact with the heel, and the oxide skin is broken down by sheer mechanical abrasion. In other words, the particles are welded into the mass, at a temperature at which welding best takes place and rapid oxidation does not.

The sawings are introduced little by little and the mass steadily puddled, until all oil is burnt off, the oxide skin broken down, and the particles join the growing solid mass of the heel. If the latter gets too liquid, drop in a lump of large scrap. When it gets too large for convenient manipulation, allow the temperature to rise until the mass is thoroughly fluid, stir in from ½ to 1 per cent. of zinc chloride and immediately skim. Ladle into chill moulds leaving enough in the heel to recommence operations, drop in a lump of scrap to reduce the heel to a pasty condition, and start again.

A word in regard to those skimmings. If they are stacked in piles intense heat is shortly developed, burning out any zinc content, converting any metallic shots to oxide, and generally reducing the value of the material. When the pot is skimmed, therefore, spread the skimmings out at once on the floor or on iron plates, so as to force it to cool rapidly. When cool, a considerable amount of metal may be riddled out of this material and re-charged for melting. The final dross, riddled free of metallic content of any importance, is a saleable commodity to industrial chemists at a few shillings a ton, which is just better than having to pay either rent for dumping or freight charges for carting away.

The percentage recovery by the above method is remarkably high, but the best results are only obtained if sawings, etc., are kept reasonably clean. The presence of oil and grease are practically unavoidable: they are used as lubricants in sawing. A certain amount of dust is also unavoidable: but if a labourer is allowed to sweep sawings right across a shop to a general heap, he will collect much dirt and foreign matter which is wholly avoidable.

This method needs constant attention, and the criticism which may be urged against it is cost of labour. In actual practice labour costs are little affected as compared with any preceeding method, whilst the yield per cent. in reclaimed ingot amply compensates for any extra trouble or supervision. The need for continual puddling renders it impossible to use a lid on the pot, and although from a technical standpoint this is not serious because of the low temperature employed, from the human point of view a word should be put in for the operator. It is very desirable in the interests of health to use a well cowled furnace for this process, and to see that chimney capacity and surrounding ventilation are beyond reproach.

Grindings, from emery wheels and buffs collect in the receivers provided, together with much fine abrasive material. The metallic content is in an extremely finely divided state, and is difficult to deal with by any known method suited to foundry routine. This material is best sold to chemical manufacturers for what it will fetch, for recovery or conversion by chemical processes.

SUMMARY.

The foregoing hints on the peculiarities of light alloys, and how they may be dealt with in the foundry, touch only the fringe of the subject. Like the warnings and hieroglyphics that plaster the highways, however, they will seem as complicated to the tyro as they may be almost irritatingly superfluous to the expert. Yet those same road signs are regarded by novice and experienced motorist alike with due respect, and so the world becomes a little safer for democracy. And that is all that is aimed at.

Obviously aluminium castings are produced successfully from one year's end to another by men who never bother their heads about specific gravity, and who have never heard of crystallisation shrinkage. There are castings produced in thousands which are poured down one hole in the cope, and that hole becomes the solitary riser: and they are poured from re-melted Zeppelins or parts of submarines sunk in the early part of the late war, regardless of chemical composition, content of alumina, regardless of anything beyond cheapness of raw material and saleability of the finished article.

It is to the credit of aluminium that such castings do sell, and that they do quite often stand up to their job. It discredits aluminium when one casting fails to stand up to the service it was designed for.

Light casting alloys are at least as reliable as any other engineering material, given attention to the above points; no aluminium casting need ever fail in service, given reasonable design for the job in hand, and careful interpretation of the instructions we have given. The advantages which accrue from the use of reliable aluminium castings are so striking, that a little organisation on the above lines will well repay those who care to take the necessary trouble.

Advantages of Aluminium Castings.

The most obvious advantage is the weight reduction. This means primarily that where one buys enough metal to make a brass casting the same weight will make three aluminium castings. In addition there is lower handling and freight charges and so on. The economical points are now fairly generally recognised. What is not quite so generally recognised is the value of low weight technically, in the case of parts which must be accelerated rapidly and brought to an abrupt standstill. As, for instance, in large quick-break switch parts, in which simple aluminium castings have been known to stand up where high tensile bronze castings failed.

The speed of machining possible with the alloys referred to is notoriously high: an economical factor in an age when time is money.

The finish obtainable on light alloy castings is at least equal to that of brass and incomparably superior to iron. A polished surface on aluminium is as beautiful as one of brass, and it lasts longer. This particularly applies to castings exposed to sulphurous fumes or an atmosphere of burnt gas. Gas fittings, for example, when made in any of the above alloys, neither tarnish nor corrode in the unsightly manner seen in brass fittings.

Finally, all the alloys outlined may readily be die-cast in cheap cast-iron chill moulds, gravity poured by unskilled labour.

The economical value of die-casting need not be unduly stressed here, since it is so widely appreciated. It is so generally recognised that the die-casting of brass has received close and costly attention of late, while in the States at least one firm produces iron castings from permanent moulds.

Neither in brass nor in iron, however, is the operation carried out with the extreme facility seen in aluminium, nor do the dies cost so little or last so long. Where great numbers of small parts to the same design are required, there the utility of an easy die-casting medium is most emphasised. And in this the alloys of aluminium excel.

Wasters are cut to a minimum, machining is largely eliminated or is simplified by ease in jigging, a large output may be steadily maintained from a very small floor space, and the strength of the casting is rather better than from a sand mould. No material, suitable as a substitute for brass in general engineering, offers these economical advantages except aluminium.

London Branch.

PATTERN SHOP AIDS TO FOUNDRY PRODUCTION.

By F. C. Edwards, Associate Member.

The popular conception of a pattern-shop, as a place where patterns are made to given drawings, is only true in part. It implies that, in making patterns, finality is attained when agreement is secured between pattern and drawing. A more mischievous half-truth would be difficult to find!

The misconception might safely be ignored, but for the fact that it frequently invades the pattern-shop itself. Here, by confining the attention of otherwise skilful craftsmen too completely to the relationship of pattern and drawing—thus obscuring the need for that special equipment which enables a pattern to fulfil its rôle as a tool for the production of castings—it imposes gratuitous handicaps on the foundry.

Actually the pattern-shop, as the intermediary between the designer and the foundryman, functions as a translator. And just as the literal translation of a foreign language is often crude and meaningless, so a pattern may be such a perfect reflection of the blue-print as to be, in service, a very imperfect—or even useless—medium for the production of castings. Something more, indeed, than the shaping of material to conform with the blue-print (admittedly, an art in itself) is required of the pattern-shop. It should present the designer's idea *with such plus or minus modifications* as will facilitate its safe transformation into the actual casting.

This predicates the existence of certain conditions. Of primary importance is the spirit of co-operation, which should actively permeate both departments. Both the pattern-shop and the foundry, of course, have their own peculiar problems, the solving of which require that long personal experience which alone can provide a reliable basis for sound judgment. And although, up to a point, they may be regarded as separate units, it is only through their harmonised efforts that the way to general efficiency lies. Such a spirit emboldens the foundry to express its troubles, and to suggest remedies—thus extending the horizon of the pattern-shop. Gradually the latter acquires the foundry point of view. It realises that a pattern should not only measure up correctly, but must submit to a higher test, that of its behaviour in the foundry.

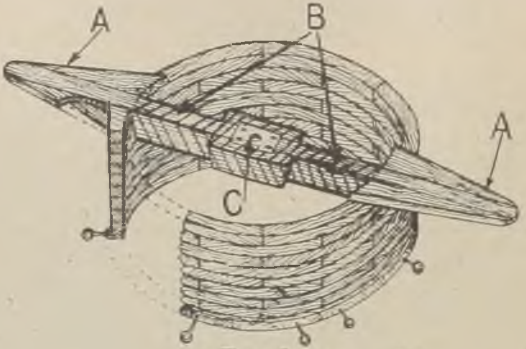


Fig. 1.

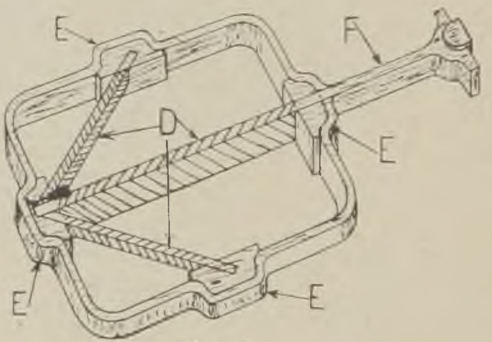


Fig. 2.

Such an atmosphere promotes the exercise of pattern-shop initiative. If this is to function efficiently, however (since it may involve some departure from the blue-print), the nature of the service for which the castings are required should

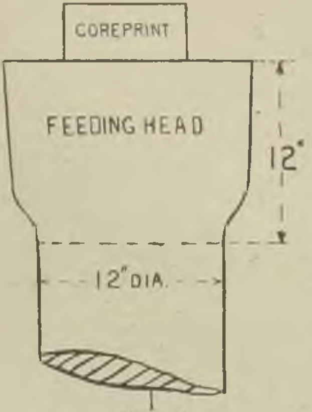


Fig. 3.

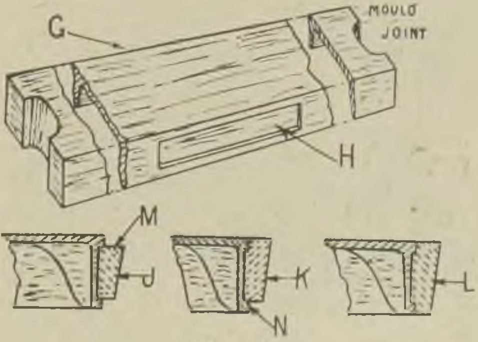


Fig. 4.

be clearly understood. No radical divergence from design—beyond recognised limits, having the complete acquiescence of the drawing office—is here suggested. The designer's idea is most likely to succeed when the pattern-shop is *au fait* with the actual requirements of the castings. For it should be remembered that questions affecting taper, fillets, clearances, machining operations, etc., are

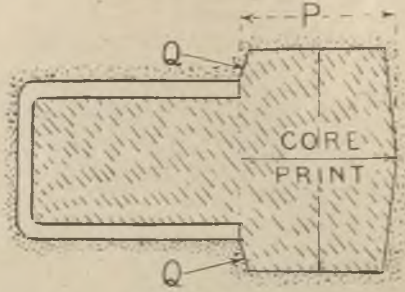


Fig. 5.

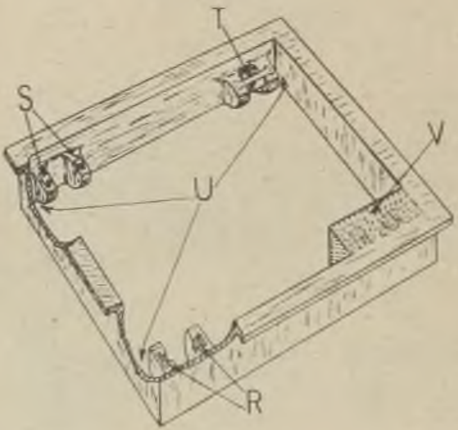


Fig. 6.

continually calling for reasoned decisions on the part of the pattern-shop.

When these conditions are fulfilled pattern-shop aids to foundry production should be abundantly forthcoming. The principal sources are as follow:—(1) Reinforcements in pattern construction as preventives against pattern shrinkage, warping, or ramming out of shape; (2) correct jointing of patterns, to facilitate moulding, and to obviate, as far as possible, unsightly joint marks on the casting; (3) the judicious employment of cores in order to eliminate difficult jointing operations and drawbacks; (4) the provision

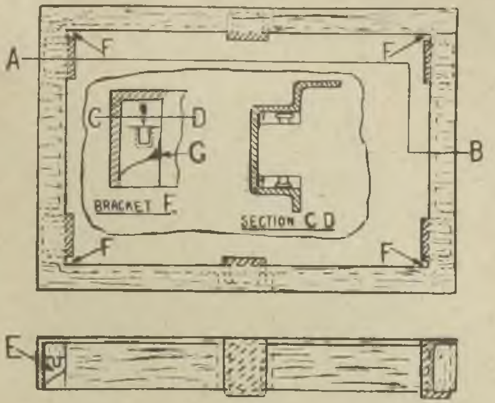


Fig. 7.

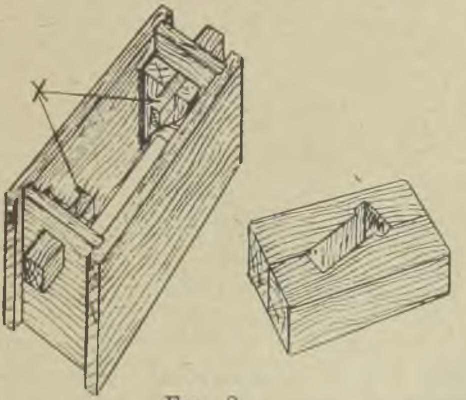


Fig. 8.

of ample bearing surfaces for cores, and the generous employment of side taper on core prints to obviate mould disturbance on the withdrawal of the pattern, and to promote accuracy of core location; (5) the adoption of easily-recognisable variations in the forms of core-prints employed for similar, though not identical, cores; (6) the limitation of small loose pieces, so far as practicable, and, where unavoidable, such pieces to be held in position by dovetails or other suitable methods as will render the loose pieces proof against displacement by ramming; (7) facilities for rapping and withdrawing patterns from the mould.

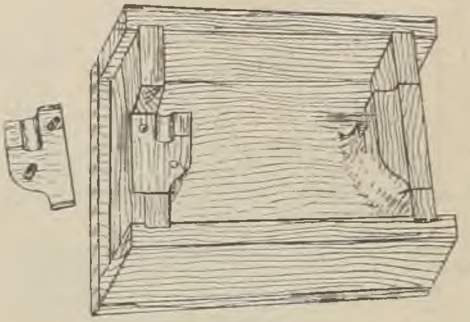


Fig. 9.

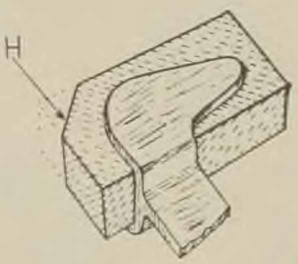


Fig. 10.

Pattern Reinforcement.

An example of pattern reinforcement is seen in Fig. 1, which represents a pattern of a mouthpiece ring. The job is moulded as shown, and leaves its own core. Lugs A A are required to be cast on opposite sides of the ring. The body of the pattern is built up of segments. A bead, which is required round the bottom edge, is seen wired on in loose sections.

Now if the lugs A were separately attached to the comparatively thin wooden ring, they would probably become loosened by rapping and pattern withdrawal after one or two castings had been made. If the moulder continued to use the pattern, further castings might be rejected because of the lugs being bent out of their required plane. In such a case all risk of lug displacement may be eliminated, and the moulder permitted to rap away to his heart's content without fear of reprisals, if both lugs are formed from one continuous piece of wood, B, extending from side to side of the ring and built into the body of the job. The connecting piece B is well tapered, and is "stoppered out" of the mould after the pattern has been withdrawn. An incidental advantage of the connecting bar is that it conveniently carries a rapping plate C. The outside bottom edge of the body of the pattern is slightly recessed so as to form a shoulder for the bead.

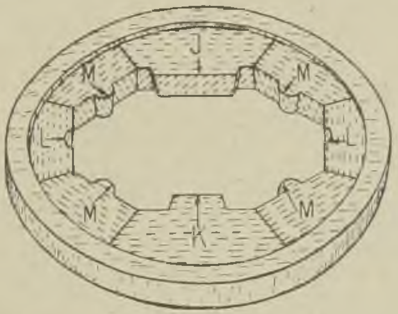


FIG. 11.

It is sometimes possible to arrange reinforcement members in such a manner as to reduce, or to cut out completely the work of stopping-off. An example of this kind is illustrated by Fig. 2, where the stopped-off reinforcement is represented by the sectioned strips D. If such a frame were sent into the foundry without some form of stiffening beyond that supplied by the shape of the required casting, it would need very special care and attention on the part of the moulder to prevent distortion or fracture of the pattern at the corners whilst the job was being rammed up. It will be noted that internal recesses E are cored out in each side of the frame. Such thickened portions form ideal anchorages for pattern reinforcements. The strips D are inserted well into the body of each block and are stopped out automatically when the cores E are placed in position. The extension F, it may be observed, is a continuation of the central reinforcing bar, halved into each end block. With the reinforcement arranged as shown, it is practically impossible to ram the pattern out of the square, and this with no addition to moulding operations.

Wherever battens are used to reinforce a weak plate (it is understood, of course, that they should only be resorted to when other methods of construction fail to give the necessary support), they should be placed on the bottom side of the pattern as moulded. If placed on the top side, they might probably be in the way of the moulding-box bars, besides entailing more or less risk in stopping off.

Pattern Suitability for Moulding.

Before proceeding with the construction of the pattern this point should be definitely settled. Nothing hinders foundry production more than a pattern made the wrong way for moulding. In cases where any considerable part of the pattern projects into the cope, the pattern should be jointed and dowelled along the plane dividing the cope from the drag. This enables the top part of the pattern to be lifted up with the cope. When the latter is turned over, the pattern can be withdrawn as easily as its counterpart in the drag. It should be remembered, however, that the moulder prefers to have as much as possible of the job in the drag. For this reason it is sometimes advisable to build the main body of the pattern in one piece, and to dowel on loosely such bosses or brackets that unavoidably project into the cope.

Cylindrical Patterns.

Whether cylindrical patterns should be jointed to mould "on the flat," *i.e.*, along their axial plane, or "on end" will depend upon: (1) the requirements of the casting, and (2) upon the moulding boxes available for the job. The pattern-shop can best serve the foundry, in these cases, by making inquiries *before* proceeding with the pattern. Cylinders, rams, etc., will generally require an extension to form the "feeding head" at the end of the pattern proper which is intended to be top as cast. This should be built in as part and parcel of the pattern. It should be of ample proportions according to the size of the job. One should err on the large side, as it is quite as easy to cut off a head, say, 12 in. long as it is to cut off one, say, 8 in. As to the best shape of riser head, there is some difference of opinion amongst foundrymen. The author, however, has found that the best results accrue from the employment of a swelled feeding head, similarly as shown in Fig. 3, in preference to a perfectly straight or plain tapered head.

Replacement of Drawbacks by Cores.

Where cores are used on the outside of a casting as alternatives, say, to drawbacks, the shape and extent of the corepoint will often determine whether such cores are to serve as aids or as hindrances to the foundry. This is especially applicable in dealing with green-sand moulds. For even if the core fits the point perfectly, and is quite flush with the mould, the casting may exhibit different surface levels consequent upon the difference in the relative hardness of the dried core and the green-sand mould respectively.

A case of this kind is illustrated by Fig. 4. Here G represents a frame casting as moulded. A recessed panel is required in one side as at H. This, of course, may either be cored out or taken out with a drawback. Coring is the simpler method for the foundry. The coreprints may be arranged in one of the three methods shown respectively at J, K, and L, which represent cross-sections through the panel portion of the pattern. In the case of J, the moulder would either joint down to the level of the top of the point M or cut away the mould to allow of the withdrawal of the pattern, and subsequently make up the mould after the core had been placed in position. It is obviously better to carry the point to the top of the job, as shown at K. This does not exhaust the available aids. For if the point is merely carried down to the bottom of the recess, the lower edge of the casting N—formed as it is from the green-sand mould—would most likely be found very uneven. The best kind of point is that as shown at L, where the core extends the full depth of the job. Incidentally neither the pattern nor the corebox is appreciably more difficult to prepare than in either of the other methods.

Balancing Cores.

Adequate bearing surface for cores also materially aids foundry production. Where a core is likely to "tip," the moulder is compelled to use chaplets, sprigs, etc. This means loss of time, in addition to the increased risk of scrap, on account of the presence of chaplets. A very simple example is seen in Fig. 5, which represents the longitudinal section of a dead-end cylinder. The part of the core P, which takes a bearing in the point, should be heavier than the portion overhanging in the mould. This renders the core completely self-supporting. The taper Q is a further aid; it facilitates the withdrawal both of pattern and core. Moreover, with an overhanging print—*i.e.*, one larger than the diameter of the casting, such a job could be moulded and cast on end, the overhanging portion Q taking the bearing.

In large, heavy cores, even where bearing surfaces at opposite sides of the core rule out all risk of "tipping," it is misguided economy to save wood by cutting down the thickness of the prints. For although the moulder may ram up iron plates on the bearing edges of the prints to obtain a firmer bearing for the core, the width of the core bearing itself—unless the moulder takes anticipatory measures to increase the bearing—will remain that as determined by the print. This, in heavy work, should not be less than 3 to 4 in., or even more.

Coring-up a Box-like Casting.

By adopting methods for eliminating risk of error in coring up moulds, the pattern-shop may save much waste of time in the foundry, besides an occasional batch of scrap castings. The mere removal of doubt, indeed, as to the correct location of cores, must tend to expedite production. The example illustrated in Fig. 6 represents a "box" casting, in which slotted bearings are required in each corner similarly, as shown at R. Now, there are at least three methods in which these bearings can be formed in the box. Single slot coreprints could be employed, as seen at S. One objection to this method is, that if even the print impressions in the (green-sand) mould were exactly as the pattern, the moulder might not maintain their correct alignment in coring up the job. Moreover, they come in the cope.

An improvement on this method is to extend the coreprint right across from one bracket to the other, as seen at T. Instead of two separate cores, the slots are now formed by one continuous core; the correct alignment of the bearings is maintained, and the cores rest securely in the drag.

There is, however, room for further improvement. It will be seen that the space, U, between the end brackets and the side of the frame is very restricted. Such a strip of green sand would require to be very securely "rodded" to prevent its becoming dislodged as the job was being poured. This risk could be eliminated by the adoption of plain, block coreprints in each corner of the box, as seen at V, and making a corebox to suit. To add further refinement to the job, the coreprints could be arranged to bring all the cores identical, *i.e.*, made from one corebox. The slots, of course, would be formed in the brackets, as part and parcel of each core—not as separate cores. An incidental advantage is that such block prints add considerably to the strength of the pattern.

Moulding a Bearing Frame.

That the overhauling of long-established methods in the light of advanced practice generally yields profitable results, is as true for the pattern-shop as it is for any other branch of engineering. Figs. 7, 8 and 9 illustrate a typical case in point. In Fig. 7 is seen plan, side elevation, and details of a bearing frame. Cored recesses containing slotted brackets, E, are required at each corner and at the centre of each side.

The pattern was originally made with coreprints projecting from the inside of the frame (shown sectioned in plan). It should be noted, that at each corner of the frame, between the edge of the coreprint and the side of the frame, there is a space, F. As in the previous example (U, Fig. 6), such a space not only causes extra work for the moulder, but may be a source of scrap. The cores were made out of the boxes shown in Fig. 8. Slot cores were made from the small box, dried, and afterwards inserted into the print impressions formed in the large core by the plugs X. This involved further risk of scrap owing to the possible mal-alignment of the slot cores. The method reigned, however, undisturbed for years.

An improved method consists of squaring up the ends of the brackets, E, as shown at G, Fig. 7 (a permissible alteration to design), which allows of a simpler core being made and the offending coreprints eliminated. The corebox is shown in Fig. 9. The brackets are joined through the slots, which enables the latter to be formed as part and parcel of the main core. This obviates the risk of incorrect alignment of the slot cores. The ends of the brackets, being squared, favour the absence of prints, and the moulding trouble at F automatically disappears. The bottom prints are retained, of course. These, in conjunction with the inside wall of the mould, against which the cores rest, are found to provide adequate bearing surface and support for the cores.

Cores to be Distinguishable.

In those cases where two or more cores in the same job are apparently, though not actually, identical, the pattern-shop should take especial care to differentiate clearly between their respective coreprints. It should not be necessary for the moulder, say, to compare cores, to measure them, or to try them against the mould in order to determine their correct location; at the first glance, he should be able to select, from a number of cores, the particular one he may require for any part of the mould. Such locating features should be arranged, of course, so as not to entail, in themselves, any extra work in moulding or coremaking.

The simplest locating "point," both for distinguishing between cores, as well as for indicating their individual orientation, is that commonly used with the square, or rectangular print, as seen at H, Fig. 10. The corner removed should be sufficiently large to avoid possible confusion with those accidentally rubbed off the core by handling: it should be definitely distinctive. A corresponding corner piece must be arranged, of course, in the corebox.

An Example.

How a more complicated job may be dealt with is seen in Fig. 11. Here a circular casting contains variously-shaped internal brackets and bosses. The inside of the mould is formed in eight sections of core. Wherever the sections are identical, the same locating feature is employed. Differences, however, are clearly registered by locating features, which differ, both in shape and size, to such an extent, that there is not much fear of wrong core location. For instance, since J is longer than K, and K is thicker than J, these cores cannot be interchanged without cutting away the mould. The two cores, L, being in every respect identical with each other, are given identical locating features. These, again, are easily seen to differ from those of M; the latter being a projection on the core, and the former a recess. It should be noted, in passing, that ample bearing surface is provided for the cores.

The great possibilities of the oil-sand core open up another field of aids to foundry production, which the pattern-shop will do well to explore. The simplicity with which these cores are made, and the comparatively short space of time required for drying even the largest core, added to the fact that they may be built into a green sand mould several days before casting, with immunity from moisture effect, places them in an altogether different category from that of the old, dry-sand core when the question arises as to the advisability or otherwise of employing cores to save difficult jointing operations, or to form delicate parts of the mould which are likely to break away whilst the pattern is being withdrawn.

Eliminating Mould Repairing.

An example of the latter kind is illustrated by Figs. 12, 13, 14 and 15. Fig. 12 represents the end of a cast-iron bearing frame, 16 ft. long, 2 ft. wide, and 7 in. deep. The pattern, as originally made, is seen in Fig. 13, which explains the method of moulding. The top of the job in the figure—which is the side as moulded—is taken away by means of a specially-constructed draw-back box. With regard to the end, it will easily be realised that after the pattern has been given the necessary rapping to enable it to be withdrawn, the mould, especially between the core-prints and facing strips, presents a very dejected appearance. Each end might possibly take half-an-hour to repair. Moreover, the disturbed print impressions would then form very unreliable guides for the slot cores.

When the pattern is arranged, as in Fig. 14, the ends of the frame, being made up as plain, well-tapered blocks, they not only require much less care in ramming up than those as shown in Fig. 13, but easily withdraw from the mould without causing any disturbance whatever. This means that mending-up is not required. Further, instead of having to place the three slot cores separately in the repaired print impressions, the moulder has but one brick-like core to handle. The box for this core is shown in Fig. 15. It will be noted that the slot cores are made as part and parcel of the large core. No variation can thus occur in the centres of the holes.

Made in oil-sand, 'this core can be produced in the time previously occupied in making the slot cores alone. Incidentally, these cores are made without being vented. Two additional advantages of the block core method, as shown in Fig. 14, are:—(1) Stronger pattern construction, and (2) the corebox can be used for other patterns having the same standard type of end.

Oil-Sand Cores and Economical Production.

The point which is emphasised by the above example is, that an altogether different standard


FIG. 12.


FIG. 13.

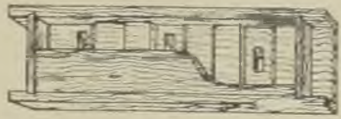


FIG. 14.

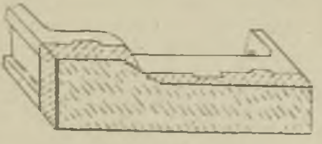


FIG. 15.

of comparison now obtains between the respective operations of moulding and coremaking than was formerly the case. Thanks to oil sand, difficult moulding problems may now be transferred from the foundry floor to the coremaker's bench *at a greatly reduced overall cost.*

By avoiding the use of loose pieces, wherever practicable, the pattern-shop may indirectly help foundry production. For loose pieces are not only liable to get out of place whilst the job is being rammed up, but may inadvertently be left in the mould to be partly, or completely, burnt away by the molten metal when the job is poured. A slight alteration in design is sometimes all that is necessary to eliminate the need for the loose piece. It is here that the pattern-shop may profitably exercise its advisory functions as the intermediary between drawing office and foundry. In close touch with both departments, and implicitly trusted, as it should be, by each, it can often point the middle path, and thus reconcile conflicting requirements.

Provision for the rapping and withdrawal of patterns from the mould is an aid that is worth much—though it costs little. Its value, especially where a number of castings are required, lies not alone in the fact that it considerably lengthens the life of a pattern, but that it enables a pattern to maintain its accuracy and finish a great deal longer than an unarmoured pattern. The neglect of this provision is *prima facie* evidence that foundry operations have not been completely visualised by the pattern-shop. It suggests the presence of other shortcomings, and the moulder is thus tempted—or, rather, driven—"to take the law into his own hands." The normal foundry procedure where a weighty pattern is devoid of rapping plates, is to accord the roughest type of treatment, usually selecting the weakest portion into which to drive a spike. A weak lug, a fragile bracket, or a badly-made joint, appear to exercise, at these moments, some fascination. The moulder then proceeds to add insult to injury by opening out the hole with a red-hot poker!

Lifting straps are equally important accessories in the case of deep, or of heavy patterns. They should not be allowed to project into the cope—*i.e.*, the top of the straps should be level with the top of the pattern. This means, of course, that the pattern must be cut away round the hole of the lifting strap. Another method, especially for "boxed-up" patterns, is that of the loose, screwed rod and top and bottom plates,

Importance of Varnishing Patterns.

A well-varnished pattern, whatever may be its other shortcomings, has an air of respectability. This, in itself, is a psychological asset, which easily offsets the cost of the varnish. Respectability commands respect. The moulder who would bruise unmercifully every available part of an unvarnished pattern, instinctively recoils from applying rough treatment to the same pattern when nicely varnished. As a physical preservative, varnish is unquestioned.

The Colouring of Pattern Parts.

Differently coloured varnish should be used to denote metal, core and machined faces respectively. Parts to be stopped-off should also be distinctively marked. It is good practice, also, to paint the pattern number on the job in large figures (it will not, of course, take the place of the raised identification figures which are to appear on the casting). The metal in which the casting is to be made should also be indicated on the pattern. This can be done either by adopting standard colours to represent the respective metals used, or merely by painting the name of the metal or alloy on the pattern. Whether the pattern is to be used directly to obtain the castings, or if it is intended for a metal pattern, should be stated. These are more or less minor aids, but they save subsequent questions, and may prevent scrap.

The above examples, taken as a whole, clearly show that a knowledge of foundry operations is essential to the pattern-shop; that this knowledge, indeed, is the inevitable price to be paid for pattern-shop efficiency. Additionally they suggest that the everyday work of the pattern-maker becomes more and more interesting in proportion as the troubles and pitfalls that beset the moulder are understood. Surely there can be no pleasure comparable to that of visualising, step by step, the various foundry operations of any given job, and arranging pattern and coreboxes accordingly. Smoothing the way here: reinforcing the ground there: barring this dangerous route: rounding that risky corner: and, generally, by the removal of doubt, to ensure a speedy and easy passage to the goal of foundry production.

Lancashire Branch.

PATTERN-MAKING AND ITS RELATION TO DESIGN AND FOUNDRY PRACTICE.

By R W. Kemlo, Associate Member.

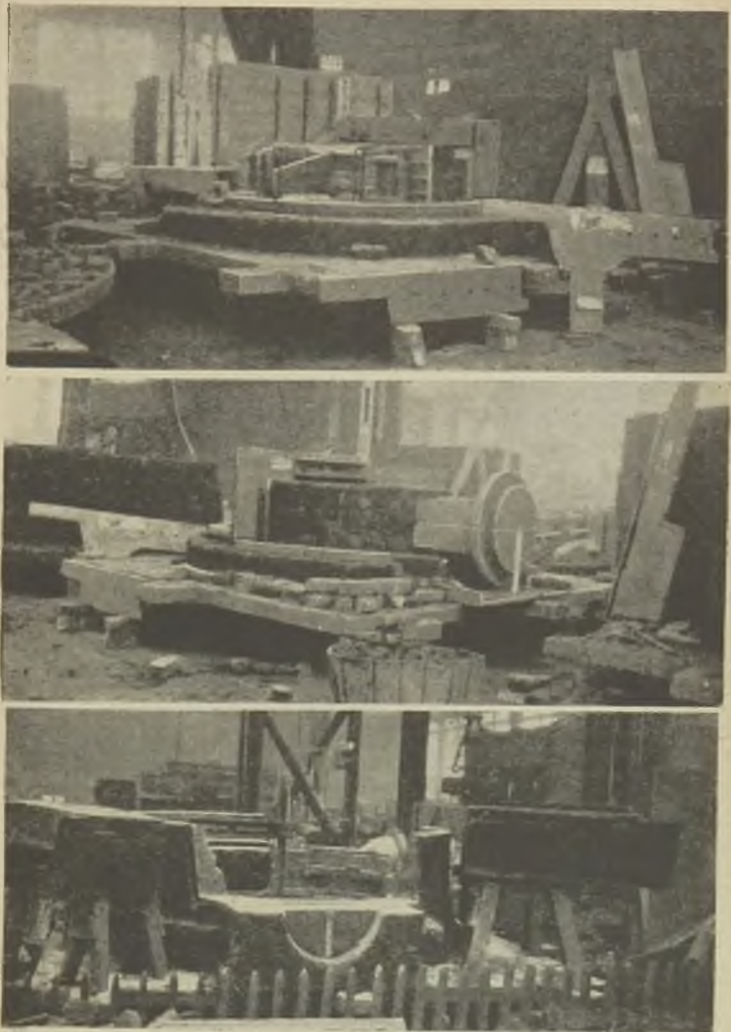
Though pattern-making as a trade in itself may be a comparatively recent introduction it is actually of great antiquity. Pre-historic man after discovering the molten metal in his fire, then finding that it could be worked into shape by hammering, eventually found that it could be run into moulds and the desired shapes obtained without so much hard labour. There is much evidence that moulds were carved from stone, and no doubt many were modelled in clay by hand without the aid of a pattern, but probably it would not take long for our pre-historic forebears to find out that by making a model of the casting he wished to produce he could make a mould much more readily.

Various materials have been used for making patterns, and no doubt pre-historic men made their early patterns in clay. In later periods wax has played a prominent part in the making of the models used, and it is well known how the moulds were made around the wax models, then placed in ovens and the wax melted out of the mould leaving the space for the metal to run into. This class of pattern was, of course, useless for repetition work.

Although the present-day pattern-maker is a specialist, he must have a sound general knowledge of engineering, he must understand the principles and method of moulding, machining and fitting together of the parts he has to make.

Relations with Drawing Office and Foundry.

This relationship is very important. Machines with machine parts are often designed by men who give very little thought as to how the parts will subsequently be made. In the rush of modern practice, the draughtsman is often called upon to give preliminary drawings to enable the pattern shop to start. One of the first essentials



Figs. 1, 2, and 3.—Showing Mould of Waterbox Struck up in Loam.

in the pattern shop is plain, readable drawings, but often these preliminaries are so faint that it is difficult to distinguish either lines or figures, and errors are liable to creep in where least expected. Preliminary drawings should be easily read and sufficient detail be given to enable the pattern-maker to visualise the job and get along with the work instead of being in doubt as to whether he is doing right or wrong. Cases could be cited where work has been put in hand from preliminary drawings which would have been made in an entirely different way if more detail had been given and the workman had been able to visualise the job before it was started. There is a great tendency to-day to design parts to save joints and machining. This is correct within reason, but it is often carried to such an extent as to cause considerably more work in the pattern shop and entailing considerably greater risks of wasters in the foundry.

Take the simple illustration of a pipe with a bend at one end. The saving of the joint and extra machining is nothing compared with the expense in moulding and the risk in the casting. The idea may be to save expense in the machine shop, but designers must remember that the castings have to be made by the foundry, and a scrap casting may cost much more than a number of machining operations. At the same time, it is not claimed that the foundry can ignore the demands of the engineers altogether, for if they can show any advancement in enginering science and the cheapening of production, the foundry must do its share to meet these requirements. The drawing office could give more attention to designs where stresses are set up in the casting, due to thick and thin sections coming in close proximity. If the heavy portions are adjacent to thin ones and there is no possibility of feeding the thick section save through the thin one, pulls and tears and internal cavities are inevitable. Many castings are so designed that there is no chance of efficiently feeding heavy sections. It is not always possible to avoid this, but it should be taken care of whenever possible. Draughtsmen should make it part of their business to find out all they can about how castings are made, as this would tend to greater simplicity in design. Although the pattern shop can generally find a way out and transfer a pattern into the foundry so that castings can be produced, the cost of that production may be a high one, whereas if the designer had known of the difficulties to be contended with he might have designed something simpler, but just as effective, which could be produced much cheaper. Sometimes a little has to be sacrificed for appearance sake, but there is no doubt that if the draughtsman knew more about moulding methods, some of the pocketed and jagged design would disappear with beneficial results to everybody.

The relationship between the pattern shop and the foundry should be such that free and open discussion should be possible when any question is in doubt. With the majority of jobs it is not necessary to call upon the moulder for his decision, the usual foundry practice being applicable, but the pattern-maker has carefully to examine the drawings and decide how the patterns must be made, taking into consideration that as the pattern is actually a tool provided for the moulder it must be made in such a manner as to facilitate the production of the casting. The method decided upon from the study of the drawing is of the utmost importance as the foundry will eventually suffer from any error of judgment at this point, so that it is here that in cases of complicated design the moulder should be brought in. He knows the conditions under which he has to work and he should know what tackle he has to use. Here inconsistencies in design may be corrected and modifications made which will simplify the work both in the pattern shop and the foundry. Unfortunately, it is often found that the moulder will not care to give his decision until he sees the pattern taking shape, but the proper time to say how a pattern should be made is before it is started and not after it is complete, and the failure of moulders to read a drawing or to visualise a job is a great disadvantage. This does not throw any reflection on the moulder as a craftsman, but it would be to his advantage and enable him to take the place he should hold in the engineering industry if he

Fig. 4.—Casting of Part of a Turbine.

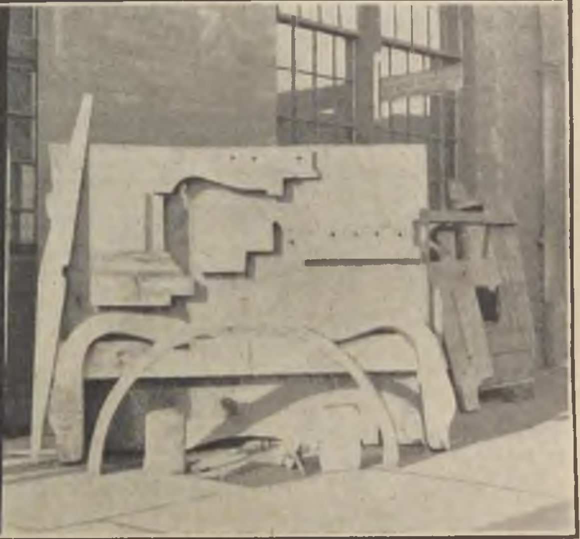


Fig. 5.—Showing Pattern-making required to Produce the Casting shown in Fig. 4.

were able to discuss a job right from the drawing board. Patterns made to suit one foundry do not always meet with the approval of another, and cases are known where patterns which have been made to suit one man and worked successfully have had to be altered when given to another man in the same shop.

Contraction Allowances.

Shrinkage or contraction causes much trouble to the pattern-maker and moulder, and at times is difficult to deal with. The average contractions for cast iron in cooling is about 1/10-in. to the foot, cast steel about 7/32-in., brass and malleable iron approximately the same as steel, but the contraction of castings varies with different factors such as the mixture of the metal, casting temperatures, the different rate of cooling, the thickness of the casting and the general design of the casting. Castings of thin section cool quicker and contract more than thick ones. It is this difference in cooling that so often causes trouble in the case of castings of unequal thickness. Large and heavy castings will contract less than thin ones and the presence of cores in castings of box sections will prevent contraction. In making his allowances, the pattern-maker has often to use his judgment working on past experience on similar classes of work. Unfortunately, he sometimes finds himself in trouble by having allowed either too much or too little. Another trouble due to contraction is distortion. A thin plate may be moulded perfectly flat and true, but when the casting is taken from the mould it will be found to be warped. This is due to the fact that cooling takes place first at the corners, then along the edges, and lastly in the centre. This is specially noticeable when a boss is cast in the centre of the plate. The chance of getting a straight casting is very remote. In many cases this can be counteracted by making allowance for this camber in the pattern, but here again the pattern-maker is working in the dark, for it is difficult to tell how much the casting will go and in which direction it will warp and often several castings have to be made before the necessary allowance can be determined.

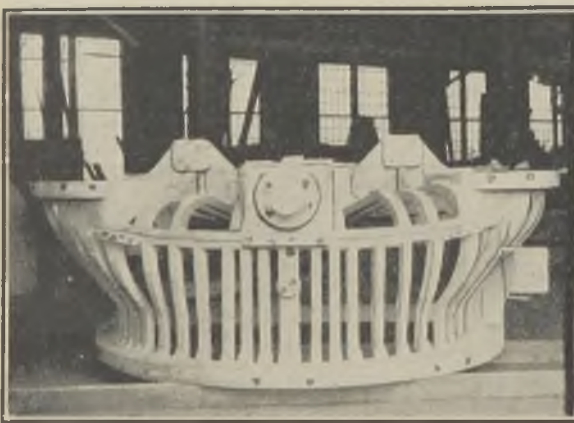


Fig. 6.—Skeleton Pattern for Part of Turbine Cylinder.

Fig. 7.—Shows the Casting made from a Skeleton Pattern.

After carefully studying the drawing the patternmaker proceeds to lay out the job full size to the contraction rule marking on all machining allowances and the exact position of cores, if any. In large work sections are laid down to enable him to visualise the job and map out the methods of building. In planning the building of a pattern, consideration has to be given as to the quantity of castings likely to be required and the strength required to resist the necessary ramming and withdrawal from the mould. The size of the job will, of course, decide a great deal. It is really surprising the amount of pressure put on a pattern when rammed up and the pull required to remove it from the mould. The pattern has, therefore, to be constructed to withstand the pull and not come to pieces when being withdrawn. Taking patternmaking in its simplest form, it is the making of a model which will be practically a duplicate of the casting required. If it is desired to produce a casting off a block, say 12 in. square by 2 in. thick, the pattern is simply a block of wood to these sizes. If a casting of a simple lever is required, the lever is reproduced in wood, sometimes making the pattern in halves to facilitate making the joint in moulding. But the time comes when more vital decisions have to be made. A casting of hollow box form with overhanging flanges or pockets may be required, and in this case the pattern, if made exactly as drawing, could not be withdrawn from the mould. Cores or drawbacks may have to be resorted to, or there may be loose pieces on the pattern which can be drawn into the mould after the bulk of the pattern has been withdrawn. In numerous cases all three methods have to be used on the same pattern. The decision as to whether a core or a drawback should be used is most important, as the cost of moulding may be considerably increased, and it is in a case of this sort that the foundry could with advantage be consulted and give their decision.

In some cases it is possible to produce a casting without going to the expense of a pattern. This is done by a method which, though sometimes entailing greater cost in the foundry, may save considerable cost in the pattern shop.

Moulding a Pipe.

As an illustration, a large straight pipe may be taken. All that is required from the pattern shop is a plain straightedge or strickle and two flanges.

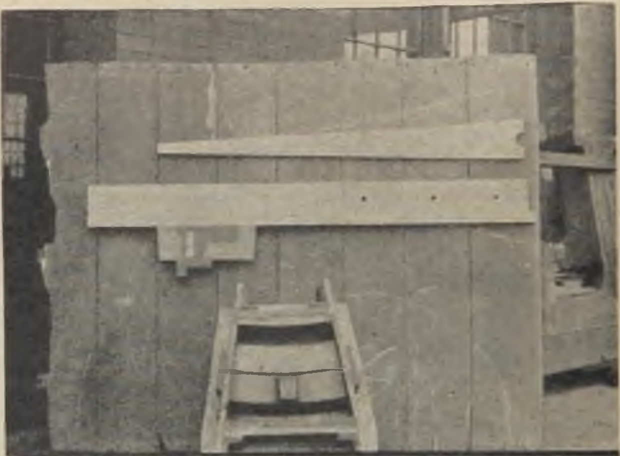


Fig. 8.—Shows Pattern-making Required to Produce a Large Ring.

Fig. 9.—Shows the Mould with Cores being Placed in Position.

The core-maker strikes the core up on a barrel of suitable size, using the straightedge, testing the diameter with callipers and finishing off to a nice smooth surface. After this has been dried in the stove it is again placed on the horses, and he adds another coat of loam equal in thickness to the thickness of the metal of the pipe, and the pattern-maker is then called in to set the flanges on the body to the exact length of the pipe. This is called a loam block or loam pattern. The moulder then uses this in the usual way, bedding the block into the floor up to the centre line, making his joint along the centre line and covering the top half with a moulding box. After he has moulded both halves, the top box is lifted off and the loam block withdrawn. The mould is finished, the flanges and the thickness of loam over the core are stripped off, and core used in the mould. Steam-engine cylinders and numerous

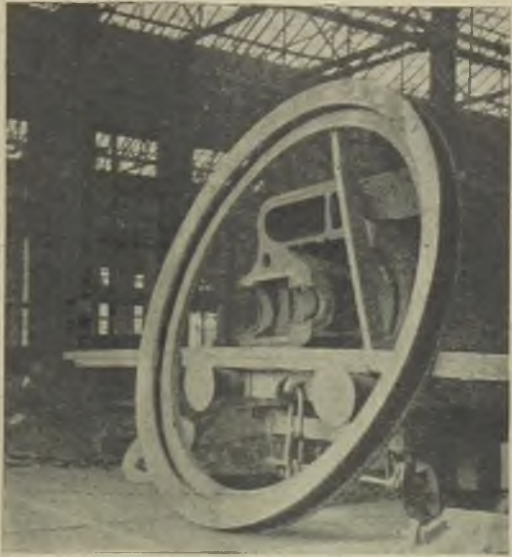


Fig. 10.—Shows Finished Casting.

cylindrical castings can be made in this way by the addition of parts which can be set up on the loam block. Thus there is what is called the necessary tackle for making loam moulds.

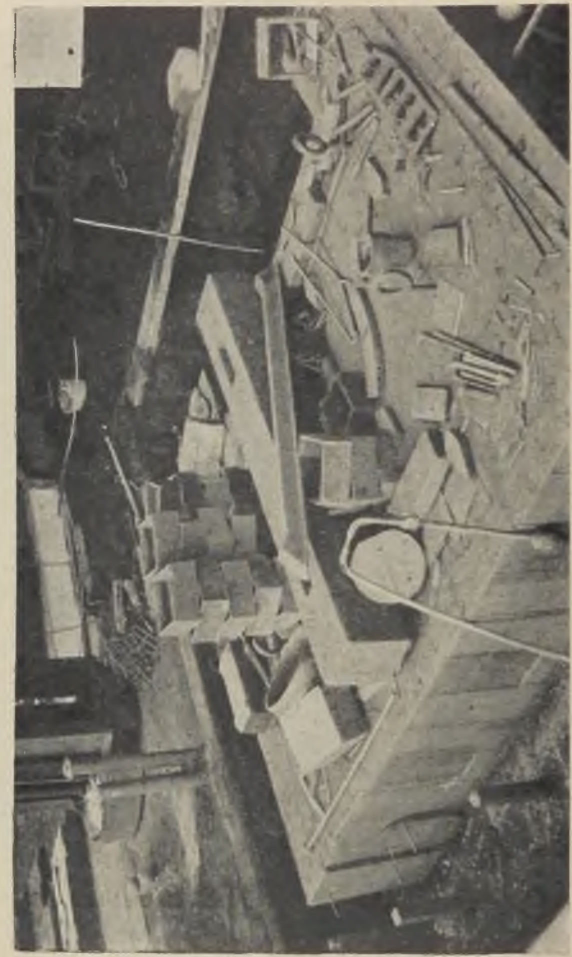


Fig. 11.—Shows Pattern of Turbine Cylinder being Rammed Up.

Condenser Water Box.

Cylinders and such large castings as turbo-generators, yokes, endbells, condensers, waterboxes and covers, and the like can be produced in loam

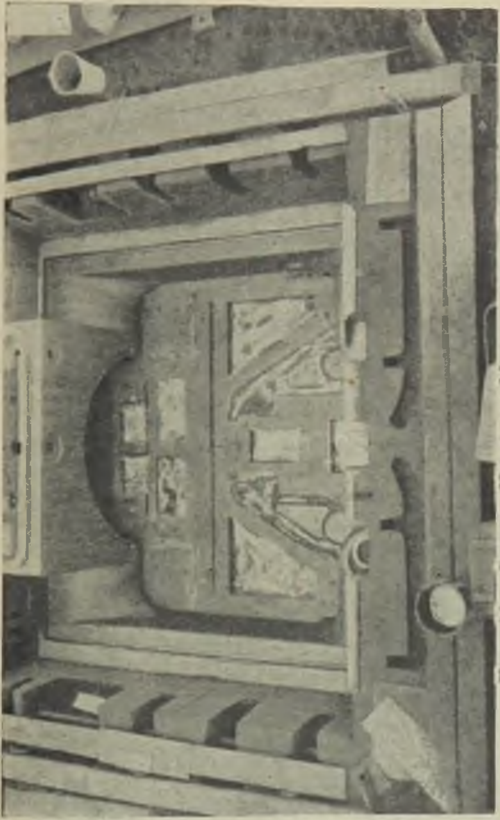


Fig. 12.—Shows View of Mould after Finishing and Ready for Coring Up.

without making full patterns. It would be quite a big job, and require a good deal of illustration to show the making of a generator stator casting, but a short general description of a mould for a surface condenser waterbox will show the principles. Figs. 1, 2, 3 illustrate the boards or strickles and general details of the mould struck up in loam. The spindle, which may be any diameter to give a rigid centre, is fixed in a

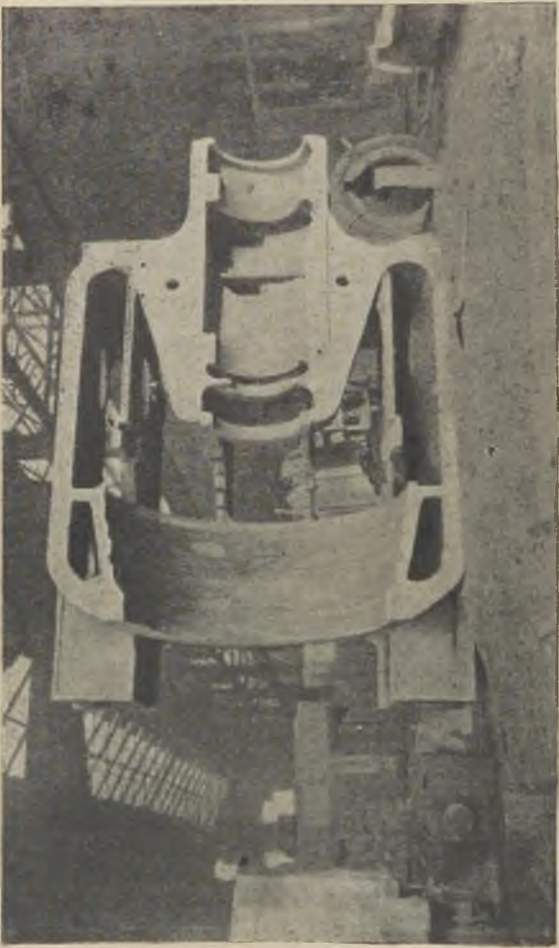


FIG. 13.—SHOWS CASTING. NOTE INTRICATE CORING.

suitable footstep in which it may revolve. On the spindle there is an arm which carries the strickles. This arm is made to slide up or down to any required height. Sometimes the spindle is a fixture in the footstep, and the arm revolves on the spindle between two collars. When the job is a deep one, two arms are necessary to hold the boards or strickles. A cast-iron plate of convenient size and thickness for the work in hand is set up level over the footstep, and the spindle, with the arm attached, is placed in position through a hole in the centre of the plate. The board which forms the seating for the core is bolted to the arm and set at a suitable distance from the plate. The plate is wetted with clay-wash, and a thin facing of loam is levelled on top of plate. The moulder then proceeds to build up on this to form the seating for the core. The bricks are laid with soft loam with open joints to allow air and gases to escape freely when the mould is being poured. The brickwork is faced with a coating of loam which is swept up in a rough state, and is then given another coating of fine slurry and swept up smooth and true with the seating board attached to this arm revolving round the spindle.

When building up the brickwork the moulder has to make provision for the branches or any facings which may come in the way. When the seating is complete the strickle is changed for the core strickle. A cast-iron ring is placed in the bottom of the seating, and on this the moulder bricks up the centre core, facing the outside of the brickwork with loam and striking up smoothly. The bottom core ring is provided with staples for lifting, and when the core is finished to the required height as determined by the board it is lifted out of its seating and placed on one side out of the way. The outside of the mould is then proceeded with. The core strickle is taken off the arm and replaced by the strickle for the outer diameter. The branches for which full patterns have to be provided are now accurately set up in position, usually by the pattern-maker, all the centre lines and measurements being taken from the spindle. The branches being in position, the moulder then builds up the outer wall of the mould, making provision for runners and the joint over the top half of the branches. The joint is necessary, as the branch pattern has to be withdrawn from the mould and provision has to be made for setting the branch core in position. The outer wall is built up and faced on the inside with loam and struck up true with the strickle which forms the outside of the casting. The top part of the mould is struck up on a plate separate from the mould using another spindle, and the strickle provided for this purpose. The building and strickling complete, the moulder now carefully removes the branches, all facings, flanges and loose pattern parts from the mould, and proceeds to make up any broken edges and finish off the mould. All surfaces which come in contact with the metal are given a coating of liquid blacking, which is carefully smoothed off to give the surface of the casting a good finish. The whole mould is then placed in a stove, and all moisture thoroughly dried out of it.

When dry the mould is placed in a pit for assembling. The centre core and branch cores are placed in position, all core vents being carefully cleared and the mould closed. The outside is then rammed all round with floor-sand, and to strengthen the walls to withstand the pressure inside the mould when it is poured. The runner boxes are placed in position and made up, and the mould is ready for casting. This is only a rough description of making the mould, but it gives some idea of how this class of pattern is used. Small sizes of waterboxes are usually moulded from full patterns, the flanges on one side being left loose and the cores made in boxes. This is the most economical method of moulding, but in larger sizes the extra cost of the pattern would be prohibitive. In the same way fly-wheels, large pulleys and the like can be made either from full patterns or from a mould built up in cores, or from a mould struck up in loam with cores to form the arms.

Turbine Cylinder.

Fig. 4 illustrates the inlet end of the top half of a turbine cylinder. The mould for this casting was built up entirely in loam, and only a small amount of pattern-making was required for the comparatively large job. It is approximately 5 ft diameter, and stands about 3 ft. high. Fig. 5 shows all the pattern-making required to produce this mould. This is a very good illustration of how simplicity of design helps to lower the cost of production, for though the cost of moulding was rather more than it would have been if full patterns and coreboxes had been provided, the cost of the pattern and boxes would have been considerable, and the saving in the foundry so small comparatively that one would not be justified in incurring the extra cost.

Skeleton Patterns.

When only one casting is required, and in cases where a casting may be only seldom called for, it is possible under certain conditions to rig up a cheap or temporary pattern. Flat plates can be made from a simple frame made to the outside sizes and thickness, the sand in the centre being strickled out. A plain ring can be made from a segment attached to an arm and rammed up a number of times to form the circle. Pipes of all sizes are frequently made from skeleton patterns. In many cases large skeleton patterns are made when the designs lend themselves to this class of work, and the number of castings required does not warrant the expense of full patterns.

Fig. 6 shows case of a typical skeleton pattern for the bottom half of the inlet end of a turbine cylinder. Owing to the irregular shape, it was hardly practicable to sweep up this mould, but the design lent itself to the making of a skeleton pattern; and Fig. 7 shows the casting ready for shipping. It is of interest to realise that the pattern-making in this case cost considerably less than full patterns, but the moulding cost was approximately one-third more than if a full pattern had been used. This shows a good saving on the first casting, but, should this casting be repeatedly called for the extra cost of moulding and the cost of fixing up, the pattern every time required will counteract any saving made. Sometimes only the outside of the mould can be struck up, and the inside is formed by cores made in coreboxes, and in some cases the centre core is struck up away from the mould. This depends upon the designs and various conditions. Loose wood patterns for moulding in green sand are made in various ways, according to their size and contour. Patterns for bedplates and castings of hollow box section are made in sections, each section being built up of frames half-lapped together and sheeted over with boards.

In patterns of large size it is out of the question to make them solid. It is obvious that they would be too heavy to handle, and by framing and boxing considerable saving in timber is effected, and the pattern will retain its shape better.

Allowances for Taper.

When making a pattern, it is necessary to make allowances for taper or draft to enable the pattern to be readily withdrawn from the sand. It will be readily understood that when the sand is firmly packed around and into all the corners of the pattern, it is liable to take much pull before it can be removed, and, if the pattern is perfectly parallel, it is impossible to withdraw it without disturbing the shape of the mould. In the same way, if sand is rammed round a pattern, there must be clearance to withdraw the pattern, and the only way to provide the necessary clearance is either by excessive rapping, which knocks the mould out of shape, or by allowing sufficient taper, which, after a slight rapping of the pattern will enable it to be readily removed from the sand. The question of taper is generally left to the pattern-maker to decide, and he is generally accused by the moulder of leaving insufficient. To quote from a recent article: "The attainments of the pattern-maker in the way of draughting and working wood into various forms count as nothing to the moulder if he constructs patterns that will not draw. The moulder's skill is proved by having a 'good cast'; the pattern-maker's (if he only knows it) by having a good draw." To have the corners, edges, or portions of a mould started or broken through ill-drawing patterns is not only aggravating, but is often the cause of defective castings. Though this matter is one which has been left to the pattern-maker to deal with, it is one which might well be considered by the draughtsman before the drawing comes to the pattern shop.

The pattern-maker's difficulty is in determining which way to allow the draft, that is, whether to make his pattern larger at one end or smaller at the other than drawing sizes. Sometimes a middle course is taken, and it is made a little larger at one end and a little smaller at the other. Even then trouble may be encountered, especially when the castings have to be machined in jigs, as slight variations in sizes at the location point throw the centres of holes out of position. The amount of taper to be allowed on a pattern will vary according to conditions. It is often necessary that certain parts have to be as square as possible, but wherever practical, taper should be allowed. It will be obvious that, if a pattern is tapered so that it will leave the sand freely, the life of the pattern will be prolonged, as it will not require to be rapped. The mould will be truer to shape for the same reason, and will not need to be mended up, as is sure to be the case when a bad draw results, and we will agree that it must be particularly aggravating to any conscientious moulder to have his mould pulled to pieces and have to patch it up again.

When the outline of a pattern is such that the mould has to be jointed through the centre line, as in the case of a cylinder, it should be made in halves. It is not always necessary to do this, but in most cases it is expedient that it should be so. It will facilitate the making of the mould joint, and more particularly it will save any disturbance of the sand when the top and bottom halves of the mould are separated. Each half of the pattern can be more readily withdrawn from the mould, it is often necessary to leave deep bosses and brackets loose, and when the pattern is withdrawn, the boss or bracket is left in the sand, and each piece is afterwards withdrawn separately.

Plate Moulding.

It is true plate moulding has not been developed in this country to the same extent as has been the case in America. Quantity production has not been appreciated in the same degree, and owing to the lack of standardisation in the engineering industry, the need for it has not been so great. In recent years, however, manufacturers have become alive to the fact that only by such methods will they be able to hold their own in the markets, and are adapting their plants to cope with modern requirements. Under these conditions arrangements must be made with the draughtsman to simplify his design. The foundryman must endeavour to understand what the designer wants, and why the pattern-maker desires to do certain things. The designer must understand that the moulder has his difficulties to overcome, and is in a position to make suggestions which may enable a casting to be more readily produced, and should be prepared to consider any suggestions made. Designs should be carefully considered before put into work to ensure that they will be quite standard, as changes in this class of work are often very expensive to make, and patched up patterns do not tend towards rapid production, often being responsible for bad draws in the mould.

It does not follow that because a pattern is on a plate that it must be used on a machine. There are some jobs that can be more economically worked from a plate pattern rammed by hand. No matter whether one is using a machine or not, it is undoubtedly true that there are advantages in using pattern plates for repetition work over using loose patterns. With pattern plates the joint is already made and an accurate parting is assured. Plate moulding means that instead of the pattern being worked loose in the sand it is fixed on to a plate which may be either wood or metal, and the plate follows the joint line of the mould. In the foundry with which the writer is connected small patterns are fixed on metal-machined plates which are generally used for standard product in large quantities, and on machine boards for what may be termed semi-standard for smaller quantities, and the larger patterns are put on wood boards called follow boards to be worked on the foundry floor. The term "follow board" signifies that one board follows the other or matches up to the other.

Whether a machine is used or not there is unquestionably great advantage in using plate patterns for repetition work. Moulding boxes should be standardised as far as possible, and so arranged that no superfluous sand has to be rammed. The patterns can then be arranged on certain standard plates or boards. With small loose patterns it is possible to group them together and make what is called an oddside. This may be made from sand, plaster of Paris or similar material, and forms the joint of one half of the mould. The first box is rammed up on this with the patterns in position and rolled over, the oddside is then removed, leaving the patterns in the half mould. The other box is then placed in position and rammed up in the usual way. But though this does effect a saving in time, the patterns will still have to be handled, whereas with the pattern plates the patterns are fixed to the plate and all withdrawn together. It will be obvious how efficient the draw will be, seeing that the plates and boxes are all drilled to the same centres, and the pins in plates and boxes form steady guides in drawing the patterns.

Mounting Patterns on Plates.

In plate moulding, when a pattern is in two halves, each half is fastened on a separate plate, each part is rammed up separately, and the moulding boxes are not brought together until the mould is ready for closing. With the plate the joint of the mould is made as the moulder rams his mould, and is quite accurate and requires no finishing.

Having decided on pattern plates and knowing what size boxes to use, the patterns must be arranged to fit as large a number as possible on the plates. This will depend on the size and peculiarities of the pattern. Very often it is only possible to get one pattern on, and sometimes as many as eighteen to twenty small patterns can be fixed on one plate. It will be obvious that when so many are on one plate the greatest accuracy has to be exercised, as each must be a duplicate of the other. It must not be imagined that only small patterns can be adapted.

Patterns of quite large dimensions are dealt with in the same way, the only consideration being that there should be sufficient quantities required to warrant the initial expense, which in the case of plate patterns is somewhat high. When two halves of a pattern are placed on separate plates, when the mould is made and the two halves are brought together, the halves must match up exactly, otherwise there will be overlapping at the joint, or in the case of a casting of a disc section there will be thick and thin metal. Obviously considerable care must be exercised in registering the respective halves, to ensure true castings.

To obtain a true register two halves of a pattern are dowelled together. The pattern is then secured to the plate and drilled through the dowel holes. The two plates are then placed face to face on the pins and the other plate is drilled, the first plate forming a jig for the second. The patterns can then be dowelled in position and secured by screws. Sometimes a job can be registered through the plate. In very many cases the patterns have to be set by measurement, all measurements being taken from the pin centres. By accurately placing a number of patterns having a flat surface along one side of a plate, a double number of castings can be obtained. Both top and bottom halves of mould are made from the one plate, and in placing the one half on to the other half the impression is on opposite sides. The runner is placed along the centre of the plate and the double set is produced, one on the bottom-half and the other on the top-half. If double the number of patterns were placed on one plate the moulder would have still to ram a top half, so the cost of half the pattern is saved.

Loose parts in this class of work should be avoided wherever possible, owing to the danger of these getting out of position in the mould, with the resultant loss of the casting, and the risk of their being lost in handling and storing. Unfortunately, loose pieces cannot always be avoided, and wherever they are used every care should be taken to ensure that every piece will fit into its proper place.

The degree of accuracy which is being called for in a rough casting to-day is really astonishing. This is due to the fact that repetition in the foundry is also repetition in the machine shop, with the use of jigs to simplify the operations of machining. These jigs are usually made to a drawing on which no allowance has been made for any slight irregularity in the casting. The jig-maker does not always realise that the moulder is working in sand, which is subject to distortion from any slight cause, such as the tapping of the plate or the withdrawal from the mould, or even the pressure of the metal when poured into the mould. The pattern-maker can sometimes make certain allowances, but he cannot always take care of this trouble, and in making jigs when a casting is not available a little discussion would many a time be beneficial in fixing certain location points which could be almost guaranteed.

Lancashire Branch.

REFRACTORIES IN THE FOUNDRY.

By H. V. Grundy and A. Phillips, Associate Members.

The thought which has prompted the authors to give this Paper is that a knowledge of the various refractory substances is of extreme importance to foundrymen generally and geologists do little to assist them. The amount of published matter upon this subject is very limited; it is found, therefore, that materials of vital consequence in the production of castings are being dealt with, and treated with a fair measure of success, from a wholly practical standpoint. Metallurgists have not acquired the same theoretical knowledge of the silicates, etc., which go to form these refractories, as they have of the chemistry of iron and steel, and consequently it has devolved upon the moulder to determine for himself what is required. During the past few years efforts have been made to fill this void, and we have had the investigations into the British Resources of Refractory Sands, conducted by Professor Boswell, of Liverpool University, of refractory materials, including fireclays, by F. R. Ennos, Dr. Alex. Scott, A. B. Searle, J. W. Mellor, and the British Cast Iron Research Association.

At present there is no complete set of standard tests or specifications upon which users of foundry refractories can rely for the selection of the best materials necessary for their various purposes, and the only way upon which foundries have to depend is by actual service tests, a method which is both time-consuming and expensive. The extent to which these materials enter into our every-day work is lost sight of by many, probably owing to the fact that we are fortunate enough to have good sources of supply, and it has undoubtedly been this abundance which has retarded investigation into this subject. Unlike some countries, England possesses important deposits of refractory materials, but little has been done until late years to ascertain their true

TABLE I.—*Sands.*

Analysis.	SiO_2	Fe_2O_3	Al_2O_3	CaO.	MgO.	Loss on ignition.	Alkalies.
Mansfield	83.5	2.74	8.31	1.5	0.47	1.95	1.53
Road	81.7	3.00	10.20	1.2	0.39	3.10	0.41
Manchester	85.15	2.61	7.77	0.66	0.63	1.90	1.28
Sea sand	90.70	2.61	2.53	1.56	0.71	1.35	0.54

Sieve Tests.	30—20	60—30	90—60	120—90	150—120
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Mansfield	3	10	25	52	10
Road	34	30	15	6	15
Manchester	0.5	29.5	47	7.0	6
Sea sand	5	60	27	5	3

Refractory Tests.

Mansfield	Seger Cone No. 28	1630 deg. C.	2966 deg. F.
Road	,, ,, 20	1530 deg. C.	2786 deg. F.
Manchester	,, ,, 33	1730 deg. C.	3146 deg. F.
Sea sand	,, ,, 30	1670 deg. C.	3038 deg. F.

	SiO_2	Fe_2O_3	Al_2O_3	CaO.	MgO.	Loss on Ignition.	Alkalies.
Erith	94.1	0.54	3.41	0.20	Trace	0.9	1.06
Belfast (Fine)..	76.0	1.90	8.50	4.60	1.30	3.40	3.99
Belfast (Average)	82.3	1.8	3.30	1.0	0.9	1.60	3.30

extent, yet not only ironfounding but glass and pottery manufacture need its assistance, and its uses are so varied that even domestic use is found for it in polishing materials. It is not the object of this Paper to go too deeply into this matter from a geological standpoint, although it is a subject of great interest, but rather from the point of view of the foundryman who has sufficient interest in his work to have a desire to know something more of the materials which form the basis of his work, and to give some idea of the approach to a study of this nature.

To what extent does sand concern the foundryman? Probably very few realise the amount used in the production of a ton of castings. The figures shown will demonstrate the extent of the indefinite conditions existing in many foundries to-day, and as the writers are of the opinion that foundry losses are proportional to this, they can safely assume that if constant conditions could be maintained in the materials used such losses would be reduced to those governed by human error. Unfortunately to do this in its entirety is not at the moment a commercial proposition, but it has to be admitted that the value of exchanging amongst foundries data relative to sands obtained locally is not fully appreciated, and many beneficial results would be obtained if we sought for a closer knowledge of the sands used locally, and of those existing in our midst.

Sands.

Chemical and physical properties of moulding sands have been determined and given specific names, thus:—(*a*) Chemical analysis and mineral analysis, (*b*) fineness, (*c*) strength, (*d*) permeability, and (*e*) durability.

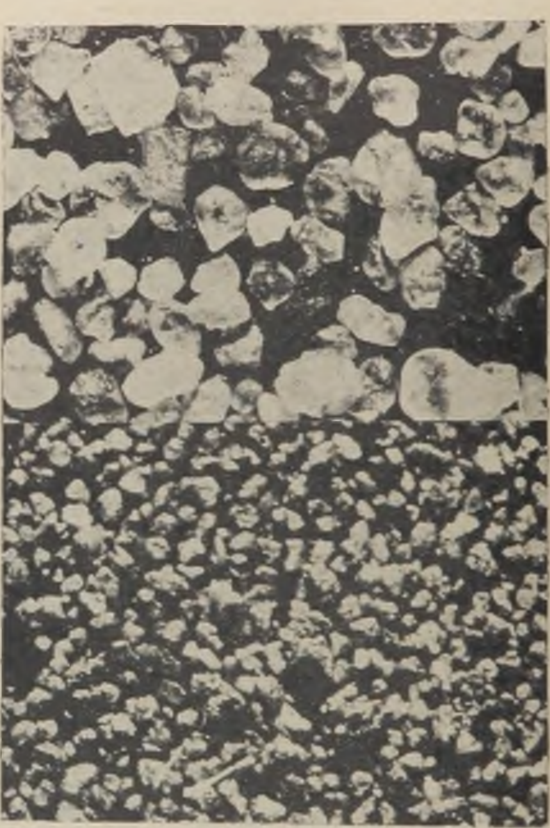
Obviously the first and probably the most important consideration is that the sand should be capable of withstanding the effect of great heat, and this property is dependent upon the amount of silica and alumina present and the comparative absence of alkalies and alkaline earths, such as potash, sodium, etc. (Table I). These latter combine with the silica and form silicates, and result in fluxing. This is a great disadvantage, and detracts very considerably from the appearance of the castings; thus it is seen that the actual value of an analysis lies in the readiness with which the figures given for silica, alumina, alkalies, lime magnesia, and iron oxides are appreciated. These are the contents to be sought for, and their influence correctly interpreted. Of course there are many other compounds present which have varying influences upon the sand, but broadly speaking they are relatively small in quantity, more or less difficult to determine, and may consequently be ignored. Further explanation of these constituents and their influence upon the whole will be given under the several headings, the next of which is fineness of grain size.

Fineness of Grain Size.

This goes to distinguish between open and close sands, and calls for little explanation. This is clearly illustrated in Figs. 1 to 5. It should, however, be particularly noted that grains approaching the pebbly condition, and those approaching silt or dust should be avoided. For general purposes a sand should be reasonably coarse, the object being to obtain a material which possesses a maximum natural porosity and permeability, with sufficient bond to enable it to be moulded into the desired shape. Pore space should be evenly distributed, and for this reason wide differences in grain-size should be avoided, and round rather than angular grains will do much to assist porosity. Of course there are many uses for sand of small grain size, as in the light casting trade and the brass foundry, but where this is used it is desirable to assist venting by means of coal dust, etc.

Green Bond.

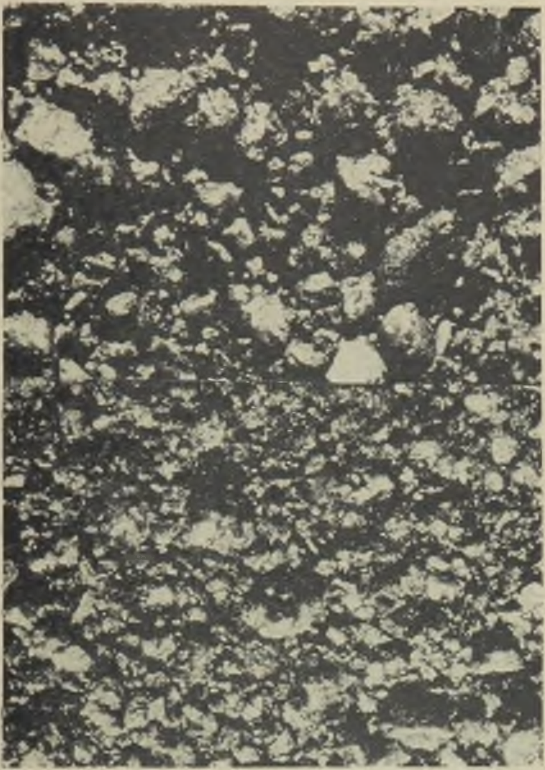
The next consideration is strength or bond, and this is of paramount importance. This property is due to the amount of clay (Al_2O_3, or expressed more precisely Al_2O_3, $2SiO_2$, $3H_2O$, *i.e.*, silicate of alumina) and ferric oxide present, and the ideal condition of their presence is in the form of thin films surrounding each grain, and in this condition it is at its maximum efficiency, as it retains in contact a certain amount of water. From data obtained it appears that all successful bonds depend upon what are known as colloids for this peculiar property. A "colloid" is a substance in a condition similar to that of gelatine or albumen, whilst in contrast a crystalloid is a substance like salt, for example. The main difference between the two is the varying amounts of surface energy, and whilst a solution of a crystalloid, such as common salt, will readily pass through a filter paper, the paper



Figs. 1 and 2.—Illustrating the Grain Size in Moulding Sands.

Fig. 1 (top) is sea sand ; Fig. 2, Mansfield. (Both are by 30 dias.)

is practically impermeable to a colloidal substance like those mentioned. Clay possesses colloidal matter to varying extents, and in varying form, such, for instance, as hydrated ferric-oxide, aluminium silicate, and hydroxide, etc., and these substances possessing as they do structures more or less resembling a sponge, are able to retain considerable quantities of water. This water is peculiar in that, unlike hygrosscopic water, it is



FIGS. 3 AND 4.—ILLUSTRATING THE GRAIN SIZE IN MOULDING SANDS.

Fig. 3 (top) coarse red sand; Fig. 4, fine red sand. (Both are by 30 dias.)

not all driven off at 110 deg. C., and consequently the life of the sand is proportionately lengthened. If a handful of sand is compressed and broken it indicates a green bond, which for general purposes is sufficiently reliable, but occasional tests of a quantitive nature can be usefully carried out from time to time.

Test for Cohesiveness.

For this test each sample of sand is dried at 110 deg. C., and the percentage of water added just before making the test piece. Test pieces are moulded in No. 1 box (Fig. 6). Sand is filled in loosely up to the top face, the top portion is then fitted on and the box is compressed until the joints meet, this enables each core to be made under similar conditions. The cores for the permeability tests are made in a similar manner with the exception that No. 2 box (Fig. 6) is used.

Fig. 5.—Illustrating the Grain Size in Moulding Sands.

Fig. 5, road sand. (By 30 dias.)

In testing for green bond the core, $\frac{3}{4}$ in × 1 in. × 8 in. long, is pushed by a ram over the edge of a horizontal glass surface until fracture occurs. Measurement is then taken of the unbroken piece.

In Table 2A is seen the green bond strength of a few of the sands commonly used in the Lancashire district.

It was thought that having the green bond strength of a number of sands a mixture could be calculated with a desired strength. Table 2B gives the various mixtures of these sands:—

Mixture No. 6 has an actual bond of 4.0 in. calculated bond of 4.2 in.

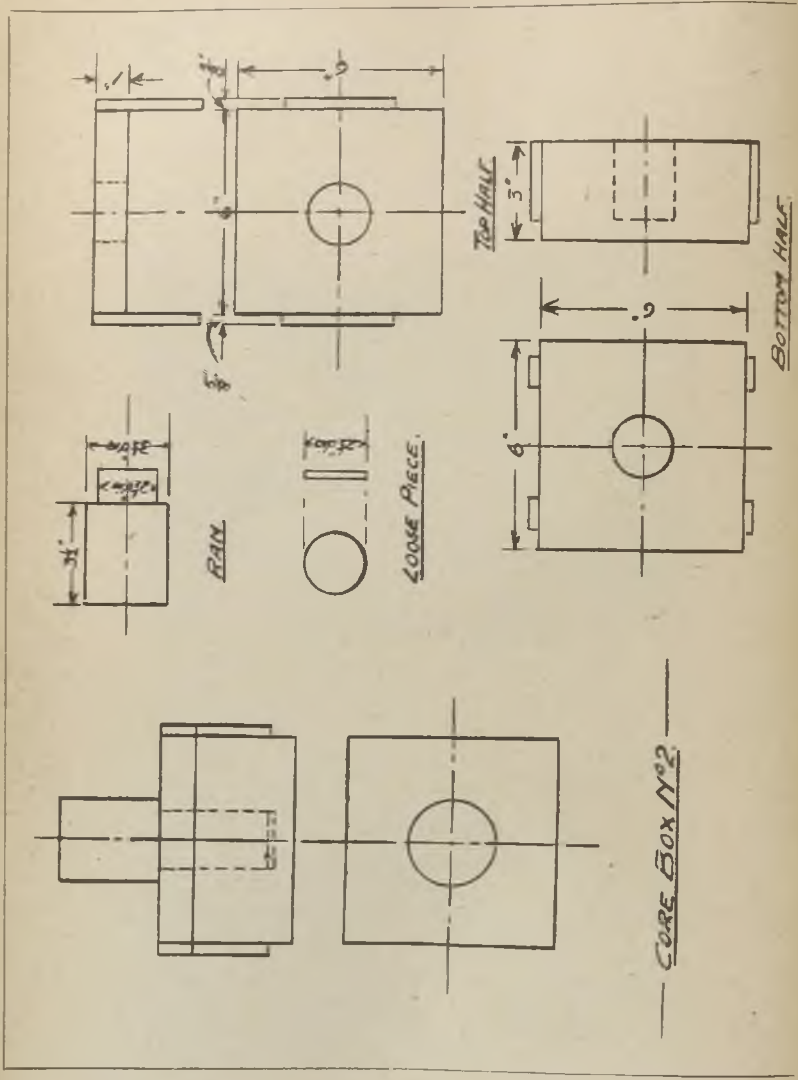
Mixture No. 7 has an actual bond of 4.0 in. calculated bond of 4.2 in.

Mixture No. 8 has an actual bond of 4.6 in. calculated bond of 4.16 in.

This assumption is not fully borne out when Mixture No. 8 is considered. It appears that the smaller grains pack in between the larger ones and affect the calculation of a bond strength.

Permeability.

Permeability is the facility with which a body allows the free passage of air or gas. As previously pointed out one of the greatest considerations in obtaining this is pore-space, evenly arranged. Rounded sand grains are a further consideration, but the one for which the moulder is responsible is the manner in which his ramming is performed, and the condition of the sand when this ramming takes place, and also the amount of water which some moulders swab with. One sometimes meets a moulder who makes constant use of a swab pot, and most moulders use it to some extent. It was the recurrence of trouble which caused the writers to seek the source of scrap in this direction, and in this criticism coremakers and moulders are included. However, the writers fitted up an arrangement of more or less simplicity, and made cores of standard design and size, but in the making of these cores varying quantities of water were used. The permeability figures obtained as a result of these experiments were most interesting, and went to show that too much care could not be given to the proper and equal tempering of sand, and that the moulder must exercise every possible care in ascertaining that he does not add too great a quantity of water either as a result of his facing sand drying or by swab pot methods. One is too apt to say that as it is a dry sand mould it does not matter to what extent water is added. It



CORE BOX No 2

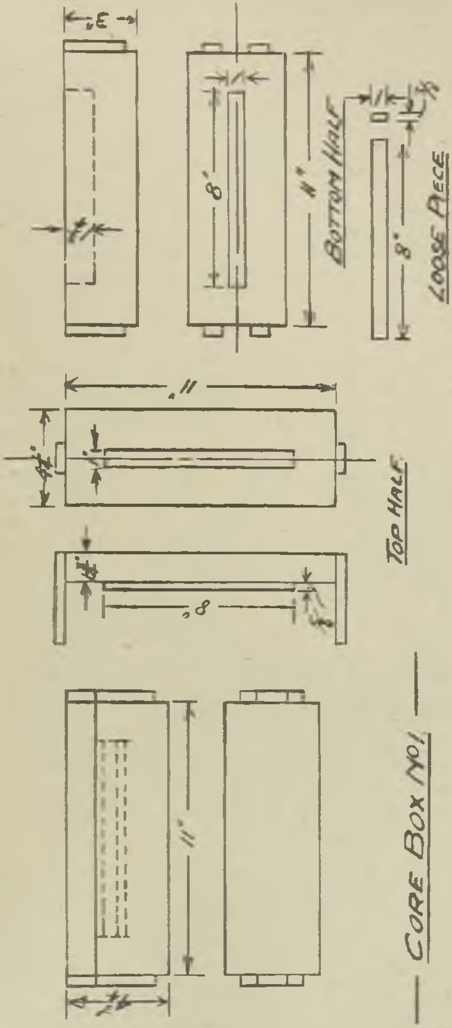


FIG. 6.—DETAILS OF TEST PIECE USED.

New Sands. TABLE IIA.—*Strength and Permeability of Sands.*

Sand.	Average Permeability.	Length after fracture.	Bond. Per cent.	Ratio of water to sand.
Mansfield	36.75 sec.	3.83 ins.	52.55	1 : 10
Manchester (fine)	34.91 ,,	3.33 ,,	58.25	
,, (coarse)	28.90 ,,	5.20 ,,	35.0	
Road sand	28.37 ,,	4.50 ,,	—	

Sand Mixtures. TABLE IIB.

No. of mixture.	Actual permeability.	Calculated permeability.	Actual bond.	Calculated bond.	Ratio of water to sand.
No. 6	28.9 sec.	32.2 sec.	4.0 ins.	4.2 ins.	1 : 10
No. 7	30.0 ,,	32.1 ,,	4.0 ,,	4.2 ,,	
No. 8	29.1 ,,	31.6 ,,	4.6 ,,	4.16 ,,	

(The amount of water required to obtain a medium bond is governed by the origin and condition of the sand. The water necessary varies from approximately 4 per cent. to 12 per cent.)

matters very largely, particularly previous to ramming or finishing, as wet sand rams much more closely than a dryer sand.

Table III shows the necessity for keeping a close control on the initial moisture content. A comparison of No. 2 Core with No. 5 Core demonstrates the effects of different degrees of ramming, especially when the sand contains a large percentage of water. When the durability test is described, an attempt will be made to explain when it is necessary to have a large percentage of water to obtain a medium bond.

Addition of Water to the Face of a Core.—Here is an attempt to produce similar conditions to a dried sand mould. The sand used in these tests was taken from the coremaker's bench. It demonstrates when comparing Nos. 1 and 3 against Nos. 2 and 4 that the amount of water sprayed on the face of a core or mould should be kept to a minimum although the mould is going to be dried.

In the permeability test-results shown the permeability is measured by noting the time taken to force 100 c.c.s. of air through a dried core 2¼ in. dia. by 1¼ in. deep. (See Fig. 7.) The volume of air is not corrected for temperature or pressure. A "blank" time is taken for each set of cores in order to obtain similar pressure for different cores.

[At this stage two cores were tested for permeability by the use of a red liquid in the graduated tube, the members being able to see this when the 100 c.c. mark was reached. By placing a rubber stopper in the outlet orifice a test was taken to see if there was any leakage. A soft rammed core took 29 secs. for 100 c.c.s. of air to pass through, similarly a harder core under similar conditions took 65 secs. for the same test.]

Durability.

An equally important phase is that of durability, by which is meant the ability with which sand can be used and re-used, and a sand which has a low degree of durability may not be profitably used even though the analysis, fineness, permeability, and cohesiveness tests may indicate its suitability. Sands possess colloidal matter, and it is this which determines to a very great

TABLE III.—*Varying Ramming and Percentage of Water.*

Test No.	Percentage of water.	Ramming.	Time to pass 100 c.c. of air through a dried core.
No. 1	12.0 per cent.	Light rammed	47.5 sec.
No. 2	12.0 ,,	Normal ,,	53.0 ,,
No. 3	12.0 ,,	Heavy ,,	82.5 ,,
No. 4	16.0 ,,	Light ,,	79.0 ,,
No. 5	16.0 ,,	Normal ,,	263.0 ,,
No. 6	16.0 ,,	Heavy ,,	449.0 ,,

The Effects of the Addition of Water to the Face of a Core made from Core Sand Mixture.

Test No.	Condition of green core.	Time to pass 100 c.c. of air through a dried core.
No. 1	Light rammed	28.0 sec.
No. 2	Light rammed. Face of core moistened with water	35.5 ,,
No. 3	Normal rammed	32.0 ,,
No. 4	Normal rammed. Face of core moistened with water	—

extent the durability of the sand. The problem is distinct from the problem of refractoriness or the resistance to fluxing, as it is conceivable that every refractory sand might have a very short life. The behaviour of much colloidal matter is distinguished by its dependence upon water, the content of which varies both with temperature and the neighbouring vapour pressure. Upon subjection to sufficient heat these colloids are destroyed. Their ability to take up water and again become possessed of a bond is lost, and the sand becomes dead. If it is not subject to too high a temperature it will rehydrate and can be used for further work. The life of a bond is controlled by this critical temperature. Many clay bonds will stand a high temperature without breaking down, but are unfortunately subject to sintering, and in this condition they lose the colloidal property of again taking up water and consequently will not again take up bond. A combination of hydrated colloidal iron oxide and clay will give a long-lived bond and one that will readily rehydrate.

From heating curves taken on various sands the authors found a flat on the curve at 110 deg. C. and another flat between 480 deg. C. and 580 deg. C., on the majority of them, which points out that practically all the water in the clay is driven off between these temperatures.

Referring to Table IV, three sands were chosen for this test, fine, coarse, and open grades. They were heated uniformly with thermo-couples embedded in the sand. Green-bond tests were carried out as previously described. A cursory examination of the results shows the fact that road sand decreases in strength very rapidly, the loss in bond strength being 15.3 per cent. at 400 deg. C.

If it is assumed that the life or durability of a moulding sand depends entirely on the amount of bonding material it can retain after being subjected to high temperatures, it would be reasonable to tabulate the three sands as follows:—

Mansfield No. 1.—Having the longest life with only 2.5 per cent. loss in bond strength at 400 deg. C.

TABLE IV.—*Relation of Green Bond to Heat Treatment.*

Sand.	Heating temperature.	Length after fracture.	Green bond.	Percentage of added water.
Mansfield	110 deg. C.	3.9 ins.	51.2 per cent.	10.0 per cent.
,, ...	400 ,,	4.11 ,,	48.7 ,,	10.0 ,,
,, ...	700 ,,	5.64 ,,	29.5 ,,	10.0 ,,
Manchester—Coarse red	110 ,,	5.30 ,,	33.7 ,,	10.0 ,,
,, ,,	400 ,,	5.70 ,,	28.7 ,,	10.0 ,,
,, ,,	700 ,,	nil	nil	10.0 ,,
,, ,,	700 ,,	5.80 ,,	27.5 ,,	26.0 ,,
Road sand	110 ,,	4.45 ,,	40.6 ,,	10.0 ,,
,, ...	400 ,,	5.97 ,,	25.3 ,,	10.0 ,,
,, ...	700 ,,			10.0 ,,
,, ...	700 ,,	5.66 ,,	29.2 ,,	18.0 ,,

TABLE V.—*Plumbago.*

	Cumberland.		Bavaria.		* Ceylon.		Canada.
Carbon	82	92	81	66	68	99	79
Volatile matter	5	1	8	1	5	—	2
Ash	13	7	11	32	27	1	19

Manchester Coarse No. 2.—With a loss in bond strength of 5 per cent.

Road Sand No. 3.—With a loss in bond strength of 15.3 per cent.

This order of merit was borne out in tests carried out for dehydration and rehydration. Sands were heated to the desired temperatures and weighed. Afterwards they were entirely covered by water and allowed to soak for 24 hours. At the end of this period the samples were heated to 110 deg. C. to constant weight and the increase in weight taken as the water of rehydration.

The writers are fully aware that the dye-absorption test is frequently used for the measurement of colloidal materials, but a test to be of any use to the foundryman must show the quality of the bond. The dye-absorption test is very misleading when adopted for testing materials like fine silica flour, etc., as a test figure can be obtained although the material has little strength or rehydration value.

From the heating test figures it appears that the proper blending of a sea sand and a bonding sand is a suitable mixture for investigation to obtain a suitable long life sand, and it would be of great interest to foundrymen to find the longest life sand or mixture of sands that can be obtained locally without having to pay heavy rail charges.

Before leaving this subject it might be of interest to emphasise that two of the sands subjected to a temperature of 700 deg. C. required more water to obtain a medium bond strength. From this point, heap sand containing a large amount of burnt sand that will not rehydrate is not suitable for use in sand mixtures as excess water is necessary to obtain a working bond.

Blackings.

Blackings are substances used to protect the face of the mould from unnecessary burning and also to ensure that the casting will leave the mould without the adherence of fused sand. Thus there is an additional means of assisting and prolonging the durability of the sand. Blackings are of several varieties and each has its special advantages. They can be divided into the following groups:—(1) Carbonaceous material: (2)

mineral materials; and (3) mixtures of No. 1 and No. 2.

In the first group are included graphite, coke, charcoal, etc. In the second group there are ground silica, talc (soapstone), china clay, cement, etc., and these are more correctly defined as mineral facings.

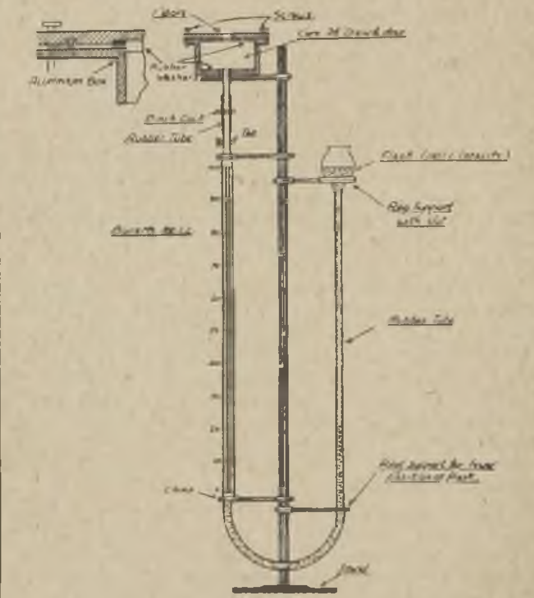


FIG. 7.

The blackings in the third group are most commonly used and consequently appear to be the best for investigation. Whichever of the materials is used there are varying methods used in their preparation and consequently it is found that in many instances what may appear to be insignificant details greatly affect the efficiency of the substance. During the past few years the writers have constantly sought for information upon this subject and are of the opinion that many good blackings are badly applied and consequently influences are not readily recognised by many, and a good deal of surprise was caused on the occasion when graphite cones were being subjected to heat tests. These cones were placed on small pieces of cast iron and after submitting them to a temperature it was found that they had actually caused a drop in the melting point of the metal in the immediate vicinity of the cone. Many surface defects upon castings can be directly attributed to blacking troubles.

Graphite.

This is the most important refractory material used for facing mould surfaces. Many varieties are offered for sale, the mineral running from the purest type, *i.e.*, flaky Ceylon quality, which is so pure that it is used for the best class of pencils, to the more common material so lacking in the greasy flaky characteristics of the purer material as to almost shade into a variety of coal. (See Table V.) The wide variation in samples from the same locality is very noticeable and it will be seen that some Ceylon plumbago contains 99 per cent. carbon. This is in a fine form that has a great covering power combined with a slow rate of burning. Other plumbagos are obtained from Cumberland, Bavaria, Canada and Mexico, with ash contents ranging from 2 per cent. in Mexican to 32 per cent. in Bavarian.

Plumbago burns slowly when heated to a high temperature with air, and leaves an ash containing most of its impurities, and as it has no apparent action on clay or sand it is used as a refractory separating layer between that and the molten metal.

Ground Coke.

Good hard coke with a low ash and sulphur content ground to extreme fineness in a ball mill and afterwards sieved, when mixed with plumbago and a suitable binder makes a satisfactory wet blacking for heavy dry-sand moulds.

Ground Gas Carbon.

Owing to the nature of its ash, etc., it is better than ground coke when mixed as a wet blacking.

TABLE VI.

Sample.	Test I.	Test II.	Test III.	Test IV.				Test V.		Fixed carbon.
	Sample fused with caustic soda. Pure graphite should remain unaffected but some insoluble matter can also remain unaffected.	About 0.05 grms. sprinkled on surface of water. Good graphite should float for say 10-15 mins.	Sample shaken with acetone. Pure graphite leaves the acetone colourless. Coke remains suspended for a long time and makes the acetone greyish. Anthracite separates out more quickly and gives a faint brown coloration. Soft coal gives a deep brown colour.	Physical properties.				Analysis.		
				Texture.	Form.	Colour.	Sp. gr.	Ash.	Volatile matter.	
Plumbago No. 4.	72.2 per cent. unaffected.	All floated	The powder settled quickly leaving the acetone slightly cloudy.	Soft and smooth.	Small flakes.	Grey black with lustre.	1.83	20.15	3.15	76.7
Plumbago No. 5.	55.0	"	"	"	"	Very black grey with lustre.	1.73	36.55	3.75	59.7
Plumbago No. 6.	44.2	Some sank slowly after 5-10 mins.	"	"	"	"	1.58	49.2	6.65	44.15

Blacking No. 7.	45.6	Some sank immediately and about 30 per cent. settled finally.	The powder settled very slowly leaving the acetone tinged dark grey.	Very hard.	Powder.	Black.	1.65	42.9	9.8	47.3
Blacking No. 8.	52.8	Some sank slowly.	The powder settled rather quickly leaving the acetone slightly tinged with grey.	Soft and smooth.	Small flakes.	Dark grey.	1.81	37.1	4.45	58.45
Sterlino No. 9.	30.7	All floated.	The powder settled rather quickly leaving the acetone slightly tinged with grey.	Harsh.	Small flakes.	Grey	1.57	59.35	4.10	36.55
Sterlino No. 10.	68.0	,,	Powder settled fairly quickly leaving the acetone cloudy.	,,	,,	,,	1.63	60.0	1.9	33.1
Charcoal No. 11.	70.0	A fairly large proportion had settled after 2 hours.	Powder remained suspended for some time. Acetone dark grey in colour.	,,	Powder.	Black.	2.10	13.95	11.72	74.33
Charcoal No. 12.	66.3	,,	,,	,,	,,	,,	2.21	14.6	11.55	73.85

It is more costly, however, and from tests carried out it appears that ground coke or anthracite is more frequently used than gas carbon. Considerable skill is required in selecting, drying, grinding and mixing carbon for blacking manufacture. In selecting carbon, the class of coal used has to be considered as the percentage and composition of the ash are of primary importance. The temperature and period of drying the carbon before grinding require skilful judgment and is only attained after long experience.

Ground Charcoal.

This is also used in some of the mixtures, the best variety being that made from hard wood.

Mineral Facings.

Talc or soapstone is of the meta-silicic class $H_2Mg_3\ (SiO_3)_4$. Its high percentage of magnesia gives to it a soapy touch similar to graphite, but it can be readily distinguished from the latter by its whitish appearance. It is fusible at temperatures lower than graphite and water is expelled on heating. From this it will be seen that no difficulty is experienced when mixed with plumbago for thin castings, but it is totally unsuitable for use on heavy classes of work.

The experience of the authors when using a wet blacking containing a high percentage of soapstone is to find slag spots containing gas holes on the face of the casting. From this it would appear that any detached blacking of this nature mixed with sand forms a fusible slag, and the holes are formed by the steam generated by the expulsion of the combined water from the soapstone. Whether or not this assumption be correct the trouble was eliminated by the use of a blacking containing a less percentage of Mg, the other conditions remaining the same.

Table VI shows various tests carried out on different plumbagos, etc. From a study of this table the materials used in the various samples can be ascertained.

From the analyses in Table VII, No. 1 is undoubtedly the best and gave the best results in the foundry. No. 2, with 2 per cent. more ash,

TABLE VII.—*Plumbagos.*

Analysis.	No. 1.	No. 2.	No. 3.
Fixed carbon	92.86 per cent.	59.58 per cent.	63.65 per cent.
Volatile matter	1.34 ,,	5.34 ,,	3.10 ,,
Ash	5.8 ,,	35.08 ,,	33.25 ,,
Analysis of the Ash :—			
SiO_2	72.77 per cent.	47.08 per cent.	60.74 per cent.
SO_3	0.48 ,,	0.41 ,,	0.44 ,,
P_2O_5	0.93 ,,	0.41 ,,	0.49 ,,
Fe_2O	4.46 ,,	14.95 ,,	16.80 ,,
Al_2O_3	16.81 ,,	30.94 ,,	15.21 ,,
CaO	1.40 ,,	0.18 ,,	1.28 ,,
MgO	1.20 ,,	1.27 ,,	1.47 ,,
Calculated melting point of Ash	1300 deg. C.	1450 deg. C.	1100 deg. C.
Figure of merit	1220	940	733

TABLE VIII.—*Firebricks.*

Analysis.	Stourbridge.	South Wales.	Scottish.	South Staffs.	South Staffs. "A."
SiO_2	59.46	59.10	57.34	52.36	69.74
$Al_2O_3.SiO_2$	34.39	33.17	37.41	41.20	24.38
Fe_2O_3	3.65	4.43	3.59	3.36	2.56
CaO	0.90	0.66	0.60	0.76	0.70
MgO	0.80	0.91	0.21	0.83	0.63
Loss on ignition	0.26	0.26	0.30	0.56	0.76
Alkali (Diff).	0.54	1.47	0.55	1.73	1.42
Refractory Tests :—					
Average 3 Seger cones	29	30	30	27	33
Temperature Cent.	1650	1670	1670	1610	1730

TABLE IX.—*Cupola Slags.*

	Chemical Analysis 6.					Blast pressure.	Erosion of lining.
	SiO_2	Al_2O_3.	FeO.	MnO.	CaO.		
No. 1	45.0	5.0	10.6	3.3	35.7	Low	Small.
No. 2	48.0	5.3	13.0	4.5	29.0	Medium ..	Medium
No. 3	53.3	6.0	17.0	6.0	17.8	High	High.

TABLE X.—*Slag Penetration.*

Test No.	Block Material.	Coating material.	Time at 1500 deg. C.	Depth of penetration, etc.
8.	Scottish ..	—	1 hour	1 in. fissures filled with slag.
9.	Silica brick	—	$\frac{3}{4}$,,	1 in. soaked right through.
10.	Ganister ..	—	1 ,,	1 in. ,, ,, ,, (cracked).
11.	Scottish ..	Ganister	$\frac{3}{4}$,,	1 in. soaked coating and block (cracked).
12.	,, ..	Fireclay 50 per cent. and sea sand 50 per cent.	$\frac{3}{4}$,,	$\frac{1}{2}$ in. through coating and into block slightly.
13.	,, ..	No. 1 cement	$1\frac{1}{4}$,,	1/32 in. very slightly attacked coating.
14.	,, ..	No. 2 cement	$1\frac{1}{4}$,,	$\frac{1}{2}$ in. coating and block (small cracks).
15.	,, ..	No. 3 cement	$1\frac{1}{4}$,,	Coating penetrated right through 3/16 in. no penetration into block.
16.	,, ..	No. 4 cement	$1\frac{1}{4}$,,	$\frac{3}{4}$ in. coating and block.
17.	,, ..	No. 5 cement	$\frac{3}{4}$,,	1 in. right through coating and block.

Coating Mixtures.

Material.	Composition.	Remarks.
Fireclay and sea sand	50 : 50	Small cracks when dried. Soaks.
No. 1 cement ..	66 per cent. alundum powder 34 ,, lime	Appears to fuse, adheres to block.
No. 2 cement ..	75 ,, alundum powder 25 ,, lime ..	Cracks on drying.
No. 3 cement ..	50 ,, alundum powder 50 ,, lime ..	Adheres well to the block, appears to be a good cement.
No. 4 cement ..	66 ,, alundum powder 34 ,, asbestos powder ..	Cracks on drying.
No. 5 cement ..	66 ,, alumdum powder 34 ,, asbestos flour ..	Cracks on drying, coating peels off block.

gave less trouble in the foundry than No. 3, probably due to a higher melting point of its ash.

From the analyses of the ash one can calculate the approximate melting points upon a basis suggested by Prost. By this means the following temperatures were obtained:—No. 1, 1300; No. 2,

FIG. 8.—SCOTCH BRICK.

FIG. 9.—SILICA BRICK.

1450; and No. 3, 1100 deg. C. From these figures it would appear that No. 2 with a melting point of 1450 deg. C. is the best of the three. One must take into consideration, however, that the ash content is only 5.8 per cent. in the sample No. 1 (1300 deg. C.) while in No. 2 (1450 deg. C.) it is 35.08 per cent. and in No. 3 (1100 deg. C.) it is 33.25 per cent.; in order to obtain a better comparison, therefore, it is necessary to take into account both carbon content of the plumbago and fusing temperatures of the ash.

If a figure of merit is employed consisting of the product of these two the results are as follows:—No. 1, 1300 × 94.2 = 1220; No. 2, 1450 × 64.9 = 940; and No. 3, 1100 × 66.7 = 733 which correspond to the results obtained in practice.

Refractories for the Cupola.

In discussing the subject of refractories used for cupolas it will be well to bear in mind that the materials used for the lining and patching of a cupola have been and are still unsatisfactory. Two different methods of refractory lining are used for cupolas. (1) Lining with radial firebricks, and (2) ramming with a refractory tamped material, either by hand or by compressed air. The question as to which is the more suitable and economical depends on local conditions and quality of material used before a conclusive opinion can be expressed.

It is an invariable principle in ceramics that basic corrosion should be met with basic bricks, and acid corrosion with acid bricks. The chemical actions that occur when melting an iron-coke-lime charge, require, in addition to considerable mechanical strength, a material which in its chemical composition offers resistance to the decomposing action. To the foundryman the special requirements of a refractory cupola lining is " the longest possible life." Acid linings are chiefly used for the cupola, although attempts have been made to use basic linings, but with unsatisfactory results.

Without going into the characteristics of the basic, neutral and acid materials such as magnesite, dolomite, zirkite, alundum or carborundum, chromite, zircon, carbon, fireclay, silica and ganister, etc., it can be safely said that fireclay bricks for lining purposes give the best satisfaction. They are less expensive, easy to instal, and require less care in handling than any other refractory material. For patching and repairs, ganister is the material commonly used, but this material, in the majority of cases is carelessly prepared and applied. Ganister should be prepared 24 hours before use, and the proper consistency is reached when sufficient water has been added to cause the ganister to form a ball that does not fall apart in the hand. Before applying, it is best to remove all the slag from the lining face and wash the old surface over with slurry of the same material as is being used; this helps the ganister to adhere to the wall. Patching a cupola with wet ganister just thrown on the wall is a bad practice. It is realised that when using these materials there is a considerable expense for repairs and stoppages, and any information on this subject is greatly appreciated by foundrymen.

FIG. 10.—SCOTCH AND GANISTER.

FIG. 11.—SCOTCH WITH FIRECLAY AND SEA SAND.

Although there is not a wide variation in these analyses it was found that No. 3 (Table VIII) gave the most satisfactory results over a twelve months' test. The chief difference between clay firebricks does not lie in the clays used or the analyses of the bricks. Grinding and mixing operations to ensure uniform and suitable material, the burning and finishing temperatures reached in manufacture, accuracy in the shape and size of the finished brick, absence of cracks and fissures and, when broken, absence of cavities, are the chief points which help to form a suitable and reliable brick.

Fig. 12.—Scotch and No. 1 Cement.

Fig. 13.—Scotch and No. 2 Cement.

Every foundryman knows that when lining a cupola it is more desirable to use blocks specially made for the purpose than the ordinary shaped fire brick, but the authors wish to point out here that many would be greatly surprised if they tested six of the blocks at present in their stocks for uniformity and accuracy of shape. When forming a circle with cupola blocks as commonly supplied it is practically impossible to avoid a number of wide joints, these, together with surface cracks on the face of the bricks, are the starting points for slag penetration, which appears to be the greatest difficulty that has to be overcome to obtain a satisfactory lining.

Fig. 14.—Scotch and No. 4 Cement.

Fig. 15.—Scotch and No. 5 Cement.

Lining Corrosion.

With regard to the action of slag on the furnace lining, the authors have observed that thinly fluid lime slags do not attack the cupola lining to the same extent as semi-fluid and more viscous slags do. The nature and chemical composition of the furnace lining appears to be of great importance to the conditions of the slag, and it is fully realised that it is the slagging and not the resistance to heat of the lining material that governs the life of the lining. In considering the action inside the cupola the sulphur in the coke burns in an excess of air to sulphur dioxide (SO_2) in front of the tuyeres. This gas decomposes and forms ferrous-sulphide and ferrous-oxide where the iron has a bright red glow, both of these constituents can be absorbed by the hot metal.

In tests carried out on electric and other furnaces with acid linings for steel manufacture, it is a well known fact that desulphurising agents will not act satisfactorily if free silicic acid is present, *i.e.*, uncombined with the clay. The purpose of a basic slag is to combine with SiO_2 and to become silicates with absorbed ferrous and manganous oxide. The writers have not been able to carry out sufficient tests to satisfy themselves that lime combines with any free silicic acid in the lining material, which would allow more sulphur to enter the metal and also hasten the decomposition of the lining. A brick, after the burning process in the kiln, contains practically all of the silicic acids combined in the clay. Whether free silicic acid in a lining is detrimental or not is a matter that is suggested for further research, the fact is however borne out that bricks containing a fair percentage of grog have a longer life than a pure clay brick. It can be said then, that a cupola slag is a product of the transformation occurring in the cupola and consists of silicates of lime, manganous and ferrous oxides, alumina and dissolved free silica.

A good index to the possibility of lining erosion is the slag composition. This is borne out by the analyses of slags from tests carried out with varying blast pressures, other conditions in the cupola remaining constant. From Table IX it will be seen that No. 1 slag shows the least lining erosion, but unfortunately the melting rate of the metal in the cupola is too slow for economical operation. No. 2, with a blast pressure of 9 ozs. and a volume of air of 2,460 cub. ft. per min. for a 37-in. cupola appears to be the most satisfactory.

Refractory Coatings.

The technical literature of the past few years has made reference to the use of thin coatings of high refractory materials on lower refractory materials. Invariably the latter have the better bond, and are used in everyday practice. Some materials used for this purpose would appear to be technically useless, but the reactions which occur on the lining face of a cupola and the face of a mould can, in the majority of cases, only be assumed. Criticism of any experiments to increase the life of these faces should therefore be guarded. The authors appreciate the fact that it would be futile to put coatings on refractory material when the co-efficient of expansion or the shrinkage of the two materials varies materially, the authors also realise that in some cases a laboratory experiment which is the necessary guide, differs materially when adopted in the foundry. Any coating, if it is to be a commercial proposition, must improve density and the mechanical strength of the surface and thus protect the lining, against abrasion, the cutting action of the flames and against penetration by slag. Tests have been made with a view to producing a satisfactory coating material for cupola linings.

Experiments were made with a slag of No. 2 composition plus 0.5 per cent. sulphur laid in hollows cut in firebricks, some of which have been thinly covered with different refractory cements. The photographs show the depth of slag penetration. (Figs. 8 to 15.)

Table X gives a tabulated result of the slag penetration tests, together with the composition of the refractory cements used in the experiments. Comparing No. 8 with No. 9, it will be seen that a cupola slag penetrated a silica brick very rapidly. No. 12 was coated with No. 1 cement consisting of 66 per cent. alundum powder and 34 per cent. lime, which appears to be a good refractory cement. This was borne out in practice, a thin coating of this cement on the face of the cupola gave satisfactory results, especially when used over the brick joints of a relined cupola.

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THE INSTITUTE OF BRITISH FOUNDRYMEN.

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E.M.—East Midlands Branch.
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L.—London Branch.
M.—Middlesbrough Branch.
N.—Newcastle-on-Tyne Branch.
S.—Sheffield Branch.
Sc.—Scottish Branch.
W. & M.—Wales and Monmouth Branch.
W.R. of Y.—West Riding of Yorkshire Branch.

Gen.—General or unattached to a Branch.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1926.	Ackroyd, A. H., White Cottage, Park Road, Timperley, Cheshire.
E.M.	1908.	Aiton, J. A. (Aiton & Company), Derby.
S.	1924.	Alder, A. J., 106, Sincil Bank, Lincoln.
N.	1924.	Allan, F., 7, Dene Street, Sunderland.
S.	1918.	Allan, J. M., Cyclops Works, Sheffield.
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S.	1906.	Allen & Company, Edgar (Subscribing Firm), Imperial Steel Works, Sheffield.
E.M.	1924.	Allin, G. E., 21, Dairy House Road, Derby.
Sc.	1920.	Andrew, J. H., D.Sc., Royal Technical College, Glasgow.
Lncs.	1919.	Andrew, J. W., 964, Oldham Road, Thornham, Royton, Oldham.
N.	1925.	Appleyard, K. C., Birtley Springs House, Birtley, Co. Durham.
B.	1925.	Ardern, W. J. A., 23, St. Michaels Hill, Handsworth, Birmingham.

B'nch.	Year of Election.	MEMBERS.
N.	1921.	Armstrong-Whitworth & Co., Ltd., Sir W. G. (Subscribing Firm), Close Works, Gateshead-on-Tyne.
M.	1926.	Armstrong, H., 20, Shaftesbury Street, Stockton-on-Tees.
N.	1920.	Arrowsmith, J. K., 4, Dean Road, South Shields.
Lncs.	1924.	Arstall, J., "Kenmarlean," Back, Bowe, Hyde, Cheshire.
M.	1927.	Ashmore, Benson Pease & Co., Ltd., (Subcribing Firm), Parkfield Works, Stockton-on-Tees.
L.	1925.	Ashwell, E. C., "Kenwyn," Stafford Road, Waddon, Croydon.
B.	1924.	Aston, A., "Holly Bank," Sedgley Road, West Tipton, Staffs.
L.	1911.	Aston, W. H., 46, Eagle Wharf Road, London, N.
B.	1921.	Athey (Major), J. W., Fordath Eng. Co., Ltd., Hamblet Works, West Bromwich.
N.	1918.	Aynsley, W. B., 62, Bath Lane, Newcastle-on-Tyne.
L.	1925.	Bagshawe, A. W. G., DunstableWorks, Dunstable.
B.	1920.	Ball, F. A., c/o Ball Bros., Stratford-on-Avon.
Sc.	1923.	Ballantyne, H. D., 91, Drumover Drive, Parkhead, Glasgow.
M.	1926.	Barbour, A. R., Bon Lea House, Thornaby-on-Tees.
L.	1923.	Bargellesi, G., via Madama, N.9 Terrara, Milan, Italy.
B.	1922.	Barnsley, W. G., The Limes, Church Road, Netherton, nr. Dudley.
L.	1911.	Bartlett, A. R., 1, Lower Park Road, Belvedere, Kent.
L.	1923.	Bartram, J., 369, Grove Green Road, Leytonstone, E.11.
M.	1926.	Bashford, T. E., "Hillingdon," South Road, Norton-on-Tees.
E.M.	1921.	Bates, W. R., United Steel Companies, Limited, Irthlingboro' Iron Works, Wellingboro'.

B'nch.	Year of Election.	MEMBERS.
Gen.	1926.	Baxter, J. P., Morro Velho, E.F.C., Raposos Minas, Brazil, S. America.
W. & M.	1922.	Bayley, J. P., "Ty-gwyn," 4, Westfield Road, Clytha Park, Newport, Mon.
L.	1920.	Beech, A. S., 97, Queen Victoria Street, London, E.C.
Sc.	1910.	Bell, W., 1, George Street, Airdrie.
—	1922.	Bell, Wm. Dixon, 72, Walpole Road, Itchen, Southampton.
L.	1926.	Belling, C. R., 10, Glebe Avenue, Enfield, Middlesex.
L.	1919.	Benbow, M., "Ombersley," Carrington Road, Dartford, Kent.
Lncs.	1925.	Bennett, A., 112, Old Road, Flowery Field, Hyde, Cheshire.
L.	1926.	Bennett, F. H., "Holyrood," 12, Kilmarton Road, Goodmayes, Essex.
S.	1920.	Benson, E. C., 303, Fulwood Road, Sheffield.
W.R. of Y.	1922.	Bentley, J. N., Plantation House, Hull Road, York.
Lncs.	1922.	Bentley, L. A., Wood End, Bromley Cross, Bolton.
B.	1924.	Bethell, R. P., 51, Sutton Road, Walsall, Staffs.
B.	1925.	Bettinson, C. L., New Bond Street Ironworks, Bardesley.
E.M.	1915.	Bigg, C. W., Someries, Darley Lane, Allestree, nr. Derby.
S.	1918.	Biggin, Frank, Rye Lodge, Ashland Road, Sheffield.
S.	1921.	Birchall, T., Latebrook House, Goldenhill, Stoke-on-Trent.
N.	1921.	Birtley Iron Company (Subscribing Firm), Birtley, Co. Durham.
B.	1922.	Blackburn, W. A., "Wynsill," Lichfield Road, Rushall, Staffs.
L.	1927.	Blackwell, F. O., 29, Westbourne Road, Luton, Beds.

B'nch.	Year of Election.	MEMBERS.
Gen.	1919.	Blair, A., 7, Derryvolgie Avenue, Belfast.
B.	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.
W.R. of Y.	1922.	Boyle, J., Swann & Davidson, Ltd., Carrick Foundry, Stanningley, Leeds.
N.	1922.	Brailsford, A., 18, Elswick Row, Newcastle-on-Tyne.
S.	1921.	Breakey, J. E., Abbeydale Hall, Dore, nr. Sheffield.
L.	1926.	Brendle, T. F., Burma Railway Quarters, Insein, Lower Burma.
Lncs.	1914.	Bridge, W., 199, Drake Street, Rochdale, Lancs.
S.	1922.	Brightside Foundry and Engineering Co., Ltd. (Subscribing Firm), Newhall Ironworks, Sheffield.
M.	1926.	British Chilled Roll & Engineering Co., Ltd. (Subscribing Firm), Empire Works, Haverton Hill, Middlesbrough.
Lncs.	1919.	Broad, W., 230, Dumers Lane, Radcliffe, Lancs.
S.	1922.	Brown, E. J., 11, Newlyn Place, Woodseats, Sheffield.
W.R. of Y.	1917.	Brown, P., Park Works, Lockwood, Huddersfield.
S.	1919.	Brown, P. B., Carsick Grange, Sheffield
Lncs.	1924.	Bruce, A., "Rose Bank," Swanpool Lane, Aughton, Ormskirk, Lancs.
B.	1926.	Buchanan, G., Niagara Foundry Co., Ltd., Bradley, near Bilston.
Gen.	1922.	Bull, R. A., 541, Diversey Parkway, Chicago, Ill., U.S.A.
L.	1924.	Bullers, W. J., Waterloo Iron Foundry, Willow Walk, Bermondsey, S.E.1.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1924.	Bullock, T. W., "Shirley," Warrington Road, Rainhill, Liverpool.
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.,Norcroft Foundry, Lister Hills, Bradford, Yorks.
S.	1923.	Butler, J., 63, Deepdale Road, Rotherham.
Lncs.	1926.	Button, L. J., 294, Nantwich Road, Crewe.
M.	1909.	Caddick, A. J., 18, Marton Road, Middlesbrough.
Lncs.	1926.	Cadman, E., 69, Manchester Road, Fairfield, Manchester.
L.	1927.	Calder, N. G., 68, Conyers Road, Streatham, London, S.W.16.
Sc.	1917.	Cameron, J. (Cameron & Roberton, Limited), Kirkintilloch.
Sc.	1919.	Cameron, T. P. (Cameron & Roberton, Ltd.), Kirkintilloch.
S.	1922.	Cammell Laird & Co., Ltd., (Subscribing Firm), Cyclops Steel and Iron Works, Sheffield.
Sc.	1927.	Campbell, H. D., Shaw (Glasgow) Ltd., Maryhill Iron Works, Glasgow.
Sc.	1911.	Campion, A. (Honorary Life), 3, Strathview Gardens, Bearsden, Glasgow.
S.	1923.	Cantrill, W. H.,249,Chatsworth Road, Chesterfield.
N.	1912.	Carmichael, J. D. (Life), Sydenham Terrace, South Shields.
N.	1912.	Carmichael, J. D., Jun., O.B.E. (Life), "Redlea," Grasmere Gardens, Harton, South Shields.
S.	1918.	Carnegie, W., Firs Hill House, Pitsmoor, Sheffield.
L.	1919.	Carpenter, H. C. H., Prof. (Hon.), 30, Murray Road, Wimbledon, S.W.19.

B'nch.	Year of Election.	MEMBERS.
S.	1921.	Castle, Geo. Cyril, 141, Rustling Road, Endcliffe, Sheffield.
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., "Padgham," Dallington, Sussex.
L.	1925.	Chell, E., A.M.I.Mech.E., 68, Ferndene Road, London, S.E.24.
Gen.	1923.	Clamer, G. H., 129, So. Berkeley Square, Atlantic City, N.Y.
L.	1925.	Clapp, H. B., 25A, Broad Bridge Street, Peterborough, N. Hants.
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.16.
M.	1926.	Clark, W. H., 90, Marton Burn Road, Middlesbrough.
E.M.	1927.	Clarke, A. S., "Lyndesfarn," Leicester Road, Loughborough.
B.	1926.	Clarke, W. H., 16, Holly Road, Edgbaston, Birmingham.
L.	1917.	Cleaver, C., 10, Ringcroft Street, Holloway, N.1.
W. & M.	1917.	Clement, W. E., Morfa Foundry, New Dock, Llanelly.
L.	1913.	Coan, R., Aluminium Foundry, 219, Goswell Road, E.C.1.
Sc.	1917.	Cockburn, N., 48, Murrayfield Gardens, Edinburgh.
L.	1925.	Cockram, G. F., 54, Murray Road, Ipswich.
L.	1926.	Coggon, H. F., August's Muffle Furnaces, Ltd., Thorn Tree Works, King Cross, Halifax.
N.	1926.	Colls, F. C., Clarendon House, Clayton Street, Newcastle.

B'nch.	Year of Election.	MEMBERS.
L.	1922.	Coll, J., Comandancia General de Ingenieros, Seville, Spain.
N.	1912.	Collin, J. J., 55, Cleveland Road, 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., 31, Poplar Avenue, Edgbaston, Birmingham.
Lncs.	1911.	Cooper, C. D., Dolphin Foundry, Chapel Street, Ancoats, Manchester.
N.	1921.	Cooper, J. H., 5, Trinity Road, Darlington.
L.	1919.	Corby, S. F. (R. B. Doulton, Ltd.), Lambeth Sanitary Engineering Works, Albert Embankment, London, S.E.1.
Lncs.	1924.	Cowlishaw, S. D., 7, Temple Street, Basford, Stoke-on-Trent.
L.	1925.	Cowper, L., 159, Eversleigh Road, Lavender Hill, S.W.11.
E.M.	1914.	Cox, J. E. (The Rutland Foundry Company, Limited), Ilkeston.
B.	1919.	Craig, A., Earlsdon House, Earlsdon, Coventry.
Lncs.	1924.	Craig, A.
B.	1922.	Cramb, F. M., 5, Triangle Villas, Oldfield Park Road, Bath.
L.	1910.	Cree, F. J., Fair View, Huntley Grove, Peterborough.
L.	1920.	Creek, W., 2, Eleanor Road, Stratford, E.
L.	1911.	Creighton, T. R., The Foundry, Stepney Causeway, E.
Lncs.	1927.	Crewdson, Capt. R. B., 16, Norfolk Crescent, Hyde Park, London, W.
W.R. of Y.	1922.	Croft, Frank, Crofts, Ltd., Bradford.

B'nch.	Year of Election.	MEMBERS.
B.	1920.	Cross, J. K., 152, Yardley Wood Road, Moseley, Birmingham.
L.	1923.	Curtis, A. L., 39, London Road, Chatteris, Cambs.
M.	1926.	Crosthwaite, C., Thornaby Hall, Thornaby-on-Tees.
M.	1926.	Crosthwaite, Ltd., R. W. (Subscribing Firm), Union Foundry, Thornaby on-Tees.
Lncs.	1925.	Daniels, W., 74, Smethurst Lane, Bolton.
N.	1925.	Darlington Railway Plant and Foundry Co., Ltd. (Subscribing Firm), Bank Top, Darlington.
Gen.	1926.	Darnis, I. S., Rampas de Uribitarte 2–1, Bilbao, Spain.
Lncs.	1926.	Davenport, J., Myrtle Bank, Grimsargh, Preston.
Gen.	1919.	Davies, P. N., 29, Brunswick Road, Brunswick, Melbourne, Victoria, Australia.
L.	1923.	Dawes, C. E., 26, Keston Road, West Green, N.15.
Lncs.	1924.	Dawson, S. E., 8, Lynton Park Road, Cheadle, Hulme, Cheshire.
Lncs.	1924.	Deakin, F., 14, Belfield Road, Reddish, Stockport.
B.	1918.	Deakin, W., 7, George Street, Parade, Birmingham.
Gen.	1925.	Dean, J. P., c/o Hoare & Co. (Engineers), Ltd., P.O. Box 22, Colombo, Ceylon.
Sc.	1927.	Deas, John, c/o John Deas & Co., Ironfounders, Market Street, Glasgow, E.
M.	1919.	Deas, P., 4, Blenheim Terrace, Coatham, Redcar.
L.	1925.	Delport, V., (Capt.), 2–3, Caxton House, S.W.1.
B.	1924.	Denham, H., "Birchwood," Walsall Road, Aldridge, Staffs.
S.	1917.	Desch, C. H., D.Sc., Ph.D., F.R.S., F.I.C., The University, Sheffield.

B'nch	Year of Election.	MEMBERS.
L.	1926.	Dews, H. C. (Dewrance & Co.), 165, Great Dover Street. S.E.I.
B.	1921.	Dicken, Charles, H., 2, Ash Street, Daisy Bank, Bilston.
S.	1924.	Didden, Capt. F. G. J., M.I.Mech.E., Broad Elms Lane, Ecclesall, Sheffield.
L.	1914.	Dobson, W. E., "Newlyn," Grand Drive, Raynes Park, S.W.
B.	1926.	Dodd, W., 68, Allport Road, Cannock, Staffs.
L.		Donaldson, T. (J. I. Thornycroft and Co., Ltd.), Woolston Works, Southampton.
Lncs.	1918.	Doughty, E., 54, St. Mary's Road, Moston, Manchester.
Sc.	1911.	Doulton, B. (Life), 3, Berrylands, Surbiton, Surrey.
M.	1927.	Downing, A. G., 2, Oxford Street, Stockton-on-Tees.
S.	1921.	Duckenfield, W., 47, Dunkeld Road, Ecclesall, Sheffield.
L.	1925.	Durnan, F., 43, Grove Road, Millhouses, Sheffield.
Lncs.	1926.	Durrans, J., The Croft, Penistone.
S.	1921.	Edginton, G., Silverdale, St. Margaret's Drive, Chesterfield.
B.	1922.	Edwards, A., "Dunbar," Old Bath Road, Cheltenham.
N.	1921.	Eldred, E. J., 8, Ford Street, Gateshead-on-Tyne.
L.	1909.	Elliot, A., Ingate Ironworks, Beccles.
L.	1904.	Ellis, J., 20, Lambourn Road, Clapham Junction, London, S.W.4.
S.	1918.	Elliss, J. A., 217, Middlewood Road, Sheffield.
S.	1913.	Else, L. H., 79, Osborne Road, Sheffield.
Sc.	1925.	English, J., c/o Miss Granger, 9, Prospect Street, Camelon, Falkirk.
L.		Ephraim, V. Rex, 21, Cromwell Road, London, S.W.7.

Branch.	Year of Election.	MEMBERS.
L.	1919.	Estep, H. Cole, The Penton Publishing Co., Penton Building, Cleveland, Ohio, U.S.A.
L.	1926.	Evans, S., 60, Brian Road, Norbury, S.W.16.
E.M.	1918.	Evans, W. T., Mount Pleasant, Sunny Hill, Normanton, Derby.
S.	1920.	Fairholme, F. C., Norfolk Works, Sheffield.
Lncs.	1926.	Farrington Steel Foundry of Leyland Motors, Ltd. (Subscribing Firm), Leyland, Lancs.
L.	1908.	Faulkner, V. C., 49, Wellington Street, Strand, London, W.C.2.
S.	1910.	Feasey, J., 192, West Parade, Lincoln.
N.	1918.	Fender, B., 15, Kenilworth Road, Monkseaton, Northumberland.
B.	1914.	Field, H., "Glenora," Richmond Avenue, Wolverhampton.
B.	1904.	Finch, F. W. (Honorary), 52, Denmark Road, Gloucester.
S.	1914.	Firth, A., 50, Clarendon Road, Fulwood, Sheffield.
S.	1914.	Firth, F. W., "Storth Oaks," Ranmoor, Sheffield.
M.	1926.	Fisher, F. E., 2, Albert Terrace, Haverton Hill, Middlesbrough.
Gen.	1907.	Flagg, S. G. (Honorary), 1,407, Morris Buildings, Philadelphia, Penn., U.S.A.
B.	1923.	Flavel, P., Bushbury Lodge, Leamington.
B.	1922.	Fletcher, J. E., M.I.Mech.E. 8, St. James Road, Dudley, Staffs.
Lncs.	1923.	Flower, E., 7, Marlborough Street, Higher Openshaw, Manchester.
W. & M.	1907.	Fontaine, C., Dock Foundry, Newport, Mon.
Sc.	1917.	Forbes, J. T., 176, West George Street, Glasgow.
B.	1926.	Fordath Engineering Co., Ltd. (Subscribing Firm), Hamblet Works, West Bromwich.

B'nch.	Year of Election.	MEMBERS.
W.R. of Y.	1922.	Forrest, H., 43, Beaumont Road, Manningham, Bradford.
N.	1919.	Fortune, T. C., 76, Falmouth Road, Heaton, Newcastle-on-Tyne.
B.	1919.	Fosseprez, G., 3, Rue du Grand Jour, Mons, Belgium.
B.	1920.	Foston, G. H., Ivy Bank, Balsall Common, Berkswell, nr. Coventry.
—	1926.	Fox, F. S., 5532, Webb Avenue, Detroit, Michigan, U.S.A.
W.R. of Y.	1925.	Frame, J. Y., 19, Sherburn Street, Hull.
L.	1926.	France, G. E., 105, Rightcliffe Road, Crosland Moor, Huddersfield.
L.	1920.	Frank, A. C., "Rozel," Knatchbull Road, Harlesden, N.W.
Sc.	1920.	Fraser, A. R., Craigard, Bearsden, Glasgow.
N.	1914.	Frier, J. W., 5, Northumberland Villas, Wallsend-on-Tyne.
L.	1919.	Furmston, A. C., Hope Cottage, 2 1 1, Neville Road, Letchworth.
W. & M.	1924.	Galletly, J. P., Ben Cleuch, Pencisely Road, Cardiff.
N.	1912.	Gallon, M. E., "The Pines," London Road, Nr. Petersfield, Hants.
N.	1921.	Gardiner, E. T., Hoppyland House, Albert Hill, Bishop Auckland.
Sc.	1919.	Gardner, J. A., 24, South Hamilton Street, Kilmarnock.
L.	1922.	Gardom, J. W., 39, St. Peters Road, Dunstable, Beds.
W.R. of Y.	1922.	Garforth, E. P., 48, Haslingden Drive, Toller Lane, Bradford.
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.
L.	1922.	Gibbs, A. F., 55, Gordon Road, Wanstead, E.11.

B'nch	Year of Election.	MEMBERS.
L.	1927.	Gibson, F., 257, Newton Road, Ashford, Kent.
N.	1925.	Gill. C. S., Westbank, Consett, County Durham.
Sc.	1920.	Gillespie, P., "Glenora," Falkirk Road, Bonnybridge.
Sc.	1925.	Gillespie, W. J. S., Ure Allan Park, Bonnybridge, Stirlingshire.
E.M.	1915.	Gimson, H., "Rhoscolyn," Toller Road, Leicester.
E.M.	1906.	Gimson, S. A., 20, Glebe Street, Leicester.
S.	1905.	Goodwin, J. T., M.B.E., M.I.Mech.E. Red House, Old Whittington, Chesterfield.
N.	1922.	Gordon-Luhrs, Henry (E. T. White and Co. (1920) Ltd.), Clare House, Kingsway, London, W.C.2.
M.	1926.	Gore, G. E., "Rosedene," Austin Avenue, Stockton-on-Tees.
W. & M.	1917.	Gould, P. L., Vulcan Foundry, East Moors, Cardiff.
W. & M.	1918.	Gould, W. C., 7, Broad Street, Barry.
Sc.	1921.	Graham, J., 68, Sherbrooke Avenue, Maxwell Park, Glasgow.
Lncs.	1922.	Grandison, W. H., 15, Gordon Road, Clovelly Estate, Worsley Road, Swinton.
L.	1926.	Grange, R., St. John's Cottage, 87, Southend, Hampstead, N.W.3.
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.	1926.	Gray, T. H., 119, High Holborn, W.C.1.
B.	1925.	Greensill, G. B., "Lynn," Jockey Road, Sutton Coldfield.
N.	1912.	Greensitt, R. H., 24, Stuart Terrace, Felling-on-Tyne.

B'nch.	Year of Election.	MEMBERS.
E.M.	1920.	Greenwood, R., The International Combustion Engineering Co., Derby.
N.	1917.	Gresty, C., 101, Queen's Road, Monkseaton.
W. & M.	1906.	Griffiths, H., 70, Partridge Road, Cardiff.
S.	1910.	Hadfield, Sir R. A. (Hon.), Hadfields, Limited, Hecla Works, Sheffield.
E.M.	1927.	Hadfield, S., White Lodge, Keyham, near Leicester.
Lncs.	1906.	Haigh, J., "Stoneclough," Carr Lane, Sandal, Wakefield.
W. & M.	1924.	Haines, A. D., Penybryn, Tynypwll Road, Whitchurch, Glam.
W.R. of Y.	1919.	Haley, G. H., Nab Wood House, 6, Tower Road, Shipley, Yorks.
L.	1926.	Hall, S., 31, Robin Hood Road, Brentwood, Essex.
Lncs.	1923.	Hammond, R., 37, Church Road, Smithills, Bolton.
E.M.	1914.	Hammond, Wm., Samson Foundry, Syston, Leicester.
Lncs.	1904.	Hampson, F. R. (J. Evans & Company), Britannia Works, Cross Street, Blackfriars, Manchester.
S.	1926.	Hampton, C. W., 5, Chorley Drive, Fulwood, Sheffield.
S.	1925.	Hardwick, H., Cemetery Road, Dronfield, nr. Sheffield.
Gen.	1910.	Harley, A., Ashlea, Stoke Park, Coventry.
B.	1925.	Harper, W. E., Dudley Foundry Co., Ltd., Moor Lane, Brierley Hill, Staffs.
L.	1918.	Harris, A. J. A. (Capt.), 41, High Road, Balby, Doncaster, Yorks.
M.	1926.	Harrod, H., 15, Egglestone Terrace, Stockton-on-Tees.
Lncs.	1918.	Hartley, Wm. Alexr., Stonebridge Foundry Company, Limited, Colne.

B'nch.	Year of Election.	MEMBERS.
Gen.	1922.	Harvey, André, 118, Spring Road, Kempston, Bedford.
S.	1909.	Hatfield, W. H., D.Met., The Brown Firth Research Laboratory, Princess Street, Sheffield.
N.	1921.	Hawthorn, Leslie & Company, R. & W. (Subscribing Firm), St. Peter's Works,Newcastle-on-Tyne.
L.	1926.	Hearn, J. E., Craig-y-don, West Hill, Luton.
Lncs.	1925.	Heatley, J., 146, Redlam, Blackburn.
Lncs.	1918.	Helm, R. W., c/o Francis Helm, Ltd., Victoria Foundry,Padiham,Lancs.
Gen.	1926.	Henderson, P.C., M.P., The Right Hon. Arthur (Honorary), 33, Eccleston Square, London, S.W.1.
Lncs.	1923.	Hensman, A. R., 121, Plymouth Grove, Charlton-on-Medlock, Manchester.
N.	1913.	Herbst, M. B., 23, Saltwell View, Gateshead-on-Tyne.
Lncs.	1926.	Hesketh, F., Yarrow Cottage, Broad Lane, Rochdale.
Lncs.	1925.	Hesketh, F. J., 23, Muriel Street, Rochdale.
Sc.	1917.	Hetherington, R., 105, West George Street, Glasgow.
Lncs.	1926.	Hetherington & Sons,Ltd., John, (Subscribing Firm) Vulcan Works, Pollard Street, Manchester.
B.	1926.	Hicatt, H. J., South Bank, Brierley Hill, Staffs.
L.	1927.	Hickman, G. E., Greensteps, Park Chase, Guildford.
L.	1926.	Hider,G. E.,Upton Foundry,Torquay.
W. & M.	1912.	Hird, B., "Woodcot," Upper Cwmbran, nr. Newport, Mon.
L.	1923.	Hobbs, F. W. G., Standard Brass Foundry, P.O. Box 229, Benoni, Transvaal, S.A.
Sc.	1919.	Hodgart, H. M., Vulcan Works, Paisley.
Lncs.	1923.	Hodgkinson, A., Ford Lane Works, Pendleton, Manchester.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1914.	Hodgson, A., 14, Park Range, Victoria Park, Manchester.
Lncs.	1912.	Hogg, J., 321, Manchester Road, Burnley, Lancs.
Lncs.	1927.	Hollindrake H. (H. Hollindrake & Sons, Ltd.), Princes Street, Stockport.
N.	1919.	Holmes, C. W. H., M.Met., c/o Birtley Iron Co., Birtley, Co. Durham.
B.	1924.	Homer, W. A., 87, Frederick Street, Walsall, Staffs.
Sc.	1914.	Hood, John 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.
L.	1924.	Hunt, N. H., 1, Albemarle Street, Piccadilly, W.1.
L.	1920.	Hunt, R. J., "Greenhills," Earls Colne, Essex.
N.	1920.	Hunter, Hy., 1, Manor Terrace, Tynemouth.
Lncs.	1917.	Hunter, H. E., Barton Hall Engine Works, Patricroft, Manchester.
N.	1919.	Hunter, Summers, C.B.E., J.P., 1, Manor Terrace, Tynemouth.
B.	1907.	Hurren, F. H. (The Rover Company, Limited), Meteor Works, Coventry,
S.	1920.	Hurst, F. A., Woofindin Avenue, Ranmoor, Sheffield.
Sc.	1927.	Hurst, H., 35, Alice Street, Paisley.
S.	1914.	Hurst, J. E., Newton Chambers and Co., Ltd., Chapeltown, Sheffield.
L.	1925.	Hutton, R. S., D.Sc., The Greenway, High Wycombe, Bucks.
S.	1911.	Hyde, J. R., A.M.I.Mech.E., 27, Hastings Road, Millhouses, Sheffield.
S.	1922.	Hyde, Robert & Son, Ltd. (Subscribing Firm), Abbeydale Foundry, Woodseats, Sheffield.

B'nch	Year of Election.	MEMBERS.
Sc.	1925.	Hyman, H., Ph.D., 55, Dixon Avenue, Crosshill, Glasgow.
S.	1915.	Jackson, L., Engineer Lieut.-Commander, R.N., Antrim Avenue, Park Lane, Sheffield.
Lncs.	1925.	Jadoul, J. E., 28, Daisy Bank Road, Longsight, Manchester.
L.	1925.	James, A. W., 1, Broomhill Road, Ipswich.
L.	1926.	James, J. A., 101, Stoke Road, Slough, Bucks.
L.	1911.	Jarmy, J. R., "Ajaccio," Abbey Road, Leiston, Suffolk.
Gen.	1927.	Jenkins, A., 5c, Strada Molins, Cospicua, Malta.
W. & M.	1924.	Jenkins, T., 51, Tydvil Street, Barry.
S.	1917.	Jenkinson, S. D., Cromwell House, Wincobank, Sheffield.
L.	1904.	Jewson, H., Norwich Road, East Dereham, Norfolk.
L.	1921.	Jewson, K. S., 4, Coopers Terrace, Gearing Road, Dereham, Norfolk.
E.M.	1909.	Jobson, V., The Derwent Foundry Company, Derby.
Lncs.	1920.	Jolley, W., Breeze Hill, Urmston Lane, Stretford, Manchester.
Lncs.	1922.	Jones, G. A., 54, Fox Street, Edgeley, Stockport.
B.	1925.	Jones, O. P., 25, Rathbone Road, Bearwood, Birmingham.
S.	1921.	Kayser, J. F., 30, Oakhill Road, Nether Edge, Sheffield.
Lncs.	1925.	Kelly, A. F., 31, Windbourne Road, St. Michaels, Liverpool, S.
L.	1917.	Kelly, Jas., 74, Rotherfield Street, N.1.
Lncs.	1922.	Kent, C. W., 16, Beech Grove, Withington, Manchester.
Lncs.	1919.	Kenyon, W. H., "Sunny Bank," Whalley Road, Accrington.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1910.	Kenyon, M. S., Waterloo, Whalley Road, Accrington.
Lncs.	1904.	Kenyon, R. W.. Entwistle & Kenyon, Limited, Accrington.
S.	1927.	Kessell, C. E. (Vickers, Ltd.), River Don Works, Sheffield.
Lncs.	1907.	Key, A. L., 271, Reddish Road, S. Reddish, Stockport.
Sc.	1927.	Kidston, R., Springbank, Falkirk.
Sc.	1914.	King, D., Keppock Ironworks, Possil Park, Glasgow.
Sc.	1904.	King, J., 100, Wellington Street, Glasgow.
W. & M.	1924.	Kinsman, W. S., 116, Miskin Street, Cardiff.
Sc.	1919.	Kinnaird, George, 21, St. Ann's Drive, Giffnock, Glasgow.
M.	1926.	Kinnell & Co., Ltd., Chas. P. (Subscribing Firm), Vulcan Iron Works, Thornaby-on-Tees.
S.	1925.	Kitching, W. T., c/o John Fowler, Don Foundry, Sheffield.
L.	1922.	Lake, W. B., Mount Place, Braintree, Essex.
L.	1921.	Lambert, Wesley, "Whitefriars," 41, Bromley Road, S.E.6.
Sc.	1907.	Landale, D. (Life), 36, Great King Street, Edinburgh.
B.	1919.	Lane, F. H. N., 46, Holyhead Road, Coventry.
Gen.	1922.	Lane, H. M., 333, State Street, Detroit, Michigan, U.S.A.
L.	1927.	Larke, W. J., Sir, K.B.E., "Eastburn," St. John's Road, Sidcup, Kent.
B.	1927.	Lathe, A., "Westlands," Campton Road, Wolverhampton.
W.& M.	1925.	Lawrence, Edward, 39, Pen-y-dre, Rhiwbina, nr. Cardiff.
L.	1921.	Lawrence, Geo. D., 5, Clare Road, Leytonstone, E.11.
Lncs.	1918.	Layfield, R. P., 42, Marsden Road, Burnley.

B'nch.	Year of Election.	MEMBERS.
B.	1909.	Lee, Howl & Company, Engineers, Tipton.
S.	1920.	Leetch, S., 126, Pitt Street, Rotherham.
—	1922.	Leonard, J. (Hon.), 41, Quai du Canal, Herstal, Belgium.
Lncs.	1922.	Lewis, A. H., 6, Coverdale Avenue, Heaton, Bolton.
W. & M.	1924.	Lewis, B. E., 6, Ty Gwyn Road, Pontypridd.
W.R. of Y.	1922.	Liardet, A. A., Leyland Motors, Ltd., Leyland, Lancs.
N.	1920.	Lillie, G., "Bloomfield," Strathmore Road, Rowlands Gill, Durham.
S.	1913.	Little, J., 20, St. Ann's Square, Manchester.
L.	1922.	Littleton, W. H., 29A, Warbeck Road, Anerley, S.E.20.
S.	1926.	Liversidge, B., 6, Nelson Street, Rotherham.
B.	1926.	Lloyd, W., 285, Arthur Street, Small Heath, Birmingham.
N.	1918.	Logan, A. (R. & W. Hawthorn, Leslie & Company, Ltd.), St. Peter's Works, Newcastle.
Lncs.	1921.	Longden, Ed., 158, Manley Road, Manley Park, Manchester.
S.	1904.	Longmuir, P., D.Met., 2, Queens Road, Sheffield.
Lncs.	1913.	Longworth, T. P., Moorside, Horrocks Fold, Bolton.
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," Lyonsdown, New Barnet, Herts.
L.	1921.	Lum, Harry, 54, Park Road, Dartford,
Sc.	1925.	McArthur, J., "Hawthorn," Shields Road, Motherwell.
W. & M.	1922.	McClelland, J. J., "Druslyn," 81, Bishops Road, Whitchurch, Glam.
N.	1922.	McCrory, C., 5, Station Road, Wallsend-on-Tyne.

B'nch.	Year of Election.	MEMBERS.
N.	1924.	McDonald, J., The Villa, Willington Quay-on-Tyne.
Sc.	1919.	McFedries, T., 17, Kirktonholm Street, Kilmarnock.
S.	1916.	McGrah, F. E., 19, Lonsdale Road, Wolverhampton.
L.	1919.	McIntosh, A. E., 1, Ecclesbourne Avenue, Duffield, Derbyshire.
Lncs.	1924.	MacKay, M., 109, Edmund Street, Rochdale.
Sc.	1914.	MacKenzie, Alex. D., 35, Braid Road, Edinburgh.
Sc.	1910.	Mackenzie, L. P., 5, Polwarth Terrace, Balcarres Street, Edinburgh.
Sc.	1922.	McKinnon, Gavin, 1477, Dumbarton Road, Scotstoun, Glasgow.
Sc.	1923.	McKinty, J., 229, 82nd Street, Brooklyn, N.Y., U.S.A.
Lncs.	1921.	McLachlan, Jas., 2, Broadoaks Road, Washway Road, Sale, nr. Manchester.
Gen.	1922.	McLain, D. (Hon.), 710, Goldsmith's Buildings, Milwaukee, Wis., U.S.A.
N.	1923.	Mackley, J. R., 20, Beaconsfield Avenue, Low Fell, Gateshead-on-Tyne.
Lncs.	1923.	McLean, C. G., 14, Jemmett Street, Preston.
N.	1918.	McPherson, T., M.B.E., 53, Percy Park Road, Tynemouth.
B.	1910.	McQueen, D., 6, Anchorage Road, Erdington, Birmingham.
Sc.	1918.	McTurk, J. B., Dorrator Iron Company, Falkirk.
B.	1925.	Maddock, D. W., 21, Waterloo Road, Wellington, Shropshire.
Lncs.	1917.	Makemson, T., 21, Beresford Road, Stretford, Manchester.
S.	1921.	Mander, T. G., Norris Deakin Buildings, King Street, Sheffield.
Lncs.	1919.	Markland, T. W., 327, Tonge Moor Road, Bolton.

B'nch.	Year of Election.	MEMBERS.
B.	1924.	Marks, A., F.I.C., A.M.I.Mech.E.
Lncs.	1922.	Marsden & Son, J. (Subscribing Firm),188,Regent Road,Liverpool.
S.	1922.	Marshall, J., "The Willows," Barrow Hill, Chesterfield.
L.	1922.	Martin, M. J. (Martin & Sons), 18, College Road, York Road, S.E.1.
L.	1924.	Mason, W. C., Richardson & Cruddas, Byculla Iron Works, Bombay, India.
B.	1927.	Mason, W. H., 32, Lord Street, Bradley, Bilston.
L.	1911.	Mather, D. G. (Mather & Smith), Ashford Foundry, South View, Godinton Road, Ashford.
S.	1915.	Mather, T., South View, Carholme Road, Lincoln.
N.	1912.	Mathews, W., 82, St. Peters Road, Holy Cross, Willington Quay-on Tyne.
L.	1926.	Matthieson, R., 37, Clareside, Enfield, Middlesex.
L.	1923.	Maybrey, H. J., B.A., D.I.C., 22a, Gloucester Road, South Kensington, S.W.7.
L.	1921.	Mayhew, C. M., 60, Ewesley Road, Sunderland.
Lncs.	1917.	Meadowcroft, Wm. H., 10, Hambledon View, Habergham, Burnley.
Lncs.	1919.	Medcalf, W., 265, Manchester Road, Burnley, Lancs.
B.	1927.	Mees, J. H., 129, King William Street, Amblecote, Stourbridge.
S.	1922.	Melmoth, F. A., "The Chalet," Ivy Park Road, Sandygate, Sheffield.
M.	1926.	Mercer, J. E., Windsor House, Cromwell Terrace, Thornaby-on-Tees.
Lncs.	1912.	Milburn, J., Hawkshead Engineering Works, Workington.
Gen.	1919.	Miles, F. W.
S.	1921.	Miles, R. (Major), Chapeltown, nr. Sheffield.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1916.	Miles, Rd. A., 46, Dean Lane, Newton Heath, Manchester.
Sc.	1927.	Miller, J., 7, Eildon Villas, Mount Florida, Glasgow.
Lncs.	1918.	Mills, Hilton, 9, Stocks, Alkrington, Middleton, Lancs.
Gen.	1924.	Mills, R. C., 90, Kelsey Street, Waterbury, Conn., U.S.A.
Gen.	1923.	Mitchell, A. M., 470, Victoria Avenue, Montreal, Canada.
Sc.	1920.	Mitchell, W. W., Darroch, Falkirk.
Lncs.	1921.	Moffat, Wm., Linden House, Chapel-en-le-Frith.
Gen.	1910.	Moldenke, Dr. R. (Hon. Member), Watchung, New York.
N.	1919.	Molineux, W. J., 2, Whitehall Road, Gateshead.
L.	1925.	Moore, A. H., Standard Brass Foundry, Benoni, S. Africa.
E.M.	1914.	Moore, H. H., Holmwood, Leicester Road, Loughborough.
L.	1926.	Moorwood, H. S., Onslow House, Sheffield.
M.	1927.	Morley, S. H., 13, Peel Street, Thornaby-on-Tees.
N.	1912.	Morris, A., Pallion Foundry, Sunderland.
B.	1925.	Morris, D., c/o Morris (Engineers)Ltd., Greatbridge, Birmingham.
L.	1925.	Mundey, A. H., Fry's Metal Foundry, 42, Holland Street, S.E.1.
B.	1926.	Murrary, J. V., 80, Manor House Road, Wednesbury.
S.	1925.	Nelson, C., 93, Hawksley Avenue, Hillsbro', Sheffield.
S.	1918.	Newell, Ernest, M.I.Mech.E., The Thorne, Misterton, *via* Doncaster.
N.	1912.	Newton, J. W., Flora House, Cobden Street, Darlington.
Lncs.	1920.	Newton, Sam, Linotype & Machinery Ltd., Altrincham.
L.	1924.	Nikaido, Y. (Lieut.-Com.), Hiro Naval Works, Kure, Japan.

B'nch.	Year of Election.	MEMBERS.
N.	1913.	Noble, H., "The Cedars," Low Fell, Co. Durham.
Lncs.	1924.	Noor, Mohamed S., 1, Zaki Pacha Buildings, Gheit El Edda, Abdin, Cairo, Egypt.
L.	1913.	Norman, A. J., 43, Dunvegan Road, Eltham, S.E.
L.	1927.	Norman, G. L., Basinghurst, Nightingale Road, Guildford.
S.	1923.	North, The Hon., J. M. W., "Lindenhurst," Chesterfield.
N.	1921.	North-Eastern Marine Engineering Company Ltd. (Subscribing Firm), Wallsend-on-Tyne.
Lncs.	1918.	Oakden, E., A.M.I.C.E., Further Hey, Woodley, nr. Stockport.
L.	1917.	O'Keefe, Wm., 62, Stanhope Street, Birmingham.
N.	1920.	Oliver, R., 35, Edith Street, Jarrow-on-Tyne.
Lncs.	1921.	Ormerod, J., 24, Barrett Street, Bury.
S.	1913.	Osborn, S., Clyde Steel Works, Sheffield.
L.	1906.	Oswald, J., Sleaford Foundry, Nine Elms Lane, S.W.8.
L.	1919.	Otto, C. A., 22, Owenite Street, Abbey Wood, S.E.
B.	1918.	Oubridge, W. 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.
N.	1921.	Palmer's Shipbuilding & Iron Company Ltd. (Subscribing Firm), Hebburn-on-Tyne.
W.R. of Y.	1922.	Parker, W., 11, Mayfield Mount, Halifax.

B'nch	Year of Election.	MEMBERS.
E.M.	1905.	Parker, W. B., 3, Murray Road, Rugby.
W.R. of Y.	1907.	Parkinson, J., Shipley, Yorks.
S.	1924.	Parramore, A., Caledonian Foundry, Chapeltown, Sheffield.
N.	1923.	Parsons, F. H., " Avondale," Heaton Park View, Heaton, Newcastle.
N.	1915.	Parsons, Hy. F., " Avondale," Heaton Park View, Heaton, Newcastle.
N.	1912.	Patterson, R. O., Thorneyholme, Wylam-on-Tyne.
N.	1912.	Paulin, W. J., 1, Stannington Grove, Heaton, Newcastle.
E.M.	1924.	Peace, A. E., Claremont, Littleover Hollow, nr. Derby.
B.	1924.	Pearce, J. G., B.Sc., Director, British Cast Iron Research Assn., 24, St. Paul's Square, Birmingham.
E.M.	1913.	Pearson, N. G. (Lieut-Col.), Beeston Foundry Company, Limited, Beeston, Notts.
Lncs.	1909.	Pell, J., 17, Mersey Street, Rosegrove, Burnley, Lancs.
Lncs.	1922.	Pellatt, D. L., 43, Hawthorn Road, Deane, Bolton.
M.	1926.	Pennington, D. G., Lea Close, Middleton St. George, Co. Durham.
Lncs.	1927.	Penrose, J., 190, Horsedge Street, Oldham.
E.M.	1918.	Perkins, J. E. S., " Hillmorton," The Park, Peterborough.
B.	1920.	Perks, C., Phœnix Castings, Ltd., Coventry.
Lncs.	1919.	Perryman, W., 17, Hurst Street, Bury.
L.	1926.	Pisek, Dr. Mont. Fr. Technical High School, Brno, Czechoslovakia.
L.	1926.	Petters, Ltd. (Subscribing Firm), Westland Works, Yeovil.
—	1927.	Phillips, E. A., Laceby, near Grimsby.
Lncs.	1922.	Place, J. H., Station Road, Simonstone, nr. Padiham, Lancs.

B'nch	Year of Election.	MEMBERS.
—	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.
Lncs.	1924.	Pollock & Macnab (Subsidiary), Ltd. (Subscribing Firm), Bredbury, nr. Stockport.
Lncs.	1926.	Poole, J., "Clevelands," Bury New Road, Whitefield Manor.
W.R. of Y.	1922.	Poole, W. H., Kings Grove, Villa Road, Bingley, Bradford.
S.	1923.	Porter, H. W., 78, Ringinglow Road, Sheffield.
B.	1919.	Pott, L. C., The Hardware Mfg. Co., Highbury Lane, Cheltenham.
E.M.	1924.	Potter, W. C., "Kenwalyn," Sykefield Avenue, Leicester.
S.	1926.	Presswood, B. A. C., South Auston, nr. Sheffield.
S.	1908.	Prestwich, W. C., "The Hallowes," Dronfield, Sheffield.
L.	1926.	Prior, W. H., 62, Andalus Road, London, S.W.9.
Sc.	1920.	Primrose, James M., Mansion House Road, Falkirk.
Lncs.	1927.	Primrose, J. S. G., 17, Salisbury Road, Chorlton-cum-Hardy, Manchester.
B.	1924.	Pritchard, P., "Eastcote," St. Agnes Road, Moseley, Birmingham.
E.M.	1904.	Pulsford, F. C., "Kenmore," Sandown Road, Leicester.
Gen.	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.

B'nch	Year of Election.	MEMBERS.
Sc.	1923.	Rattray, W. J., c/o Burns & Co., Ltd., Howrah, Bengal, India.
S.	1921.	Rawlings, Geo., 23, Banner Cross Road, Sheffield.
Sc.	1920.	Rennie, A., "Kilnside," Falkirk.
Sc.	1927.	Rennie, W., "Ardenlea," Cumbernauld, Dumbartonshire.
Lncs.	1919.	Rhead, E. L., Prof. (Honorary), College of Technology, Manchester.
L.	1923.	Rhydderch, A.,
W. & M.	1925.	Richards, C. E., 53, Merches Gardens, Grange, Cardiff.
Lncs.	1919.	Richardson, W. B., Hope Foundry, Farnworth, nr. Bolton.
Sc.	1911.	Riddell, M., Dungoyne, 35, Aytoun Road, Pollokshields, Glasgow.
M.	1926.	Ridsdale, N. D., 3, Wilson Street, Middlesbrough.
M.	1926.	Ritchie, R. J. H., Cambridge House, Linthorpe, Middlesbrough.
M.	1926.	Robbins, A. G., 19, Newcomer Terrace, Redcar.
B.	1923.	Roberts, E., 117, Radford Road, Leamington.
B.	1919.	Roberts, G. E., "Rosedale," Earlsdon Avenue, Coventry.
Lncs.	1921.	Roberts, G. P., 153, Brandlesholme Road, Bury, Lancs.
Sc.	1922.	Robertson, Donald M., Garrison Chambers, Falkirk.
Lncs.	1927.	Robinson, F. O. "Braemar," Birchfield Road. Widnes.
W.R. of Y.	1908.	Robinson. J. G., 17, Gibraltar Road, Halifax.
Lncs.	1912.	Roe, S., 23, Grantham Street, Oldham.
Gen.	1909.	Ronceray, E. (Hon.), 3, Rue Paul Carle, Choisy-le-Roi, Seine, Paris, France.
Gen.	1925.	Ropsy, P. A., 27, Rue Dodoens, Antwerp, Belgium.
B.	1923.	Roxburgh, W., 29. Clifton Road, Rugbv.

B'nch.	Year of Election.	MEMBERS.
S.	1918.	Russell, F., c/o General Refractories Company, Limited, Wicker Arches, Sheffield.
E.M.	1924.	Russell, P. A., 88, Dulverton Road, Leicester.
E.M.	1906.	Russell, S. H., Bath Lane, Leicester.
N.	1915.	Sanderson, F., 10, Westgate Road, Newcastle-on-Tyne.
S.	1921.	Sandford, J., 46, Clifford Road, Sheffield.
N.	1915.	Saunders, J., Borough Road Foundry, Sunderland.
B.	1921.	Scampton, Chas., South Avenue, Stoke Park, Coventry.
M.	1927.	Scholes, A., Alma House, Junction Road, Norton-on-Tees.
Lncs.	1927.	Seddon, W. E., 14, Samuel Street, Rochdale.
B.	1910.	Sexton, A. Humbolt (Hon. Life), 6, Clarendon Road, St. Helier, Jersey, C.I.
L.	1922.	Shannon, H., 112, Madrid Road, Barnes, S.W.
Sc.	1920.	Sharpe, Daniel, 100, Wellington St., Glasgow.
S.	1906.	Shaw, J., Mount Vernon, 15, Western Parade, Southsea.
L.	1907.	Shaw, R. J., 41, Dorset Road, South Ealing, W.5.
M.	1922.	Shaw, W. (Subscribing Firm), Wellington Cast Steel Foundry, Middlesbrough.
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.
L.	1927.	Shepherd, H. H., c/o Crane Bennett, Ltd., Nacton Works Ipswich, Suffolk.

B'nch.	Year of Election.	MEMBERS.
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.	1912.	Shillitoe, H., "Westwood," Potter's Bar, N.
N.	1920.	Shipley, H. J., East Cottage, Delacour Road, Blaydon-on-Tyne.
Lncs.	1907.	Simkiss, J., Abington House, Hyde Road, Gorton, Manchester.
N.	1913.	Simm, J. N., 61, Marine Avenue, Monkseaton.
Lncs.	1924.	Simpson, H., 102, Edmund Street, Rochdale.
S.	1926.	Singleton, T., 2, Warwick Street, Sheffield.
Sc.	1926.	Skinner, F. J., Lochend House, Maryhill, Glasgow.
W.R. of Y.	1921.	Slingsby, W., Highfield Villa, Keighley.
L.	1925.	Small, F. G., "Meliden," Burdon Lane, Cheam.
N.	1921.	Smalley, O., Park Villa, Thrybergh, Rotherham.
Sc.	1927.	Smart, G., Rowallan Stepps, Glasgow.
S.	1922.	Smith, A., "Oakroyd," Dodworth Road, Barnsley.
S.	1922.	Smith, A. Qualter, "Lynwood," Dodworth Road, Barnsley.
B.	1925.	Smith, B. W., 167, Orphanage Road, Erdington, Birmingham.
N.	1908.	Smith, E., Belle Vue, Harton, South Shields.
S.	1921.	Smith, Fredk., Devonshire Villas, Barrow Hill, nr. Chesterfield.
E.M.	1921.	Smith, George, Cavendish Place, Beeston, Notts.
N.	1905.	Smith, J., "Harton Lea," Harton, South Shields.
M.	1926.	Smith, J. D., 19, Shaftesbury Street, Stockton-on-Tees.

B'nch.	Year of Election.	MEMBERS.
N.	1917.	Smith, J. E., 7, Lily Avenue, Jesmond, Newcastle.
M.	1926.	Smith, J. L., "Holmesdale," Billingham, nr. Stockton-on-Tees.
N.	1922.	Smith Patterson & Company, Limited (Subscribing Firm), Pioneer Works, Blaydon-on-Tyne.
N.	1913.	Smith, R. H., 16, Dulverton Avenue, South Shields.
B.	1925.	Smith, W. S., 15, Broadfields Road, Erdington, Birmingham.
L.	1923.	Snook, S. W. G., 30, Lawrence Road, Tottenham, N.15.
L.	1914.	Sommerfield, H. G., Charterhouse Chambers, Charterhouse Square, London, E.C.1.
Lncs.	1926.	Southerst, R., 8, Raven Street, Bury.
S.	1925.	Spafford, Arnold V., Imperial Works, Brown Street, Sheffield.
Lncs.	1927.	Spedding, O. L., "Ramsgill," Prince's Road, Heaton Moor, Stockport.
E.M.	1914.	Spiers, T. A., "Delamere," Uppingham, Road, Leicester.
Lncs.	1922.	Staveley Coal & Iron Company (Subscribing Firm), Staveley Works, nr. Chesterfield.
S.	1927.	Steele, F. E., 29, Merlin Way, Firth Park, Sheffield.
Sc.	1920.	Steven, A. W., Lauriston Ironworks, Falkirk.
E.M.	1914.	Stevenson, E., "Charnwood," Albert Avenue, Carlton Hill, Notts.
N.	1912.	Stobie, V., Oakfield, Ryton-on-Tyne
L.	1915.	Stone, E. G., 20, Cantley Avenue, Clapham Common, S.W.4.
L.	1912.	Stone, J., 106, Harlaxton Road, Grantham.
Gen.	1922.	Stones, J., 2, Marshall Road, Agarpara, Kamarhatti P.O., Calcutta, India.
E.M.	1916.	Street, W., 20, Burleigh Road, Loughborough.

B'nch	Year of Election.	MEMBERS.
Lncs.	1921.	Stubbs, Limited, Jos. (Subscribing Firm), Mill Street Works, Ancoats, Manchester.
Lncs.	1912.	Stubbs, Oliver (Hon. Life), (J. Stubbs, Limited), Openshaw, Manchester.
Lncs.	1919.	Stubbs, R. W., 209, Dickenson Road, Longsight, Manchester.
N.	1921.	Stothard, A., 32, Grainger Street, West, Newcastle.
M.	1927.	Styles, W. E., 9, Cromwell Terrace, Thornaby-on-Tees.
W.R. of Y.	1922.	Summerscales, W. H. G., Rockfield, Keighley.
E.M.	1927.	Summersgill, E., (Senior) 47, Station Road, Long Eaton, Notts.
W.R. of Y.	1919.	Summersgill, H., Stanacre Foundry, Wapping Road, Bradford.
Gen.	1926.	Swaine, G., c/o Marshall, Sons & Co., India, Ltd., Argarpara Works, Karnarhatty, P.O. 24, Parganas, Bengal, India.
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.
Lncs.	1927.	Tait, W., Mere (near) Knutsford, Cheshire.
L.	1925.	Tarrant, W. J., Eiffeldale, Longfleet, Poole, Dorset.
N.	1927.	Tate, C. B., 17, The Crescent, Whitley Bay.
Lncs.	1924.	Taylor, A., 84, Hornby Road, Blackpool.
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.	1925.	Taylor, T., Point Pleasant Hall, Wallsend-on-Tyne.
Lncs.	1920.	Thompson, H., 6, Dobson Road, Bolton.
N.	1923.	Thomson, A., Percy House, Percy Park Road, Tynemouth.
W.R. of Y.	1922.	Thornton, W. G., 1,081, Grangefield Avenue, Thornbury, Bradford.
L.	1924.	Thornycroft and Co., Ltd., John I. (Subscribing Firm) (T.Donaldson), Iron Foundry, Woolston Works, Southampton.
M.	1926.	Thorpe, S. P., 14, Park Terrace, Stockton-on-Tees.
L.	1925.	Tibbenham, L. J., The Limes, Stowmarket.
M.	1926.	Todd, H., 26, Rockliffe Road, Linthorpe, Middlesbrough.
S.	1927.	Tonge, J., Bovey Court, Vereeniging, S. Africa.
—	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.
M.	1924.	Toy, S. V., The Ridge, Saltburn-by-the-Sea.
N.	1927.	Travers, D. Le., 29, Clayton Road, Newcastle.
L.	1922.	Tremayne, Chas., 26, Eversley Road, Charlton, S.E.7.
Sc.	1922.	Tullis, D. R., Aillig, Campbell Drive, Bearsden, Glasgow.
L.	1926.	Turner, A. C., 10, Holmdene Avenue, Dulwich, S.E.24.
B.	1910.	Turner, Prof. T. (Hon. Member), The University, Birmingham.
B.	1927.	Turner, T. H., M.Sc., 17, Acacia Road, Bournville, Birmingham.
Sc.	1923.	Tutchings, A., 152, Greenhead Drive, South Govan, Glasgow.
Lncs.	1909.	Tweedales & Smalley, Limited, Globe Works, Castleton, Lancs.

B'nch.	Year of Election.	MEMBERS.
B.	1918.	Tyson, E. H., 269, Gillatt Road, Edgbaston, Birmingham.
S.	1916.	Underwood, G. H., Pye Bridge House, Pye Bridge, Alfreton, Derbyshire.
Sc.	1913.	Ure, G. A., Bonnybridge, Scotland.
Gen.	1927.	Vanzetti, Comm. Img. Carlo, C.B.E., General Manager, Fonderia Milanese di Acciaio, Milan, Italy.
Gen.	1922.	Varlet, J. (Hon.), Esperance Longdoz Works, Liege, Belgium.
S.	1924.	Varma, J. P., 3, Bingham Park Crescent, Sheffield.
S.	1922.	Vickers, Limited (Subscribing Firm), River Don Works, Sheffield.
Lncs.	1922.	Vickers, Limited (Subscribing Firm), Barrow-in-Furness.
B.	1917.	Vickers, T., 14, New Street, Birmingham.
S.	1917.	Village, R., Bircholme, Dronfield, nr. Sheffield.
Sc.	1911.	Waddell, R. C., 2, Percy Street, Ibrox, Glasgow.
Lncs.	1924.	Wainwright, T. G., The Mount, 195, Huddersfield Road, Stalybridge.
L.	1911.	Walker, C. F., 42, Windsor Street, Wolverton, Bucks.
S.	1907.	Walker, E., Effingham Mills, Rotherham.
Lncs.	1924.	Walker, J. S. A., Major, Walker Bros., Ltd., Wigan.
M.	1926.	Walker, T., 22, Vansittart Terrace, Redcar, Yorks.
S.	1918.	Walker, T. R., 42, Firth Park Crescent, Sheffield.
N.	1921.	Wallsend Slipway & Engineering Co., Ltd. (Subscribing Firm), Wallsend-on-Tyne.
Gen.	1922.	Walters, A. F. (H. I. Dixon & Company, Limited), The Omiar Founding Eng. Company, Limited, Love Lane, Mazagon, Bombay, India.
N.	1927.	Walton, S. H., 73, Highbury, Jesmond, Newcastle-on-Tyne.

B'nch.	Year of Election.	MEMBERS.
S.	1908.	Ward, A. J. (T. W. Ward, Limited), Albion Works, Saville Street, Sheffield.
S.	1914.	Ward, J. C., Oak Park, Manchester Road, Sheffield.
L.	1919.	Wares, F. J., 216, Cromwell Road, Peterborough.
E.M.	1910.	Wassell, A., Kilburn Hall, nr. Derby.
S.	1915.	Watson, J., 31, Hornton Court, Kensington, W.8.
N.	1919.	Watson, J. H., 6, Sidney Grove, Newcastle-on-Tyne.
W.R. of Y.	1922.	Watson, Jos. J., 3, Springdale Avenue, Huddersfield.
B.	1917.	Webb, B., 531, Stourbridge Road, Scott Green, Dudley.
L.	1925.	Webster, F. K., Deptford Star Foundry, Rolt Road, Deptford, London, S.E.8.
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., 1, Hilton Road, Frizinghall, Bradford.
S.	1910.	Wells, G. E. (Edgar Allen & Co., Limited), Imperial Steel Works, Sheffield.
S.	1914.	Wells, J. A. E., "Thrift House," Ringinglow Road, Sheffield.
Lncs.	1926.	West, Walter, 12, The Crescent, Leyland, Lancs.
S.	1921.	Wharton, E., Rosemont, Station Road, Brimington, Chesterfield.
N.	1913.	Wharton, J., Maryport, Cumberland.
B.	1925.	Whitehouse, E. J., "The Knoll," Penn, Wolverhampton.
S.	1916.	Whiteley, A., 7, Glen Road, Nether Edge, Sheffield.

B'nch.	Year of Election.	MEMBERS.
Lncs.	1910.	Whittaker, C., & Company, Limited, Dowry Street Ironworks, Accrington.
B.	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., "Lyndhurst," Wargrave Road, Newton-le-Willows, Lancs.
Sc.	1919.	Williams, H., c/o J. Cochrane, Ltd., Barrhead.
W. & M.	1924.	Williams, R. G., 179, Crogan Hill, Barry Dock.
W. & M.	1916.	Williams, W., Alexandra Brass Founddry, East Dock, Cardiff.
L.	1927.	Williams, W. L., 61, Grenville Road, Braintree, Essex.
N.	1913.	Willott, F. J., 17, Park Road, Clydach-on-Tawe, Swansea Valley.
M.	1912.	Wilson, F. P., "Parkhurst," Middlesbrough.
N.	1922.	Wilson, R. R., "Canonbury," Rowlands Gill, nr. Newcastle-on-Tyne.
L.	1927.	Windsor, W. T., "Pax," Coggeshall Road, Braintree, Essex.
Sc.	1906.	Winterton, H., "Moorlands," Milngavie, Dumbartonshire.
W.R. of Y.	1912.	Wise, S. W., 110, Pullan Avenue, Eccleshill, Bradford.
B.	1925.	Wiseman, Alfred, Ltd. (Subscribing Firm), Glover Street, Birmingham.
B.	1919.	Wood, D. Howard (Capt.), Kingswood Park Road, Moseley, Birmingham.
N.	1922.	Wood, E., Capt., B.Sc., "Overtoun," 20, Beverley Road, Monkseaton.
B.	1909.	Wood, E. J. (Patent Axlebox and Foundry Company, Limited), Wednesfield Foundry, Wolverhampton.
Lncs.	1926.	Woodcock, A., 163, Hartington Street, Moss Side, Manchester.

B'nch.	Year of Election.	MEMBERS.
B.	1914.	Wright, E. N. (Life), Oxford Lodge, Penn Fields, Wolverhampton.
Sc.	1919.	Wyllie, W., 66, Titchfield Street, Kilmarnock, Ayr.
L.	1925.	Yar Khan, M. M., 102, Beulah Hill, Upper Norwood, London, S.E.
Lncs.	1911.	Yates & Thom, Limited, Canal Engineering Works, Blackburn.
L.	1914.	Young, H. J., F.I.C., 3, Central Buildings, Westminster, S.W.1.

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
M.	1926.	Adcock, F. H., 7, Beech Grove, Middlesbrough.
Sc.	1919.	Affleck, J., B.Sc., 21, Overdale Avenue, Langside, Glasgow.
W.R. of Y.	1927.	Ackeroyd, H., Broughton Fields, Broughton, nr. Skipton.
B.	1915.	Aldridge, S., 91, Dale Street, Walsall.
B.	1925.	Allen, Wm., Chuckery Foundry, Walsall, Staffs.
S.	1927.	Alford, A. L., 408, Windmill Lane, Shiregreen, Sheffield.
Sc.	1926.	Anderson, J. Y., 33, Alice Street, Paisley.
Lncs.	1907.	Andrew, F., 120, Gas Street, Failsworth, Manchester.
Lncs.	1925.	Anson, A., 60, South Royd Street, Tottington, Bury.
L.	1925.	Armishaw, W. J., 44, Common View, Letchworth, Herts.
M.	1926.	Armstrong, G., 23, Chipchase Street, Middlesbrough.
L.	1925.	Armstrong, L. R., 39, Lessinden Mansions, N.W.5.
Sc.	1920.	Arnott, J., A.I.C., G. & J. Weir, Ltd., Cathcart, Glasgow.
Sc.	1926.	Arnott, James, 114, Broomhall Road, Newlands, Glasgow.
Lncs.	1916.	Ashton, F., 24, Isherwood Street, Heywood, Lancs.
Lncs.	1918.	Ashton, L., 59, Seymour Street, Radcliffe, Lancs.
Lncs.	1923.	Astall D., 380, Oldham Road, Limehurst, Ashton-under-Lyne.
L.	1905.	Aston, D. A., 36, Bastwick Street, St. Luke's, London, E.C.
Lncs.	1922.	Atkinson, Albert, 1, Guy Street, Padiham, Burnley.
S.	1916.	Atkinson, F., "Woodlands," Richmond Road, Handsworth, Sheffield.
N.	1925.	Atkinson, G., 10, Queen's Drive, Whitley Bay.
E.M.	1923.	Austin, J. T., 24, Danvers Road, Leicester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
N.	1922.	Askew, J., 20, Mount Road, West Sunderland.
S.	1920.	Avill, Wm., 44, Albion Road, Rotherham.
S.	1912.	Ayres, J. A., "Aldbourne," Ecclesfield, Sheffield.
Sc.	1918.	Bacon, A. H., 228, Saracen Street, Possilpark, Glasgow.
S.	1924.	Bacon, P., 86, Bridge Street, Swinton, nr. Rotherham.
Lncs.	1926.	Bagley, J., 34, Guest Street, Leigh, Lancs.
S.	1909.	Bailey, P. T., 17, Hallowes Lane, Dronfield, nr. Sheffield.
Sc.	1916.	Bain, W., Ardmore, Bonnybridge, Scotland.
B.	1918.	Baker, W., "Kara Gwent," Coalway Road, Penn Fields, Wolverhampton.
N.	1925.	Balderston, R. A., 21, Wentworth Place, Newcastle-on-Tyne.
Lncs.	1927.	Barber, C., 43, Birch Street, West Gorton, Manchester.
M.	1926.	Barclay, D., 45, Edward Street, Stockton-on-Tees.
S.	1922.	Barker, A. G., 26, Victoria Road, Balby, Doncaster.
B.	1919.	Barker, S. B., 34, Darby Road, Coalbrookdale, Salop.
S.	1924.	Barker, W., 136, Nidd Road, Attercliffe, Sheffield.
S.	1913.	Barnaby, N. F. (John Brown & Company, Limited), Scunthorpe.
Lncs.	1910.	Barnes, G., 16, Tremellen Street, Accrington.
Lncs.	1915.	Baron, E., 24, Grimshaw Lane, Newton Heath, Manchester.
L.	1914.	Barrett, H. G., Letchworth Castings Co., Letchworth, Herts.
Lncs.	1924.	Barrett, S., 150, Chorley New Road, Horwich, nr. Bolton.

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
E.M.	1916.	Barringer, E. A., 80, Lambert Road, Narborough Road, Leicester.
L.	1911.	Batch, J., 60, Robertson Street, Queen Street, Battersea, S.W.
B.	1927.	Bate, F., 48, Sweetpool Road, West Hagley, Stourbridge.
B.	1904.	Bather, H. K. (Chamberlain & Hill), Chuckery Foundry, Walsall.
S.	1920.	Batty, F., 52, Hampton Road, Pitsmoor, Sheffield.
E.M.	1926.	Baxter, J., 108, Stene Hill Road, Derby.
L.	1921.	Baxter, Percy L., 131, Ampthill Avenue, Benoni, Transvaal, S. Africa.
N.	1923.	Bean, A. S., Beresford Park, Sunderland.
W.R. of Y.	1924.	Bean, E., 8, The Hollies, Sidmouth Street, Hull.
L.	1925.	Beardshaw, A., 50, Jackmans Place, Letchworth, Herts.
W.R. of Y.	1923.	Beaumont, G., 25, Oxley Street, Pontefract Lane, Leeds.
E.M.	1919.	Beck, H. J., 131, Upper Dale Road, Derby.
Lncs.	1925.	Becker, M. L., 15, Upper Lloyd Street, Manchester.
Lncs.	1927.	Beech, T. L., 86, Cyprus Street, Stretford, Manchester.
S.	1920.	Beeley, W. H., Clarence Lane Works, off Eccleshall Road, Sheffield.
B.	1924.	Beeny, H. H., 57, Bramble Street, Coventry.
W.R. of Y.	1927.	Beilby, A. R., 14, Foss Islands Road, York.
Sc.	1917.	Bell, J., 60, St. Enoch Square, Glasgow.
N.	1925.	Bell, J., 65, Park Avenue, Whitley Bay, Northumberland.
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.
W.R. of Y.	1912.	Berry, F., 125, Watkinson Road, Illingworth, Halifax.
Lncs.	1917.	Berry, R. I., 31, Bury Road, Bamford, Rochdale.
B.	1926.	Bettinson, J. S., Cole Bank, Hall Green, Birmingham.
Lncs.	1926.	Bevins, J., 1, Little Union Street, Ulverston.
Sc.	1920.	Binnie, Alex., 15, Cochrane Buildings, Pleasance Square, Falkirk.
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., 10, Prince Edward Street, Crosshill, Glasgow.
E.M.	1921.	Blackham, E. L., 44, May Street, Derby.
E.M.	1920.	Blackwell, Wm., 36, Arthur Street, 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, Leicester.
W.R. of Y.	1926.	Blair, J. W., 13, Milton Street, Hull Road, York.
N.	1920.	Blenkinsop, S. D., Hillcroft, High Fell, Gateshead-on-Tyne.
E.M.	1924.	Bloor, F. A., "Inglemere," Stenson Road, Derby.
N.	1919.	Blythe, J. D., 81, Northumberland Terrace, Willington-on-Tyne.
B.	1925.	Bode, C., 14, Farm Road, Sparkbrook, Birmingham.
W.R. of Y.	1922.	Booth, G. E., 80, Institute Road, Eccleshill, Bradford, Yorks.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
N.	1915.	Borthwick, T., Crookhall House, Leadgate, Co. Durham.
Sc.	1920.	Bound, W. H., Wh. Ex. A.M.I. Mech.E., 12, Dufton Road, Linthorpe, Middlesbrough.
Lncs.	1921.	Bowden, J., 72, Grange Road, Chorlton-cum-Hardy, Manchester.
L.	1906.	Bowman, A., 48, Lathom Road, East Ham, E.6.
W. & M.	1926.	Boxall, H. A., 33, Gellydeg Street, Maesycummer-via-Cardiff.
S.	1926.	Bradbury, J., 14, Littlemore Crescent, Newbold, Chesterfield.
S.	1916.	Bradley, H., "Cotswold," Bocking Lane, Woodseats, Sheffield.
N.	1918.	Bradley, J. H., 7, Crawley Road, Wallsend-on-Tyne.
B.	1925.	Bradshaw, J. H. D., 4, Foley Street, Wednesbury, Staffs.
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, Hollinwood Park, Stockport.
Lncs.	1923.	Brereton, C. F., c/o Mrs. Oldham, 25, Manchester Road, Chorlton-cum-Hardy, Manchester.
Lncs.	1917.	Brierley, A., 21, Milnrow Road; Rochdale.
Lncs.	1923.	Brockbank, A. H., 3, Hawkens Street, Old Trafford, Manchester.
W.R. of Y.	1926.	Brook, J., 10, Elford Terrace, Roundhay Road, Leeds.
L.	1917.	Brookfield, D., 285, Camden Road, Holloway, N.7.
Lncs.	1925.	Broughton, H., 1, Chip Hill Road, Deane, Bolton.
N.	1917.	Brown, C. Hy., 57, Whitehall Road, Gateshead-on-Tyne.
L.	1917.	Brown, E. H., 91, Devonshire Road, Forest Hill, S.E. 23.
Lncs.	1923.	Brown, G. H., 95, Derbyshire Lane, Stretford, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1917.	Brown, J., 227, Milnrow Road, Rochdale.
S.	1909.	Brown, T. W., 9, Coupe Road, Burngreave, Sheffield.
Sc.	1914.	Bruce, A., 52, Ashley Terrace, Edinburgh.
Sc.	1926.	Bruce, W. T., (S. & S. Brown V. Blanchard), Taller Minerva, Punta Arenas, Straits of Magellan, Chile, South America.
Sc.	1927.	Bryden, Walter Myreton, Bonnybridge, Stirlingshire.
Lncs.	1926.	Buck, A., 9, St. Paul's Road, Blackpool, N.S.
N.	1920.	Buckham, G. H.. "Harewood," Grange Road, Newcastle-on-Tyne.
L.	1926.	Buckingham, F. A. T., 114, Richmond Road, Gillingham, Kent.
B.	1925.	Bullows, W. D., c/o Castings, Ltd., Selbourne Street, Walsall, Staffs.
N.	1920.	Burcham, J., 35, Alverthorpe Street, South Shields.
S.	1924.	Burkinshaw, J. W., 13, Laverack Street, Handsworth, Sheffield.
N.	1925.	Burn, R. D., B.Sc., A.I.C., "Aslo," Irwin Avenue, Wallsend-on-Tyne,
Sc.	1917.	Burns, J. K., 77, Sandy Road, Renfrew.
N.	1925.	Burrell, J., 2, Bede Crescent, Willington-on-Tyne.
W.R. of Y.	1921.	Butterfield, P., 10, Eastfield Place, Sutton-in-Craven, Keighley, Yorks,
Lncs.	1923.	Butterworth, A. W., 214, Frederick Street, Werneth, Oldham.
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.	Buxton, J., 68, Luke Lane, Hurst, Ashton-u.-Lyne.
Lncs.	1926.	Cairns, F., 59, Blodwell Street, Seedley, Manchester.
B.	1924.	Callaghan, G. M., 6, Foxgrove, Acocks Green, Birmingham.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1920.	Cameron, N., Cavendish Villas, Devonshire Road, Totley Rise, Nr. Sheffield.
Lncs.	1926.	Campbell, A. B., 125, Stamford Road, Audenshaw, Manchester.
Sc.	1912.	Campbell, D. McGregor, Torwood Foundry, Larbert.
L.	1914.	Campbell, J., 9, Western Gardens, Ealing, W.
Lncs.	1918.	Campbell, W., 12, Denbeigh Street, Stockport.
S.	1927.	Carlisle, E. A., 3, Silver Hill Road, Ecclesall, Sheffield.
Lncs.	1925.	Carr, H., 7, Lord Street, Stalybridge.
L.	1921.	Carrell, Hy. Alfred, 6J, Peabody Buildings, Farringdon Road, E.C.
Lncs.	1914.	Carter, E., 59, Chief Street, Oldham,
W.R. of Y.	1927.	Carter, S., Cowley Lane, Lepton, nr. Huddersfield.
W.R. of Y.	1923.	Carver, W., 112, Valley Road, Pudsey, near Leeds.
W.R. of Y.	1922.	Causer, L. W., 79, Fitzroy Road, Barkerend Road, Bradford.
S.	1925.	Chambers, J. F., 31, Duke Street, Staveley, Chesterfield.
W.R. of Y.	1922.	Chappelow, Thos., 181, Taylor Street, Batley, Yorks.
Sc.	1921.	Charters, J., 12, Walworth Terrace, Glasgow.
Lncs.	1925.	Cheetham, E., 5, Eldon Road, Edgeley, Stockport.
S.	1911.	Chope, H. F., 38, Church Street, Sheffield.
N.	1920.	Clark, J. W., 133, St. Thomas' Terrace, Blaydon-on-Tyne.
L.	1923.	Clark, W., 9, Jubilee Road, Basingstoke.
M.	1919.	Clarke, A. S., Leicester Road, Loughborough.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
N.	1912.	Clarke, J., Droston, Tayport, Fife.
N.	1920.	Clements, H. F., c/o Wm. Jacks & Co., Ltd., Ocean Buildings, Prince Street, Singapore, Straits Settlements.
Sc.	1922.	Cleverley, A.M., B.Sc., 45, Kennard Street, Falkirk, Scotland.
Lncs.	1922.	Cleworth, Alf., 25, Walnut Street, Bolton.
Lncs.	1921.	Coleman, J. I., West Dene, Brooklyn Road, Wilpshire, Blackburn.
W. & M.	1926.	Coles, F. L., 46, Burnaby Street, Cardiff.
S.	1920.	Coles, W. H., 2, Gordon Avenue. Woodseats, Sheffield.
S.	1916.	Collins, B. L., Folds Crescent, Abbey Lane, Sheffield.
W.R. of Y.	1926.	Collinson, K. H., 11, Grandmere Place, Halifax.
S.	1907.	Cook, A. H., W. Cook & Sons, Ltd., Washford Road, Sheffield.
E.M.	1916.	Cook, F., 168, Woods Lane, Derby.
S.	1914.	Cook, W. G., Washford Road, Sheffield.
Lncs.	1927.	Cooke, J., 116, Derbyshire Avenue, Stretford, Manchester.
Lncs.	1926.	Cooke, T., 15, Finchley Road, Hale, Cheshire.
M.	1926.	Cooper, A., 50, Upper Oxford Street, South Bank.
S.	1914.	Cooper, J. F., 176, Attercliffe Road, Sheffield.
L.	1925.	Cooper, M. J., Heath Way, Northumberland Heath, Erith, Kent.
B.	1915.	Cooper, W., 123, Wyley Road, Coventry.
N.	1919.	Corbett, W. A., "Dinguardi," Bungalow 19, High Farm Estate, Wallsend-on-Tyne.
S.	1914.	Coupe, B., 317, Bellhouse Road, Shiregreen, Sheffield.
Lncs.	1926.	Coupe, Wm., junr., 36, Kittlingborne, High Walton, nr. Preston.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1919.	Cree, A., 160, Mount Amnan Drive, King's Park, Cathcart, Glasgow.
E.M.	1926.	Creese, H. J., 46, Kensington Street, Leicester.
Lncs.	1910.	Critchley, F., 631, St. Helens Road, Bolton.
S.	1912.	Critchley, T., 52, Limpsfield Road, Brightside, Sheffield.
Lncs.	1927.	Cullinmore, G., 15, Lincoln Square, Farnworth, Widnes.
B.	1906.	Curnow, M. H., 41, Cemetery Lane, West Bromwich.
Sc.	1926.	Currie, J., 1, Sutherland Crescent, Bathgate.
S.	1914.	Currie, J. A., "Rose Cottage," Grindleford, Derbyshire.
B.	1907.	Dalrymple, D., 20, Beeches Road, West Bromwich.
S.	1920.	Darby, A., 5, Dobbin Hill, Greystones, Sheffield.
S	1909.	Darley, F., 187, Burngreave Road, Pitsmoor, Sheffield.
S.	1915.	Darley, G. F., Cawwood & Co., Ltd., Westgate Foundry, Rotherham.
E.M.	1923.	Darrington, L. G., 27, Kingston Avenue, Hallam Fields, Ilkeston.
Sc.	1922.	Davidson, W. B., (Jas. Keith & Blackman Co., Ltd.), Arbroath.
W. & M.	1924.	Davies, E. H., 224, Cardiff Road, Aberaman.
B.	1925.	Davis, A., 3/247, Gt. Russell Street, Birmingham.
L.	1916.	Davis, E. J., 11, Beclair Street, Belfast.
Lncs.	1923.	Davis, J., 50, Old Road, Dukinfield, Cheshire.
Sc.	1926.	Davis, Thos., 633, Dumbarton Road, Partick, Glasgow.
L.	1914.	Davis, W. H., 8, Pye Street, Portsmouth.

ASSOCIATE MEMBERS.

B'nch.	Year of Election.	
S.	1922.	Day, A. B., 19, Scarsdale Road, Dronfield, near Sheffield.
Lncs.	1925.	Dean, J., 48, Northgate Road, Stockport.
Lncs.	1924.	Deeley, F., 52, Bewsey Street, Warrington.
Lncs.	1918.	Demaine, F. C., 9, Rising Sun Lane, Garden Suburb, Oldham.
Lncs.	1922.	Demaine (jun.), F. C., 9, Rising Sun Lane, Garden Suburb, Oldham.
Lncs.	1926.	Denison, H., 20, Second Avenue, Kidsgrove, Stoke-on-Trent.
M.	1926.	Denwood, W., 7, Pearl Street, Haverton Hill, Middlesbrough.
W.R. of Y.	1922.	Derrington, H., 6, Victoria Terrace, Hopwood Lane, Halifax.
L.	1909.	Derry, L. B., 3, Preston Road, Yeovil, Somerset.
E.M.	1924.	De Ville, J. C., 16, Co-operative Street, Derby.
B.	1925.	Dexter, B. J., 80, New Rowley Street, Walsall.
S.	1915.	Dickinson, J., 49, Yarboro' Road, Lincoln.
N.	1916.	Dickinson, S., 103, Bede Street, Roker, Sunderland.
B.	1920.	Dicks, G. E., 110, Richmond Hill, Langley, near Birmingham.
S.	1914.	Dixon, A. F., 9, Bristol Road, Sheffield.
L.	1916.	Dobson, J., 3, Bond Isle Terrace, Stanhope, Co. Durham.
N.	1924.	Dodds, J., 64, Scotswood Road, South Benwell, Newcastle-on-Tyne.
Lncs.	1921.	Dolphin, J. H., 201, Eskrick Street, Halliwell, Bolton.
W. & M.	1924.	Domville, S., 301, Railway Street, Cardiff.
Sc.	1919.	Donaldson, J. W., B.Sc., Scott's Shipbuilding and Engineering Company, Limited, Greenock.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1919.	Dorsie, J. C., Maplewood, Kirkintilloch.
B.	1920.	Dubberley, F., 44, Great Arthur Street, Smethwick, Staffs.
Lncs.	1925.	Duckworth, J. A., 42a, Ormerod Street, Accrington.
Lncs.	1924.	Dudley, Wm., 11, Barlow Street, Lower Openshaw, Manchester.
Sc.	1917.	Duncan, J., 78, Jellicoe Street, Dalmuir.
Lncs.	1921.	Dunkerley, James, 10, Old Hall Drive, Gorton, Manchester.
L.	1920.	Dunn, J. W., 144, Coulson Road, Coventry.
Lncs.	1913.	Eastwood, J. H., 83, Princess Street, Castleton, nr. Manchester.
L.	1912.	Eccott, A. E., The Elms, 68, Smithies Road, Plumstead, S.E.
N.	1923.	Eckford, J. W., 34, Tynedale Avenue, Monkseaton.
S.	1925.	Edginton, J., 3, Coupe Road, Burngreave, Sheffield.
Sc.	1911.	Edmiston, M., Rose Vale, Windsor Road, Renfrew.
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.
E.M.	1925.	Elder, A., 90, Stenson Road, Derby.
Sc.	1927.	Elder, P., 10, Napier Crescent, Bainsford, Falkirk.
E.M.	1909.	Ellson, J., Manor View, Ripley, Derby.
S.	1924.	Emmott, J., 33, Bowood Road, Sheffield.
Sc.	1920.	Erskine, N. A. W., Morton Cottage, Camelon.
Lncs.	1924.	Evans, H., 93, Second Avenue, Trafford Park, Manchester.
B.	1927.	Everest, A. B., B.Sc., Ph.D., Chad Hill, Harborne Road, Edgbaston, Birmingham.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
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.	1924.	Fellingham, T. R., 81, Henshaw Street, Stretford, Manchester.
Lncs.	1923.	Fellows, F., 21, Bright Street, Gorton, Manchester.
L.	1924.	Fenn, J. H., 25, Francemary Street, Brockley, S.E.4.
Sc.	1912.	Ferlie, T., Steel and Iron Founder, Auchtermuchty, Fifeshire.
S.	1927.	Firth, T. C., Storth Oaks, Ranmoor, Sheffield.
L.	1926.	Fish, F. W., 166, Glebe Street, Letchworth, Herts.
Lncs.	1922.	Fist, Thomas, 127, Hughes Street, Hallewell, Bolton.
N.	1922.	Flack, E. W., 3, Falshaw Street, Washington Station, Co. Durham.
B.	1927.	Flavel, S. W. B., 11, Avenue Road, Warwick Street, Leamington Spa.
B.	1918.	Flavell, W. J., Carter's Green Passage, West Bromwich.
Lncs.	1923.	Flint, W. H., 225, Peel Green Road, Patricroft, Manchester.
Lncs.	1919.	Flitcroft, E., School Hill Ironworks, Bolton.
E.M.	1925.	Food, F. H., 108, Upper Conduit Street, Leicester.
N.	1912.	Ford, H., 14, Oakwellgate Chare, Gateshead-on-Tyne.
W.R. of Y.	1924.	Foster, H., 10, Highfield Place, Bramley, Leeds.
L.	1912.	Fowler, T. E., 72, Station Road, New Southgate, N.11.
	1923.	Fox, F. S., 6333, Tuxeda Avenue, Detroit, Michigan, U.S.A.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1909.	Fraser, A., 1, Bridge Street, Chilvers Coton, Nuneaton.
Lncs.	1924.	Frith, W., 8, Buckley Street, Ashton New Road, Clayton, Manchester.
N.	1920.	Futers, R. Wm., 107, Sandwich Road, South Shields.
E.M.	1925.	Gale, B., 15, Ridgway Street, Nottingham.
Sc.	1904.	Galt, J., Henry & Galt, Sneddon Foundry, Paisley.
B.	1920.	Gaunt, J. W., 101, Beeches Road, West Bromwich.
L.	1927.	Gerrard, J. Norbreck, Alexandra Road, Peterborough.
E.M.	1926.	Gill, F., 470A, Bennett Road, Mapperley, Nottingham.
Sc.	1927.	Gillepsie, H. Mc. K., "Stenhouse," Carron, Falkirk.
Lncs.	1923.	Gilpin, W., "Sunnyside," Birch Grove, Rusholme, Manchester.
E.M.	1924.	Gilson, A. J., 15, Marcus Street, Derby.
M.	1926.	Gleave, J., 1, Victoria Street, Haverton Hill, Middlesbrough.
Lncs.	1922.	Gledhill, F., 205, East View, Bradford Road, Brighouse, Yorks.
B.	1917.	Glyn, T. A., 67, Green Lane, Handsworth, Birmingham.
W.R. of Y.	1922.	Goff, R. M., 78, Lower Rushton Road, Thornbury, Bradford.
Lncs.	1924.	Goodwin, G. W., 11, Wycliffe Road, Urmston, Manchester.
E.M.	1919.	Goodwin, T., Braeside Street, New Bedford, Derby.
B.	1922.	Gospel, W., Gutta Percha Co., c/o The Staffordshire Stainless Iron Co., Ltd., Baldwin Street, Bilston, Staffs.
Sc.	1919.	Graham, R., 116, Stratford Street, Maryhill, Glasgow.
E.M.	1917.	Grant, George, 62, Leicester Road, Quorn, nr. Loughborough.
Sc.	1912.	Gray, J., 2, Station Road, Dumbarton.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1925.	Greaves, H. A., 25, Raven Road, Nether Edge, Sheffield.
S.	1924.	Greaves, J., 3, New Houses, Piccadily, Chesterfield.
S.	1919.	Greaves, J. B., 121, Upperthorpe, Sheffield.
S.	1924.	Green, A., 31, Broom Grove, Rotherham.
Lncs.	1924.	Green, A. E., 66, Wolseley Road, Preston.
S.	1917.	Green, F. N., Brook House, Ecclesfield, Sheffield.
S.	1926.	Green, J. W., 16, Littlemoor Crescent, Newbold, Chesterfield.
S.	1914.	Green, P., 54, Rolleston Road, Firth Park, Sheffield.
Lncs.	1927.	Greenhalgh, A., 36, John Street, Heywood. Lancashire.
Lncs.	1920.	Greenhalgh, W., 86, Crosby Road, Bolton.
M.	1926.	Greenwell, O., 12, Angle Street, Grove Hill, Middlesbrough.
Lncs.	1924.	Greenwood, T., 1, Schofield Street, Todmorden.
Lncs.	1926.	Greenwood, Wm., 44, Cecil Road, Eccles, near Manchester.
L.	1926.	Gregory, A. W., 98, Ashton Road, Luton.
L.	1918.	Gregory, E., 16, Mansfield Road, Beech Hill, Luton.
B.	1926.	Griffiths, A. G., 2, Tilbury Grove, King's Heath, Birmingham.
E.M.	1924.	Griffiths, S., 94, Stenson Road, Derby.
M.	1926.	Griffiths, W., Valley View, Station Road, Amersham, Bucks.
Lncs.	1925.	Grieve, J. E., 24, Tindall Street, Reddish, Stockport.
Lncs.	1919.	Grimwood, E. E. G., 129, Glebelands Road, Ashton-on-Mersey.
Lncs.	1912.	Grundy, H. V., Pentrich, Campbell Road, Brooklands, Cheshire.
L.	1920.	Gurney, S. J., 11, Burns Road, Battersea, S.W.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
M.	1926.	Hackwood, J., 52, Byelands Street, Middlesbrough.
Sc.	1920.	Haig, J., 7, Victoria Road, Larbert, N.B.
Sc.	1920.	Haig, T., 23, Livingston Terrace, Larbert, N.B.
S.	1909.	Hall, E. D., 50, Napier Street, Sheffield.
L.	1921.	Hall, Geo., "Glenthorne," Swan Hill, Oxton, Birkenhead.
N.	1914.	Hall, J. J., Clyde Vale, Rowlands Gill, Co. Durham.
E.M.	1925.	Hallamore, J. C., Oak Farm, Burton Road, Littleover, nr. Derby.
Sc.	1925.	Hamil, W., 50, Woodhead Avenue, Kirkintilloch.
W.R. of Y.	1927.	Hammond, D. W., 63, Waverley Road, Great Horton, Bradford.
B.	1924.	Hammond, G. A., 13c, Hill Top, West Bromwich, Staffs.
L.	1921.	Hammond, L., 27, North Way, North Heath, Erith.
E.M.	1925.	Hancock, D., 43, Drewry Lane, Derby.
B.	1927.	Hand, A. F., 18, Holyhead Road, Oakengates, Salop.
L.	1918.	Hand, H. E., 189, Manwood Road, Crofton Park, S.E.4.
E.M.	1924.	Hanson, C. H., 285, Abbey Street, Derby.
W. & M.	1924.	Harding, J. W., 14, Welford Street, Barry.
Gen.	1927.	Hares, A., Park Crescent, 648, Stapleton Road, Bristol.
L.	1927.	Harford, A. E., 85, Sumatra Road, West Hampstead, N.W.6.
Lncs.	1926.	Hargraves, R. C., 114, Chapel Street, Levenshulme, Manchester.
Lncs.	1919.	Hargraves, R. R. (Grandridge and Mansergh, Ltd.), Wheathill Street, Salford, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
M.	1927.	Harper, F. A., 17, Brankingham Terrace, Stockton-on-Tees.
Lncs.	1911.	Harper, H., 28, Alexandra Street, Castleton, nr. Manchester.
B.	1927.	Harper, J., 113, Mansfield Road, Aston, Birmingham.
L.	1925.	Harrington, W. T., 21, Vernon Road, Stratford, London, E.15.
Lncs.	1922.	Harris, F., 18, Holland Street, Padiham, Lancs.
S.	1926.	Harris, R. S., Callywhite Lane, Dronfield, Sheffield.
M.	1926.	Harrison, A. G., 11, Bevan Terrace, Norton Road, Stockton-on-Tees.
Sc.	1916.	Harrower, J. (Bo'ness Iron Company), Bo'ness, Scotland.
L.	1927.	Hart, W. F., 5, Bishops Avenue, Braintree, Essex.
Lncs.	1924.	Hartley, R., 15, Oxford Road, Bootle, Liverpool.
Sc.	1914.	Hartley, R. F., London Road Foundry, Edinburgh.
M.	1926.	Harvey, D., 4, Rydal Road, Stockton-on-Tees.
S.	1926.	Hatton, W. H., Broomhall Lane, Sheepbridge, Chesterfield.
E.M.	1925.	Hawley, T. H., 53, Willow Brook Road, Leicester.
Sc.	1910.	Hay, J., 120, Brownside Road, Cambuslang, Glasgow.
B.	1910.	Hayward, G. T., 8, The Laurels, Marroway Street, Birmingham.
Lncs.	1923.	Hayward, R., 39, Belgrave Road, New Moston, Manchester,
E.M.	1922.	Hayward, Wm., Fairhaven, Pastures Road, Stapleford, nr. Nottingham.
Lncs.	1925.	Heatley, H., 146, Redlam, Blackburn.
W.R. of Y.	1925.	Heaton, B., Messrs. Hall & Stell, Dalton Lane, Keighley.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1906.	Heggie, C., 79, Holly Lane, Erdington, Birmingham.
Lncs.	1922.	Henderson, G., 1120, Eleventh Street, Trafford Park, Manchester.
L.	1910.	Henderson, G. B., 23, College Road, Woolston, Southampton.
N.	1923.	Henderson, J. W., c/o Singapore Harbour Board, Keppel Harbour, Singapore, Straits Settlements.
Sc.	1911.	Henderson, R., 67, Love Street, Paisley.
Sc.	1921.	Henry, John, 75, Alma Street, Grahamston, Falkirk.
Lncs.	1922.	Henshaw, J. E., 427, Stockport Road, Lower Bredbury, Stockport.
E.M.	1920.	Hey, James Wm., 43, Howe Street, Derby.
B.	1927.	Hibbert, J. C., 39, Montague Road, Erdington, Birmingham.
L.	1922.	Hibbert, J., 138, Burlington Road, Thornton Heath, Croydon.
L.	1925.	Hickenbottom, W. J., 50, Waterloo Road, Dunstable.
Lncs.	1915.	Hill, A., 114, Middleton Road, Heywood, Lancs.
Lncs.	1925.	Hill, H. G., 495, Stretford Road, Old Trafford, Manchester.
E.M.	1917.	Hilton, H. J. S., 29, West Avenue, Derby.
Lncs.	1909.	Hilton, T. G., 171, Rose Hill Road, Burnley.
B.	1921.	Hinley, Geo. H., 53, Park Lane East, Tipton, Staffs.
W.R. of Y.	1922.	Hird, W., The Corner, Harden, Bingley, Yorks.
B.	1918.	Holder, F. W., 131, Eagle Street, Coventry.
E.M.	1926.	Holland, G., Costock, nr. Loughborough.
S.	1920.	Holland, G. A., Red House, Clay Cross, near Chesterfield.
Lncs.	1922.	Holland, W., 1151, Chester Road, Stretford, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
E.M.	1925.	Holloran, J., 162, Brook Street, Derby.
Lncs.	1924.	Holt, A., 41, Carmen Street, Ardwick, Manchester.
B.	1917.	Homer, W. C., 51, Lodge Road, West Bromwich.
B.	1924.	Hopkins, O. W., 72, Abbey Road, Bearwood, Birmingham.
Lncs.	1925.	Hopwood, A., 154, Chestergate, Stockport.
L.	1921.	Hotchkis, J. D., 29, Romberg Road, London, S.W.17.
B.	1922.	Houghton, J., 15, Mayfield Road, Coventry.
Lncs.	1924.	Howard, E. J. L., 8, Queens Terrace, Clarence Road, Longsight, Manchester.
Lncs.	1921.	Howcroft, J., 5, St. James' Street, New Bury, Farnworth, nr. Bolton.
W. & M.	1922.	Howe, C. A., G. I. P. Loco Works, Parcl. Bombay, India.
L.	1927.	Howell, L. H., 67, Foyle Road, Blackheath, London, S.E.3.
W.R. of Y.	1917.	Hoy, R. E., 33, Brunswick Avenue, Beverley Road, Hull.
N.	1923.	Hudson, F., 28, Curtis Road, Fenham, Newcastle-on-Tyne.
Lncs.	1926.	Hudson, R., 39, St. Andrew Avenue, Droylesden, Lancashire.
B.	1924.	Hulse, J. C., 8, Cecil Street, Walsall, Staffs.
S.	1925.	Hunt, A., 18, Hollingwood Common, Barrow Hill, nr. Chesterfield.
S.C.	1926.	Hunter, J. M., 77, Prestwick Road, Ayr.
Sc.	1923.	Hunter, R. L., Newlands House, Polmont, Stirlingshire.
L.	1922.	Husselbury, E., Rosemead, Winifred Road, Bedford.
L.	1924.	Hutchings, T. C., 10, Lopen Road, Silver Street, Edmonton, London, N.18.
B.	1925.	Hyde, Sidney, 25, Inhedge, Gornal, near Dudley.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1917.	Inskip, A., 992, Ashton Old Road, Openshaw, Manchester.
Sc.	1920.	Irvine, A., The Point, King Street, Larbert, N.B.
W.R. of Y.	1925.	Jackson, A., 73, First Street, Low Moor, Bradford.
Lncs.	1925.	Jackson, A., 27, Marlboro' Street, Accrington.
Lncs.	1923.	Jacques, T., The Cottage, Hill Top, Romiley, nr. Stockport.
B.	1914.	James, W., 96, Grove Lane, Handsworth, Birmingham.
L.	1925.	Jarvis, B., 30, Princes Street, Dunstable, Beds.
N.	1919.	Jay, H. C., 32, Bayswater Road, West Jesmond, Newcastle-on-Tyne.
Sc.	1927.	Jeffrey, R. S. M., Lithgow Avenue, Kirkintilloch.
N.	1921.	Jobes, G. B., 18, South Street, Gateshead-on-Tyne.
B.	1919.	Johnson, J. B., 27, Ball Fields, Tipton.
M.	1926.	Johnson, L., 45, Lanehouse Road, Thornaby-on-Tees.
N.	1925.	Johnson, N., 17, Chester Road, Sunderland, Co. Durham.
B.	1924.	Johnston, W. L., 49, Gough Road, Coseley, nr. Bilston, Staffs.
Lncs.	1916.	Jones, J. H., "Elleray," Temple Drive, Swinton, Manchester.
Lncs.	1919.	Jowett, H., 53, Turf Hill Road, Rochdale.
L.	1927.	Kain, C. H., 7, Victoria Street, Braintree, Essex.
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., "Dunottar," Campbell Road, Brooklands, Cheshire.
Sc.	1927.	Kennedy, D., 23, Copland Road, Govan, Glasgow.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1912.	Kennedy, J., "Dunard," Howieshill, Cambuslang.
E.M.	1918.	Kerfoot, John, 23, Cumberland Road, Loughborough.
Sc.	1914.	Kerr, W., 101, Ardgowan Street, Glasgow.
Lncs.	1925.	Kershaw, J., 31, Birkdale Street, Cheetham Hill, Manchester.
Lncs.	1927.	Kidd, S. (Junior), 4, St. Stephens Street, Oldham.
Sc.	1927.	Kilpatrick, A., 463, Cullen Terrace, Carron Road, Falkirk.
N.	1925.	Kirby, A. D., 6, Falshaw Street, Washington Station.
Lncs.	1924.	Kirkham, J., 13, Gt. James Street, W. Gorton, Manchester.
W.R. of Y.	1922.	Kirkbride, A. D., 24, Springswood Avenue, Shipley, Bradford, Yorks.
Sc.	1920.	Kirkwood, J., 102, Balgrayhill Road, Springburn, Glasgow.
B.	1922.	Kitchen, B., 1, Hughes Avenue, Birches Barn Road, Wolverhampton.
B.	1919.	Klyver, F. D., 45, Farman Road, Coventry.
S.	1908.	Knowles, J. (c/o. Walkers), Manchester Road, Stocksbridge, Sheffield.
B.	1927.	Lafford, T. W., 8, Pensnett Road, Brierley Hill.
L.	1922.	Laidlow, Wm., 9, Griffin Road, Plumstead, S.E.
Lncs.	1923.	Laing, J., 23, Aspley Road, Bedford.
Lncs.	1927.	Lally, W., 1a, Duchy Street, Seedley Road, Pendelton, Manchester.
Sc.	1922.	Lang, Wm., 64, Second Avenue, Radnor Park, Clydebank.
Sc.	1907.	Lawrie, Alex., 40, Glebe Road, Kilmarnock.
Sc.	1919.	Lawrie, R. D., 49, Thorncliffe Lane, Chapeltown, Sheffield.
S.	1920.	Laycock, E.,213, Grimesthorpe Road, Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1914.	Leaf, J. W., District Bank House, Castleton, nr. Rochdale.
E.M.	1925.	Lee, H., 20, Moss Street, Derby.
N.	1913.	Lee, J., 38, Point Pleasant Terrace, Wallsend-on-Tyne.
Gen.	1921.	Leech, Wm. Creighton (N.S.W. Gov. Railways), Wentworth and Rutledge Street, Eastwood, Sydney, N.S.W.
S.	1925.	Levesley, Wm., 32, Westbourne Road, Broomhill, Sheffield.
S.	1920.	Lewin, H., "Westbrook," St. John's Road, Newbold, Chesterfield.
B.	1919.	Lewis, D. (John Harper & Company, Limited), Albion Works, Willenhall, Staffs.
B.	1925.	Lewis, E. J., 61, Grafnant, Church Vale, West Bromwich.
B.	1910.	Lewis, G., Strathmore, Paget Road, Wolverhampton.
W.R. of Y.	1926.	Liddemore, A. E., Cliffe Terrace, Ingrow, Keighley.
Sc.	1925.	Liddle, R., 117, Roseberry Street, Oatlands, Glasgow.
Lncs.	1927.	Liley, M., 64, Buxton Crescent, Turf Hill Estate, Rochdale.
E.M.	1923.	Limbert, H., 15B, Factory Street, Loughborough.
Lncs.	1925.	Lineker, A. W., Ruddington House, Beaconsfield, C.P., South Africa.
L.	1919.	Lisby, T., 7, Meanley Road, Manor Park, E.
N.	1919.	Little, J. E. O., 1, Gibson Terrace, Maryhill, Dundee.
Sc.	1910.	Littlejohn, A., 11, Esmond Street, Yorkhill, Glasgow.
L.	1922.	Littleton, W. H., 29a, Wabeck Road, Anerley, S.E.20.
Lncs.	1925.	Lockett, E., 38, Jackson Street, Gorton, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1922.	Longden, J., 11, Drumry Road, Clydebank.
W.R. of Y.	1922.	Lowe, E., 35, Foster Road, Ingrow, Keighley, Yorks.
Lncs.	1927.	Lowe, J., 175a, Dill Hall Lane, Church, near Accrington.
Lncs.	1910.	Lupton & Sons, H. E., Scaithcliffe Works, Accrington.
W.R. of Y.	1927.	Loxton, C. R., 26, Elmet Avenue, Roundhay, Leeds.
B.	1908.	Mace, C., 64, Port Street, Manchester.
Sc.	1926.	McArthur, J. N., 24, Bank Street, Hillhead, Glasgow.
N.	1919.	McBride, T. B., 3, Kingsley Avenue, Whitley Bay.
Sc.	1910.	McCall, J. J., 162, Cambridge Drive, N. Kelvinside, Glasgow.
S.	1922.	McCleallan, C. J., 110, Carver Street, Sheffield.
Sc.	1919.	McConnell, W., 136, Carsaig Drive, Craigton, Glasgow.
Sc.	1925.	McCulloch, W., 174, Newlands Road, Cathcart, Glasgow.
M.	1927.	McCusker, C. B'., 32, Lanehouse Road, Thornaby-on-Tees.
M.	1927.	McCusker, M. S., 6, Wood Street, Stockton-on-Tees.
Lncs.	1924.	McDermott, J. P., 118, Briersill Avenue, Rochdale.
S.	1913.	Macdonald, W. A., 219, Ringinglow Road, Ecclesall, Sheffield.
E.M.	1924.	McDonald, D. M., 45, Stenson Road, Derby.
Sc.	1913.	McDonald, W. F., 5, Hutchinson Place, Cambuslang.
Sc.	1917.	MacDougall, Miss E., 22, Clarendon Street, St. George's Cross, Glasgow.
Sc.	1911.	McEachen, J., Regent Street, Kirkintilloch.
Sc.	1910.	Macfarlane, J., 51, Kings Park Avenue, Cathcart, Glasgow.
B.	1904.	McFarlane, T., Farm Road, Horsehay, Salop.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1914.	McGavin, R., 5, McKenzie Avenue, Clydebank.
Sc.	1920.	McGovan, A., 69, Battlefield Avenue, Langside, Glasgow.
Sc.	1910.	McGowan, R. R., Colliston-by-Arbroath.
Sc.	1910.	Mackay, G., 103, Glasgow Road, Paisley.
S.	1916.	Mackley, A., 151, Malton Street, Sheffield.
Lncs.	1923.	McKenzie, Wm., c/o J. Hodgkinson, Ltd., Ford Lane Works, Pendleton, Manchester.
Sc.	1922.	McKinnon, J. C., Leaside Cottage, Cogan Street, Barrhead.
Lncs.	1922.	Maclachlan, J. R., 7, Newall Mount, Otley, Yorks.
Sc.	1910.	McLachlan, W., 5, Dawson Terrace, Carron, Falkirk.
N.	1922.	McLaughlin, P., 9, Polmaise Street, Blaydon-on-Tyne.
W. & M.	1925.	McLean, J., Donella, 12, Dinas Street, Grange, Cardiff.
Sc.	1915.	McNab, J., Bells Wynd, Falkirk.
Sc.	1925.	McNiven, Alex, 13, Dawson Street, Falkirk.
Sc.	1910.	McPhie, H., 40, Philip Street, Falkirk.
Lncs.	1927.	McVie, J., Glen View, 23, Infirmary Road, Blackburn.
Sc.	1926.	McWhirter, A., 74, Ochie Street, Tollcross, Glasgow.
Gen.	1925.	Mahindra, J. C., 6 and 7, Clive Street, Calcutta, India.
Lncs.	1921.	Mallett, E., 1152, Chorley Old Road, Bolton.
N.	1924.	March, T., 25, Clifford Street, Blaydon-on-Tyne.
B.	1909.	Marks, J., 73, Crosswells Road, Langley, Birmingham.
Lncs.	1923.	Marlow, E., 53, Flixton Road, Urmston, Manchester.
Sc.	1910.	Marshall, G., "Fereneze," Russell Street, Burnbank, Lanarkshire.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
L.	1922.	Marshall, H. C., 29, Westward Road, S. Chingford, E.4.
Sc.	1912.	Marshall, W. G., "Kyleakin," Larkhall, Scotland.
Lncs.	1925.	Marsland, J., 205, Manchester Road, Droylesden, Manchester.
Lncs.	1913.	Marsland, T., 401, Manchester Road, Droylesden, Manchester.
Gen.	1924.	Mason, A., 2, Lindsey Street, Frodingham, Scunthorpe, Lincs.
W.R. of Y.	1922.	Martin, F., 67, Nowell Terrace, Harehills Lane, Leeds.
Lncs.	1927.	Martin, W., 34, St. George Street, Withington, Manchester.
B.	1925.	Massey, J. S., 49, Hawkes Lane, Hill Top, West Bromwich.
Lncs.	1917.	Masters, J., "The Hollins," Vane Road, Longden Road, Shrewsbury.
B.	1922.	Masters, T. J., 12, Glover Street, West Bromwich.
B.	1909.	Mathews, J., 20, Earl Street, Walsall.
B.	1921.	Mauby, R. A., Hopstone, Bridgnorth, Salop.
Lncs.	1926.	Mazarachi, A. C., 42, Ullet Road, Liverpool.
Lncs.	1925.	Meadowcroft, H., 14, Worcester Street, Rochdale.
Sc.	1914.	Mearns, A., Bengal Iron Co., Kulti, E. I. R., India.
Lncs.	1926.	Mellors, W., 166, West Street, Oldham.
M.	1926.	Menzies, A., 2, Poplar Road, Thornaby-on-Tees.
Lncs.	1926.	Merigold, J. J., 67, Swans Lane, Bolton.
B.	1921.	Meston, J. M., Priory House, Priory Street, Coventry.
S.	1913.	Miller, A., 90, Bawtry Road, Tinsley, Sheffield.
S.	1918.	Milner, H., 163, Cross Hill, Ecclesfield, nr. Sheffield.
W.R. of Y.	1923.	Milner, J. W., 29, Welbeck Street, Sandal, Wakefield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1927.	Mitchell, W. C. 2, Lang Street, Paisley.
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.
W.R. of Y.	1927.	Moffitt, R., 172, Devonshire Street, Keighley, Yorks.
Sc.	1916.	Moir, J. D., Bo'ness Iron Company, Ltd., Bo'ness, Scotland.
Sc.	1926.	Moir, T., 10, Alma Street, Falkirk, N.B.
B.	1916.	Mole, T., 7, Delville Road, Church Hill, Wednesbury.
E.M.	1921.	Moodie, Colin, 169, Station Road, Beeston, Notts.
Lncs.	1926.	Moore, R. C., 61, Fitzwarren Street, Seedley, Manchester.
B.	1916.	Moore, W. H., Devonia, Moat Road, Langley Green, Birmingham.
N.	1920.	Moorhead, H. A., 22, Moorland Crescent, Walker Estate, Newcastle.
Sc.	1909.	Morehead, J. S., 98, Wilton Street, Kelvinside, Glasgow.
B.	1919.	Morewood, J. L., 37, Paignton Road, Rotton Park, Birmingham.
B.	1926.	Morgan, E. S., 22, Clipton Road, Saltley, Birmingham.
W. & M.	1922.	Morgan, W., Bryn Derwen, Bryn Terrace, Porth, Glam., So. Wales.
S.	1924.	Morris, T. R., 3, Albert Street, Masboro', Rotherham.
Lncs.	1925.	Morris, W., 16, Bird Street, Preston.
N.	1924.	Mudie, T., 34, Beech Grove, Monkseaton.
Sc.	1927.	Muir, W., "Bellevue," Carronshore, Falkirk.
N.	1913.	Murray, J., 5, Elmwood Avenue, Willington. Quay-on-Tyne.
S.	1914.	Naylor, A., 239, Abbeyfield Road, Pitsmoor, Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1915.	Naylor, F., 26, Nowell Crescent, Harehills Lane, Leeds.
B.	1926.	Neath, F. K., 16, Sarehole Road, Hall Green, Birmingham.
Lncs.	1925.	Needham, G. A., 11, Newbridge Lane, Stockport.
W.R. of Y.	1925.	Neild, G., 3, Baden Terrace, Hough End, Bramley, Leeds.
N.	1914.	Nekervis, J., 14, Broughton Road, South Shields.
Gen.	1921.	Newland, J. E., 37, Provost Street, Holbeck, Leeds.
Lncs.	1920.	Newport, F., 1428, Ashton Old Road, Higher Openshaw, Manchester.
W.R. of Y.	1926.	Nichol, W. E., 19, College Road, Crosland Moor, Huddersfield.
Lncs.	1912.	Nicholls, J., 146, Hulton Street, Trafford Road, Salford.
N.	1921.	Nicholson, J. D., 13, Taylor Street, South Shields.
Sc.	1918.	Nisbet, H. L., Lilyburn, Hillend Road, Lambhill, Glasgow.
Lncs.	1920.	Noble, A., 42, Central Road, Gorton, Manchester.
Lncs.	1924.	Noble, J., 53, Reddish Lane, Gorton, Manchester.
B.	1924.	Northcott, L., 9, Kirk Lane, Plumstead Common, London, S.E.18.
S.	1921.	Offiler, G., 9, Ward Place, Highfields, Sheffield.
Lncs.	1920.	Oldham, R., 191, Dill Hall Lane, Church, Lancs.
Lncs.	1923.	Ollier, A. L., 53, Gorse Street, Stretford, Manchester.
N.	1910.	Olsen, W., Cogan Street, Hull.
Sc.	1920.	Orman, Wm., 55, Sunnyside Street, Camelon, Falkirk.
E.M.	1927.	Orme, R. F., Ardorn House, Sydney Road, Hillmorton, Rugby.
S.	1924.	O'Shea, D. B., Vickers, Ltd., Broadway House, Westminster, S.W.
E.M.	1922.	Ottewell, H., The Mead, Swanwick, Alfreton, Derby.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
B.	1922.	Owen, A. C., Gladstone House, Ketley Bank, near Wellington, Salop.
Lncs.	1924.	Owen, W., 33, Granville Road, Gorton, Manchester.
S.	1914.	Oxley, C., 101, Montgomery Road, Sheffield.
B.	1924.	Palmer, A., 14, Marsh Hill, Stockland Green, Birmingham.
Lncs.	1923.	Palmer, T., 5, Marmaduke Street, Oldham.
B.	1925.	Parkes, I., 157, Whitehall Road, Greets Green, West Bromwich.
L.	1920.	Parnell, H., "Freda Villa," 25, Queen's Road, Burnham-on-Crouch.
Lncs.	1925.	Parrington, P., 30, Vernon Street, Bury.
B.	1926.	Parsons, D. J., 23, Imperial Avenue, Kidderminster.
Sc.	1914.	Patrick, A., 65, Mungalhead Road, Falkirk.
B.	1925.	Patrick, J., 5, St. Margaret's Street, Canterbury, Victoria, Australia.
L.	1925.	Payton, T. G., 33, King Street, Dunstable, Beds.
N.	1925.	Pearson, C. E., 2, Pearl Street, Saltburn-by-Sea.
E.M.	1906.	Pemberton, H., 15, Wolfa Street, Derby.
Lncs.	1919.	Perkins, F. S., 55, Slaney Street, Newcastle-under-Lyme, Staffs.
L.	1927.	Perry, A. E., 153, Dartmouth Park Hill, Highgate, London, N.19.
Lncs.	1922.	Phillips, A., 38, Gorse Crescent, Stretford, Manchester.
B.	1927.	Phillips, H., "Fairholme," Parkvale Avenue, Wednesbury, Staffs.
B.	1918.	Picken, J., Lilac Cottage, Doseley, Dawley, Salop.
L.	1920.	Pierce, G. C., 11, Athelney Street, Bellingham, S.E.6.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1926.	Pollard, C. D., 392, Firth Park Road, Sheffield.
Lncs.	1918.	Potts, W., 1, Far Lane, Hyde Road, Gorton, Manchester.
W.R. of Y.	1922.	Poulter, H., 4, Beech Grove, Undercliffe, Bradford, Yorks.
Lncs.	1922.	Prescott, J., 3, Louisa Street, Bolton, Lancs.
Lncs.	1922.	Priestley, Jos., 258, Waterloo Street, Bolton, Lancs.
Lncs.	1922.	Priestley, Thos., 185, Kay Street, Bolton, Lancs.
L.	1912.	Primrose, H. S. (Campbell & Gifford), 17, Victoria Street, S.W.1.
B.	1909.	Pugh, C. B., Ramsey House, Bescot, Walsall.
S.	1917.	Pugsley, T. M., 45, Leslie Street, Vereeniging, Transvaal, South Africa.
M.	1926.	Ramsey, J. E., 95, Princes Road, Middlesbrough.
M.	1926.	Rand, T., 11, Pearl Street, Saltburn-by-Sea.
L.	1926.	Randle, L. A., 45, Nichols Street, Coventry.
Sc.	1904.	Rankin, R. L. (Sharp & Company), Lennox Foundry, Alexandria, Scotland.
L.	1920.	Rasbridge, W. J., 160, Evelyn Street, Deptford, S.E.
Lncs.	1910.	Rawlinson, W., "Fairhaven," Portland Road, Ellesmere Park, Eccles, Manchester.
L.	1917.	Reaman, H., 13, Adelaide Road, Brockley, S.E.4.
S.	1907.	Redmayne, L., Little London Road, Sheffield.
E.M.	1916.	Reffin, J. J., 79, Barclay Street, Fosse Road South, Leicester.
Lncs.	1927.	Reynolds, J. A., "Nirvana," Eccleston Park, near Prescot.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1907.	Reynolds, W., 13, Park View Terrace, Oldham.
W.R. of Y.	1922.	Rhodes, W., 20, Hope View, Carr Lane, Windhill, Shipley, Yorks.
S.	1922.	Rhodes, Wm., Beech Holme, Ecclesfield, nr. Sheffield.
L.	1925.	Richards, W. S., 68, Beatrice Avenue, Keyham Barton, Devonport.
W. & M.	1924.	Richardson, R. J., Llanblethian House, nr. Cowbridge.
N.	1912.	Richardson, W., 204, South Frederick Street, South Shields.
M.	1926.	Richardson, J. W., 424, Linthorpe Road, Middlesbrough.
L.	1924.	Richman, A. J., "Strathaven," Brooks Hall Road, Ipswich.
Lncs.	1927.	Ridyard, A., 26, Astonwood Road, Higher Tranmere, Birkenhead.
Lncs.	1911.	Riley, J., M.Sc., A.M.I.C.E., A.M.I. Mech.E., M.I. & S.I., 3, Glen Road, off Lees Road, Oldham.
S.	1912.	Roberts, G. E., 149, Sharrow Vale Road, Sheffield.
N.	1921.	Robertson, H., 60, Ryhope Road, Grangetown, Sunderland.
Sc.	1920.	Robinson, C. H., 42, Smith Street, Hillhead, Glasgow.
Lncs.	1920.	Robinson, F., 369, Wigan Road, Deane, Bolton.
B.	1925.	Robinson, J., 8, Esplanade East, Calcutta, India.
M.	1917.	Robinson, J. H., c/o. R. W. Crosthwaite, Ltd., Union Foundry, Thornaby-on-Tees.
N.	1919.	Robson, F., 44, Stannington Place, Heaton, Newcastle-on-Tyne.
S.	1913.	Rodgers, F., Brightside Foundry & Engineering Co., Ltd., Newhale Iron Works, Sheffield.
S.	1913.	Rodgers, J. R. R., 362, Firth Park Road, Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1924.	Rodgers, P., Jubilee Place, Bonnybridge.
B.	1917.	Roe, H. J., 29, Park Road, Moseley, Birmingham.
E.M.	1913.	Roe, J., Globe Foundry, Stores Road, Derby.
Gen.	1920.	Rogers, C. F., 28, Maycock Road, Coventry.
Sc.	1926.	Rolland, W., 10, Victoria Drive, Scotstoun, Glasgow.
Sc.	1922.	Ross, E. J., 12, Afton Street, Langside, Glasgow.
Lncs.	1922.	Rowe, F. W., 41, Moorside Avenue, Crosland Moor, Huddersfield.
E.M.	1924.	Rowell, E. L., 1, Rathbone Place, Middle Hill, Nottingham.
W.R. of Y.	1922.	Rowntree, F., 28, Campbell Street, Bowling Back Lane, Bradford, Yorks.
S.	1927.	Roxburgh, J., 720, Abbeydale Road, Sheffield.
M.	1926.	Rutherford, C., "Inglefield," Egglescliffe, near Yarm., S.O.
N.	1925.	Rutledge, W. B., 61, North View, Heaton, Newcastle-on-Tyne.
Lncs.	1924.	Ryding, F., 52, Barnsley Road, Wigan, Lancs.
W.R. of Y.	1927.	Ryner, A. S., West Bank, Heworth, York.
L.	1913.	Samson, A, 18, Martin Road, Ipswich.
L.	1923.	Sanders, H. H., 21, Etherley Road, Harringay, N.15.
S.	1921.	Sanders, Horace L., 72, Murray Road, Ecclesall, Sheffield.
B.	1905.	Sands, J., 27, Victoria Street, West Bromwich.
M.	1926.	Sault, A., 10, Pine Street, Norton-on-Tees.
W.R. of Y.	1922.	Sayers, H., 53, Acre Road, Middleton, near Leeds.
S;	1927.	Scholes, A., 35, Bromwich Road, Woodseats, Sheffield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1924.	Scholes, W. H., 15, Hope Park Road, Bent Hill, Prestwich, Manchester.
Sc.	1923.	Scott, C., 7, La France Avenue, Bloomfield, New Jersey, U.S.A.
N.	1916.	Scott, G. W., 1, Northumberland Villas, Wallsend-on-Tyne.
N.	1921.	Scott, H., 41, Greenhow Place, Elswick, Newcastle-on-Tyne.
N.	1918.	Scott, W., 7, Lynwood Avenue, Blaydon-on-Tyne.
M.	1926.	Seaman, A., 1, Cowper Bewley Road, Haverton Hill, Middlesbrough.
Lncs.	1925.	Self, D., 11, Croft Street, Failsworth, Manchester.
S.	1921.	Senior, George, 305, Upperthorpe, Sheffield.
Lncs.	1925.	Service, J., 78, Highfield Road, Seedley, Manchester.
W.R. of Y.	1913.	Shackleton, H. R., Upper Pear Tree Farm, Hainsworth Shay, Keighley.
W.R. of Y.	1922.	Shaw, A., 28, Marlboro' Road, Shipley, Bradford.
L.	1924.	Shawyer, G. H., 81, Edward Street, Deptford, S.E.8.
L.	1926.	Shawyer, junr., G. W., 81, Edward Street, Deptford, S.E.8.
B.	1924.	Shearman, F. E., 63, Summerfield Crescent, Birmingham.
Lncs.	1926.	Shepherd, F. L., 215, Tottington Road, Bury.
S.	1923.	Sherratt, W., 39, Horndean Road, Pitsmoor, Sheffield.
E.M.	1925.	Sherriff, C., 62, Herbert Street, Loughborough.
B.	1925.	Shore, A. J., "Bradda," Quinton Hill, Birmingham.
B.	1920.	Shorthouse, W. H., 60, Edward Street, West Bromwich.
B.	1927.	Shwalbe, S., 62, Milverton Road, Erdington, Birmingham.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W. & M.	1925.	Silverwood, H. Wm., 320, Newport Road, Cardiff.
Lncs.	1922.	Simkiss, H., 28, Energy Street, Bradford Road, Manchester.
S.	1917.	Simpson, C. D., 17, Willis Road, Hillsbro', Sheffield.
S.	1925.	Simpson, F. A., 110, Edward Street, Sheffield.
B.	1914.	Simpson, H., Greenhurst, Doseley, Dawley, Salop.
W.R. of Y.	1925.	Simpson, J. A., 3, Jesmond Place, Hunslet Hall Road, Leeds.
N.	1916.	Sinclair, J., 25, Granville Street, Millfield, Sunderland.
Lncs.	1905.	Skelton, H. S., "Lindsey," Old Lane, Eccleston Park, Prescot, Lancs.
S.	1925.	Skerl, J. G. A., M.Sc., Dept. of Applied Science, St. George's Square, Sheffield.
L.	1925.	Skidmore, B., 2, Jackmans Place, Letchworth, Herts.
E.M.	1925.	Slade, R. H., 254, St. Thomas Road, Derby.
L.	1911.	Slater, H. O., "Sunny Hill," Lessners Park, Belvedere, Kent.
Lncs.	1906.	Smethurst, J. H., Briery Croft, Lodge Lane, Warrington.
L.	1927.	Smith, A. C., 9, Greenway Gardens, London, N.W.3.
Lncs.	1925.	Smith, F., 85, Greenbank Road, Rochdale.
Gen.	1919.	Smith, F. G., 15, Cherry Street, Coventry.
S.	1913.	Smith, J., Abney House, Gleadless Road, Sheffield.
Sc.	1921.	Smith, J., 6, Kennard Street, Falkirk.
N.	1914.	Smith, J. M., Brass Foundry, Elswick Works, Newcastle.
B.	1917.	Smith, S., 114, Tetley Road, Hall, Green, Birmingham.
Lncs.	1909.	Smith, S. G., 86, Barton Road, Stretford, Manchester.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Lncs.	1924.	Smith, W., 358, Halifax Road, Todmorden.
E.M.	1925.	Smith, W. F., 152, St. Thomas Road, Derby.
E.M.	1926.	Smith, W. H., 9, Leopold Street, Derby.
W.R. of Y.	1924.	Smith, Wm., 10, Bell Street, Newsome Road, Huddersfield.
Sc.	1924.	Sneddon, F. M., 28, Forest Street, Mile End, Glasgow.
S.	1924.	Somerfield, H., 146, Sandygate Road, Sheffield.
L.	1904.	Sperring, B. F., 244, Lake Road, Portsmouth.
Sc.	1920.	Spittal, J., 82, Norham Street, Shawlands, Glasgow.
Lncs.	1926.	Stacey, C. W., 5, Harcourt Street, Gorse Hill, Stretford, Manchester.
Lncs.	1926.	Stanley, F., 16, Fir Street, Patricroft.
B.	1927.	Stanton, L., 8, Low-wood Road, Erdington, Birmingham.
Sc.	1918.	Stark, W. C., 37, Summertown Road, Govan.
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., 240, Bellhome Road, Sheffield.
B.	1914.	Stephen, S. W. B., The Woodlands, Hagley Road West, Birmingham.
L.	1921.	Stevens, Wm., "Newland," Church Rd., Rodbourne, Cheney, Swindon.
Lncs.	1921.	Stevenson, M., 9, Fountains Avenue, Firwood, Bolton.
Sc.	1925.	Stirling, E., York Place, Kirkintilloch,
N.	1914.	Stobbs, R., 199, Stanhope Road. South Shields.
S.	1919.	Stocker, W. E., 109, Ellesmere Road, Pitsmoor, Sheffield.
L.	1915.	Stone, E. G., 20, Cautley Avenue, Clapham Common, S.W.
Lncs.	1920.	Storer, W. H., 255, Settle Street, Great Lever, Bolton.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
W.R. of Y.	1926.	Stott. E., 4, Orchard Street, Otley, Yorks.
L.	1925.	Stubbs, R. G., 290, Commercial Road, Peckham, S.E.15.
L.	1922.	Summers, H. G., 35, Perry Hill, Catford, S.E.6.
E.M.	1927.	Summersgill, E. (Junior), 47, Station Road, Long Eaton, Notts.
Lncs.	1910.	Sutcliffe, A., 1, Firwood Grove, Tonge Moor, Bolton.
W.R. of Y.	1922.	Sutcliffe, A., "Thorncliffe," Wellington Road, Todmorden, Yorks.
Lncs.	1919.	Sutcliffe, W., 3, Birkdale Road, Turf Hill, Rochdale.
Lncs.	1923.	Swann, H., 31, Alexandra Road, Patricroft, Manchester.
Sc.	1927.	Syme, T. R., 90, Rolland Street, Maryhill, Glasgow.
N.	1922.	Tait, A. H., Armagh House, Wallsend-on-Tyne.
S.	1913.	Tait, E., 47, Tyzack Road, Woodseats, Sheffield.
Lncs.	1922.	Tate, C. M., Brook Royd, Todmorden Road, Burnley.
Gen.	1906.	Taylor, A. (Fielding & Platt, Limited), Atlas Ironworks, Gloucester.
B.	1925.	Taylor, A., The Willows, Gipsy Lane, Willenhall.
B.	1925.	Taylor, E. R., 148, South Road, Handsworth, Birmingham.
W. & M.	1905.	Taylor, F. (Taylor & Sons, Limited), Britonferry, South Wales.
B.	1926.	Taylor, F., J.P., "The Willows," Gipsy Lane, Willenhall, Staffs.
Lncs.	1921.	Taylor, James, 3, Tremellen Street, Accrington.
S.	1926.	Taylor, R. J. S., Hill Crest, Broomhall Lane, Old Whittington, Chesterfield.
L.	1925.	Teasdale, I., Homeland, Norton Village, Letchworth.
N.	1921.	Temple, G. T., 35, Grosvenor Drive, Whitley Bay.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Sc.	1926.	Tennant, A. McA., 2, Union Road, Bathgate.
Lncs.	1922.	Thatcher, E. H., The Newport Foundry Co., Mill Parade, Newport.
N.	1924.	Thom, J., 11, Moorland Crescent, Walker, Newcastle-on-Tyne.
L.	1909.	Thomas, E., 41, Kingshill Road, Swindon.
W.R. of Y.	1922.	Thompson, E., Thryburg Street, Leeds Road, Bradford.
L.	1926.	Thompson, J. S., 21, Erith Road, Belvedere, Kent.
Sc.	1925.	Thomson, D. B., 1 Knowe Terrace, Hillend Road, Lambhill, Glasgow.
S.	1921.	Thomson, T. A., 8, Clifton Dale, York.
S.	1923.	Thornton, A. E., 34, Hampton Road, Pitsmoor, Sheffield.
Lncs.	1911.	Timmins, A. E., 133, Roose Road, Barrow-in-Furness.
Lncs.	1924.	Timperley, T., 30, Ventnor Road, Heaton Moor, Stockport.
E.M.	1927.	Tompkin, S. E., 332, East Park Road, Leicester.
Sc.	1925.	Tonagh, Chas., 70, Stevenson Street, Calton, Glasgow.
Lncs.	1919.	Toplis, H., Hans Renold, Limited, Burnage Works, Didsbury, Manchester.
Lncs.	1914.	Topping, G., 17, Bebbington Street, Clayton, Manchester.
L.	1925.	Torode, G. F., 537, Oxford Road, Reading.
B.	1909.	Toy, J. H., 87, Edgbaston Road, Smethwick, Staffs.
Sc.	1920.	Trapp, P., Kilnside Cottage, Falkirk.
E.M.	1924.	Tunnicliffe, F. J., 9, Augusta Street, Derby.
Sc.	1923.	Turnbull, Alex. W., Primrose Cottage, Bonnybridge.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1918.	Turner, W., 90, Edgedale Road, Sheffield.
B.	1923.	Twigger, T. R., Post Office, Bubbenhall, nr. Kenilworth.
L.	1925.	Underwood, W. G., 9, Sears Street, New Church Road, Camberwell, S.E.5.
Sc.	1920.	Ure, R., Stenhouse House, Carron, Falkirk.
E.M.	1921.	Vaughan, Benj. H., 25, Holmes Street, Derby.
B.	1917.	Vaughan, G. A., Pen Glen, Tivedale Road, Burnt Tree, Tipton.
Lncs.	1921.	Vernon, G. W., 11, Ashfield Road, Burnley.
N.	1914.	Wainford, E. H., High Row, Gainford, Darlington.
Lncs.	1925.	Walker, A., 117, Robert Street, Newton Heath, Manchester.
S.	1921.	Walker, Alex. W., 113, Dalton Green Lane, Huddersfield.
Sc.	1920.	Walker, D., 5, New Houses, Anderson Street, Bonnybridge.
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.
Sc.	1920.	Walker, Wm., 10, Larbert Road, Bonnybridge, Falkirk.
Lncs.	1915.	Walwork, R. N., Western Road, Wilmslow, Cheshire.
E.M.	1924.	Ward, J. C., 56, Danvers Road, Leicester.
B.	1919.	Wareham, H., 37, Broadway, Coventry.
E.M.	1925.	Warner, Amos, 252, St. Thomas Road, Derby.
S.	1911.	Wasteney, J., Vulcan Foundry, Eckington, nr. Chesterfield.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
Gen.	1914.	Watson, R., Saxilley House, 49, York Street, Rugby.
Sc.	1919.	Watt, R., Etna Ironworks, Falkirk.
L.	1927.	Watts, W., 23, Bolt Street, Deptford, London, S.E.8.
Sc.	1920.	Waugh, Wm., 21, Dundas Crescent, Laurieston, Falkirk.
N.	1921.	Weathers, J. H., 76, Stanton Street, Newcastle-on-Tyne.
B.	1923.	Webb, A. W. J., 1, Sidney Street, Gloucester.
B.	1927.	Webb, A. E., 45, Brettel Street, Dudley, Worcester.
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.
B.	1926.	Webster, W., 74, Horseley Road, Tipton, Staffs.
B.	1911.	Westwood, J. H., 1583, Stratford Road, Hall Green, Birmingham.
Lncs.	1925.	Wharton, L., 4, Ridehalgh Street, Colne, Lancs.
W.R. of Y.	1913.	Whitaker, E., 145, St. Enoch Road, Wibsey, Bradford.
M.	1926.	Whitehead, A., "Avondale," St. Luke's Avenue, Thornaby-on-Tees.
L.	1911.	Whiting, A., Brynbella, Pembroke Road, Erith, Kent.
L.	1924.	Whiting, A. F., 56, Battle Road, Erith, Kent.
S.	1925.	Wild, A. J., Midland Brass Foundry, Attercliffe, Sheffield.
E.M.	1926.	Wild, H., 14, Albert Promenade, Loughborough, Leicestershire.
M.	1926.	Wilkes, R., 39, Pearl Street, Haverton Hill, Middlesbrough.
B.	1920.	Wilkins, A. J. R., 149, Toll End Road, Ocker Hill, Tipton.
M.	1910.	Wilkinson, T., Stockton Street, Middlesbrough.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
S.	1919.	Williams, A., 31, Burngreave Bank, Sheffield.
B.	1919.	Williams, A. Morgan, 43, Queen's Road, Coventry.
Lncs.	1925.	Williams, O., 25, Thirlmere Avenue, Stretford, Manchester.
B.	1923.	Williams, R., 166, Cross Road, Foleshill, Coventry.
Sc.	1911.	Williamson, H., 3, Nain Street, Dalmuir.
Sc.	1920.	Williamson, J., 111, Stirling Street, Denny, Stirlingshire.
L.	1920.	Willsher, W. H., "Breydon," Oakhill Gardens, Woodford Green, London, E.18.
Lncs.	1919.	Wilson, A. E., 84, Dewhurst Road, Syke, Rochdale.
L.	1925.	Wilson, A. M., Elm Villa, Mildmay Road, Burnham-on-Crouch.
L.	1927.	Wilson, C. H. V., 31, King's Avenue, Clapham Park, London, S.W.4.
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., "Ambleside," Osmaston Park Road, Derby.
W.R. of Y.	1926.	Winter, N.F.S., Green Hayes, Halifax.
S.	1924.	Winterton, H. T., Wm. Cumming & Co., Whittington Mills, Chesterfield.
B.	1924.	Wiseman, A. A., 149, Toll End Road, Tipton, Staffs.
Lncs.	1912.	Wolstenholme, J., 111, Carlton Terrace, Bury, and Bolton Road, Radcliffe, Manchester.
B.	1922.	Wood, A., 30, Toll End Road, Toll End, Tipton, Staffs.
B.	1927.	Wood, A., Sunny Bank Hill, Crest Avenue, Brierley Hill.
S.	1926.	Wood, E. A., 30, Dixon Street, Rotherham.

B'nch.	Year of Election.	ASSOCIATE MEMBERS.
E.M.	1921.	Wood, James H., 18, Alcester Road, Sheffield.
W.R. of Y.	1922.	Wood, John, 6, Hudswell Street, Sandal, Wakefield.
M.	1926.	Woolley, H. E., 5, Albion Terrace, Saltburn-by-Sea.
W.R. of Y.	1914.	Worcester, A. S., 162, Victoria Road, Lockwood, Huddersfield.
B.	1927.	Worley, S. C., "Ashmore," 153, Bearwood Road, Smethwick, Birmingham.
Lncs.	1917.	Worrall, J. N., 77, Ansdell Road, Turf Hill, Rochdale.
W. & M.	1926.	Wren, J., "Westholm," Edward Street, Griffithstown, Mon.
Lncs.	1925.	Wright, H. G., 78, Lloyd Street, Heaton Norris, Stockport.
W.R. of Y.	1923.	Wright, L. L., 168, Oxford Road, Gomersall, near Leeds.
B.	1927.	Wright, R. E., Oxford Lodge, Maryhill, Glasgow.
Sc.	1913.	Wright, W., Burnbank Foundry, Falkirk.
Lncs.	1924.	Wylie, J. F., 206, Stockport Road, Bredbury, Stockport.
Lncs.	1925.	Yates, J., 37, King Edwards Avenue, North Shore, Blackpool.
Lncs.	1926.	Yates, W., 38, Clifford Street, Leigh, Lancashire.
Lncs.	1924.	Yeoman, Robert, 18, Lord Street, Stockport.
Lncs.	1926.	Yeoman, S., 18, Lord Street, Stockport.
Sc.	1919.	Young, J., 45, Cochrane Street, Paisley.
N.	1921.	Young, James, 72, Carlisle Street, Felling-on-Tyne.

ASSOCIATES.

B'nch.	Year of Election.	
N.	1925.	Adams, F., 98, Avondale Road, Byker, Newcastle.
N.	1926.	Ainsworth, L. H., 3, Albert Avenue, Wallsend-on-Tyne.
B.	1925.	Andrews, E., 214, Highfield Road, Saltley, Birmingham.
S.	1920.	Ayres, Sidney, 299, Bellhouse Road, Shiregreen, Sheffield.
B.	1925.	Bache, T. R., 181, Walsall Street, West Bromwich.
N.	1925.	Badsey, R. C., 5, Lovaine Terrace, North Shields.
N.	1920.	Banks, V. L., St. Cuthbert's Vicarage, Newcastle-on-Tyne.
Sc.	1926.	Bell, W. M., 2, Bellfield Street, Barrhead.
N.	1921.	Bentham, J. W., 9, Cumberland Street, Gateshead-on-Tyne.
N.	1924.	Betham, W. S., 9, South Frederick Street, South Shields.
N.	1925.	Blackwell, J., 113, George Street, Willington-Quay-on-Tyne.
Sc.	1926.	Blackwood, W. S., 12, Napier Street, Linwood, N.B.
S.	1924.	Blades, H., 37, Petre Street, Pitsmoor, Sheffield.
Sc.	1926.	Blythe, N. C., 11, Danes Drive, Scotstoun, Glasgow.
S.	1924.	Bolsover, C. A., 27, Pear Street, Sheffield.
B.	1922.	Boudry, C., 46, Holly Lane, Smethwick.
N.	1922.	Bowden, F., 5, Holmwood Grove, West Jesmond, Newcastle-on-Tyne.
B.	1914.	Boyne, W., 157, Wood End Road, Erdington, Birmingham.
M.	1926.	Cannon, W. R., 9, South View, Billingham, Stockton-on-Tees.

B'nch.	Year of Election.	ASSOCIATES.
N.	1917.	Carr, S., 44, Stanley Street, Rosehill, Wallsend-on-Tyne.
L.	1924.	Chamberlain, E. E., 75, Albert Street, Slough, Bucks.
N.	1923.	Chapman, L. B., Daisy Cottage, Dene Villas, Chester-le-Street, Co. Durham.
Sc.	1926.	Clark, J., 28, King Street, Paisley.
S.	1920.	Coates, L., 30, Oakwood Road, Rotherham.
W. & M.	1925.	Coles, H., 101, Woodlands Road, Barry Dock.
Sc.	1925.	Coubrough, W. J., 68, Guthrie Street, Maryhill, Glasgow.
L.	1926.	Cummings, F. C., 3, Waller Road, New Cross, London, S.E.14.
Gen.	1918.	Currie, E. M., 3, Stockton Road, Coventry.
N.	1924.	Cuthbertson, J., 81, Dunsmuir Grove, Gateshead-on-Tyne.
Lncs.	1927.	Daintith, R., 286, Rishton Lane, Gt. Lever, Bolton.
S.	1927.	Dalton, W. E., 310, Owler Lane, Sheffield.
N.	1924.	Davidson, T. H., 156, Croydon Road, Newcastle-on-Tyne.
N.	1923.	Davison, R., 79, Second Avenue, Heaton, Newcastle-on-Tyne.
N.	1924.	Dickinson, B., 9, South Frederick Street, South Shields.
N.	1924.	Dodd, C., 6, Relton Terrace, Monkseaton.
B.	1925.	Dubberley, W., 27, Lewisham Road, Smethwick, Birmingham.
N.	1926.	Dunbar, J., 16, Burn Terrace, Willington Quay-on-Tyne.
N.	1918.	Eglen, T., 22, Morley Street, Heaton, Newcastle-on-Tyne.
L.	1922.	Ellis, J. P., 20, Lambourn Road, Clapham Junction, S.W.4.

B'nch.	Year of Election.	ASSOCIATES.
B.	1925.	Evans, E. H., 100, Brunswick Road, Handsworth, Birmingham.
Sc.	1927.	Ewen, G., 29, Oakbank Terrace, Glasgow.
N.	1923.	Farrell, T. P., 6, St. Mary's Terrace, Willington Quay.
N.	1917.	Ferguson, J., 62, South Palmerston Street, South Shields.
S.	1922.	Firth, Tom L., 191, Fox Street, Sheffield.
N.	1925.	Fleck, J., 75, Lamb Street, Walker-on-Tyne.
N.	1913.	Ford, A., 43, Moore Street, Gateshead.
S.	1926.	Fretwell, J., 153, Sheffield Road, Stonegravels, Chesterfield.
B.	1924.	Frost, C., 55, Wavnerley Road, Small Heath, Birmingham.
N.	1923.	Gould, M., 42, Elswick East Terrace, Newcastle-on-Tyne.
Sc.	1924.	Graham, T., 25, William Street, Dumbarton.
L.	1924.	Graves, J. H., 38, Solway Road, Wood Green, N.22.
S.	1926.	Gray, H., 337, Sheffield Road, Whittington Moor, Chesterfield.
N.	1925.	Green, S., 67, Cottenham Street, Newcastle-on-Tyne.
B.	1925.	Greenway, J. F., 43, Douglas Road, Handsworth, Birmingham.
N.	1925.	Grigor, R., 38, Grey Street, Wallsend-on-Tyne.
B.	1925.	Hadley, E. T., 207, Horsley Heath, Tipton, Staffs.
B.	1909.	Hamilton, G., 18, Anderson Road, Tipton.

B'nch.	Year of Election.	ASSOCIATES.
W. & M.	1925.	Harding, W. L., 14, Welford Street, Barry.
N.	1923.	Harle, J. E., 162, South Palmerston Street, South Shields.
M.	1926.	Harvey, E. J., 4, Rydal Road, Stockton-on-Tees.
N.	1924.	Harvey, J. E. B., 96, Marshall Wallis Road, South Shields.
Sc.	1927.	Harvie, R., 21, Campbell Street, Maryhill, Glasgow.
S.	1926.	Hatton, A., 15, Littlemoor Crescent, Newbold, Chesterfield.
S.	1921.	Heeley, John Jas., 36, Gertrude Street, Owlerton, Sheffield.
Sc.	1924.	Higgins, N., 7, Portland Rows, Hurlford, Ayrshire.
Sc.	1920.	Hill, T., 9G, Mitchell Street, Airdrie.
Lncs.	1925.	Hindley, W., 13, Charles Street, Farnworth, near Bolton.
W. & M.	1926.	Hird, J., "Woodcot," Upper Cwmbran.
N.	1925.	Hodgkinson, H. D., 5, Leopold Street, Jarrow-on-Tyne.
E.M.	1917.	Holmes, A., 87, Albert Promenade, Loughborough.
Lncs.	1926.	Holt, Samuel (Junior), 83, Ridgway Street, Bradford Road, Manchester.
Lncs.	1923.	Hopkins, W., 70, Tootal Drive, Weaste, Manchester.
E.M.	1916.	Hughes, J. O., Alma Lodge, Carisbrooke Road, Leicester.
N.	1927.	Hunter, R. W., 104, Shrewsbury Crescent, Humbledon Hill, Sunderland.
M.	1926.	Jameson, J. R., 9, Olive Street, Hartlepool.
B.	1919.	Johnson, J. B., junr., Slater Street, Great Bridge, Tipton.
N.	1925.	Jones, J., 21, Cooper Street, Sunderland Road, Gateshead-on-Tyne.
L.	1924.	Jones, T. H., 40, Glengall Road, Cubitt Town, E.14.

B'nch.	Year of Election.	ASSOCIATES.
Sc.	1922.	Jones, W. C., Blair Terrace, Hurlford, Ayrshire.
N.	1922.	Kelly, F. J., 1545, Walker Road, Newcastle-on-Tyne.
Sc.	1924.	Laughland, H., 15, Burnside Street, Kilmarnock.
N.	1925.	Laven, J., 140, Richardson Street, Wallsend-on-Tyne.
N.	1920.	Lindsay, A. W., 16, Phillipson Street, Willington Quay-on-Tyne.
N.	1924.	Lowes, W., 1, Baden Street, Chester-le-Street.
Lncs.	1914.	Lucas, G. W., 36, Langford Street, Leek, Staffs.
Sc.	1926.	McAllister, W. C., 144, Drumoyne Road, South Govan, Glasgow.
N.	1924.	McDonald, C. R., The Villa, Willington-Quay-on-Tyne.
N.	1925.	McDougal, T. D., 3, Westmoreland Street, Wallsend-on-Tyne.
Sc.	1924.	McGowan, V. M., 1, Albert Street, Paisley.
Sc.	1926.	McGurnaghan, M., 206, Gallowgate, Glasgow.
Sc.	1913.	McLeish, J., 7, Buchanan Terrace, Paisley.
Sc.	1924.	MacNab, R., 13, Walker Street, Paisley.
Sc.	1926.	McPhee, J. McA., 70, High Street, Paisley.
N.	1926.	McQuillan, J., 1, Lodge Terrace, Wallsend-on-Tyne.
Sc.	1925.	Magee, J., 83, Lounsdale Drive, Paisley.
Sc.	1927.	Main, J. W., 175, Holm Street, Glasgow, C.2.

B'nch.	Year of Election.	ASSOCIATES.
Sc.	1924.	Martin, A. L., 31, George Street, City, Glasgow.
M.	1926.	Martin, J. H., 7, South View, Cargo Fleet, Middlesbrough.
B.	1924.	Mason, J. L., 11, Kentish Road, Handsworth, Birmingham.
L.	1925.	Mata, C. H., 51, Grosvenor Road, Canonbury, N.5.
N.	1923.	Matthews, G. W., 82, St. Peter-Road, Holy Cross, Willington-Quay-on-Tyne.
Lncs.	1923.	Meadowcroft, H., 10, Hambledon, View, Habergham, Burnley.
Sc.	1924.	Meikle, A. S., 207, Kent Road, Glasgow.
B.	1925.	Meredith, C., 4, Thomas Street, Smethwick, Birmingham.
N.	1922.	Miller, J. G., 79, Clarence Street, Newcastle-on-Tyne.
N.	1925.	Morland, R. H., 106, Clifford Street, Byker, Newcastle-on-Tyne.
N.	1925.	Nesbit, G. L., 4, Coben Avenue, Mexborough.
N.	1925.	Nesbitt, I., 26, Bede Crescent, Holy Cross Estate, Willington-Quay-on-Tyne.
N.	1924.	Nichol, J., 131, George Street, Willington-Quay-on-Tyne.
N.	1925.	Nuttall, G., 88, High Street East, Wallsend-on-Tyne.
N.	1925.	Osborne, G. F., 39, Franklin Street, Sunderland.
N.	1922.	Paterson, J. W., 108, Corbridge Street, Byker, Newcastle-on-Tyne.
N.	1923.	Peacock, J. E., 40, Bolam Street, Newcastle-on-Tyne.
N.	1923.	Peacock, S., 12, John Street, South Shields.
N.	1922.	Picken, A. D., 87, Cuthbert Street, Hebburn-on-Tyne.

B'nch.	Year of Election.	ASSOCIATES.
N.	1922.	Pittuck, M. D. (Miss), c/o H. J. Young. 3, Central Buildings, Westminster. S.W.1.
Lncs.	1926.	Pollard, Wm., 7, Powell Street, Burnley, Lancs.
W.R. of Y.	1926.	Poole, F. T. L., 85, Starr Hill, Wyke. Bradford.
N.	1926.	Pratt, S., 29, Randolph Street, Jarrow-on-Tyne.
E.M.	1916.	Radford, H. P., 151, Barclay Street. Fosse Road South, Leicester.
N.	1917.	Rang, E. J., M.Sc., 8, Bath Terrace. Tynemouth.
N.	1926.	Reay, T., 27, Percy Street, Wallsend-on-Tyne.
N.	1922.	Redpath, J., 25, Burnley Street. Blaydon-on-Tyne.
W. & M.	1925.	Rees, L. W., 158, Holton Road. Barry Dock.
Sc.	1923.	Reid, J. N. (junr.), Elmbank, Larbert.
Sc.	1923.	Riddell, J., 113, Coventry Drive, Glasgow.
M.	1926.	Robinson, J., 172, Abingdon Road, Middlesbrough.
N.	1924.	Robson, J., 15, Hawthorne Grove, Wallsend-on-Tyne.
N.	1925.	Robson, J., 20, Frederick Street, Gateshead-on-Tyne.
N.	1923.	Rollin, C. N., Stanhope House, Westhoe Village, South Shields.
Sc.	1927.	Ross, W. (Junior), 2, Macdonald Street, Rutherglen, Glasgow.
N.	1926.	Rowley, J. S., 51, South Terrace, Wallsend-on-Tyne.
N.	1925.	Ruff, J., 88, Richardson Street, Wallsend-on-Tyne.
M.	1926.	Saunders, A., 34, Queens Road, North Ormesby, Middlesbrough.
N.	1925.	Scott, R. J., 32, North Terrace, Wallsend-on-Tyne.
L	1926.	Sherman, W. T., " Woodlands " Avery Hill Road, New Eltham.

B'nch.	Year of Election.	ASSOCIATES.
S.	1925.	Smedley, C. C., 41, Abbey Lane, Woodseats, Sheffield.
B.	1925.	Smith, W. H., 21, Horsely Road, Tipton, Staffs.
N.	1925.	Soulsby, W. A., 14, Armstrong Street, Gosforth.
N.	1912.	Spence, W. D., 124, Heaton Park Road, Newcastle-on-Tyne.
N.	1922.	Spencer, F. C., "Donsfell." New Horsley, Ovingham-on-Tyne.
B.	1910.	Spiers, F., 32, Kenilworth Road, Handsworth, Birmingham.
N.	1925.	Spowart, D., 9, St. Nicholas Road, Hexham-on-Tyne.
N.	1926.	Stafford, J., 143, Harriet Street, Byker, Newcastle-on-Tyne.
N.	1923.	Stobbs, T., 199, Stanhope Road, South Shields.
N.	1924.	Stoddart, J., 7, Ferndale Avenue, Wallsend-on-Tyne.
N.	1925.	Strong, Leslie, 59, Marine Avenue, Monkseaton, Northumberland.
E.M.	1915.	Styles, W. T., 52, Roe Street, Derby.
B.	1910.	Sutton, W. H., 147, Anthony Road, Saltley, Birmingham.
Sc.	1913.	Sword, J., 13, Paisley Road, Barrhead.
N.	1926.	Symon, J. A., 10, Mayfair Road, West Jesmond, Newcastle-on-Tyne
Lncs.	1926.	Tate, W. G., Brook Royd, Todmorden Road, Burnley.
M.	1926.	Taylor, D., 35, Langby Avenue, Thornaby-on-Tees.
N.	1926.	Thompson, J. T., 42, Monk Street, Gateshead-on-Tyne.
N.	1921.	Tunnah, R. C., 22, Ripso Gardens, Jesmond, Newcastle-on-Tyne.
Sc.	1924.	Turnbull, J., Primrose Cottage, Bonnybridge.
N.	1921.	Turnbull, R. G., S.S. "Cairnross," Edinburgh Docks, Leith.

B'nch.	Year of Election.	ASSOCIATES.
S.	1922.	Tyler, G. H., 86, Pickmere Road, Pitsmoor, Sheffield.
N.	1922.	Van-der-Ben, C. R., 169, Dunsmuir Grove, Gateshead-on-Tyne.
M.	1926.	Vause, W., 33, Hannah Street, Thornaby-on-Tees.
L.	1927.	Ward, E., 56, Park Street, Stoke Newington, London, N.16.
L.	1911.	Wells, G. E., 89, Larcom Street, Walworth, S.E.
W.R. of Y.	1926.	Wilks, W., 40, Balfour Street, East Bowling, Bradford.
Sc.	1927.	Wilson, J. R., 4, Killermont Street, Glasgow.
B.	1926.	Whitehouse, T., 4, Carlton Road, Smethwick, Staffs.
M.	1926.	Whitfield, C. S., 131, Victoria Road, Middlesbrough.
N.	1927.	Wood, N., 100, Rodsey Avenue, Gateshead-on-Tyne.
S.	1920.	Wordsworth, W. A., 11, Coverdale Road, Millhouses, Sheffield.
N.	1925.	Worley, E. R., 2, Primrose Hill, Low Fell, Gateshead-on-Tyne.
Sc.	1927.	Wright, J., 198, James Road, Townhead, Glasgow.
Sc.	1926.	Young, H., 4, Glasgow Road, Paisley.

Members changing their addresses are requested to notify the same immediately to the General Secretary or to the Branch Secretary of the District.

NAME INDEX.

SUBJECT INDEX.