ROY STUBBS

President, 1934-35

MR. R. W. STUBBS was educated at the Victoria Park School, Manchester, and then at the Manchester Grammar School. He studied metallurgy, machine drawing and chemistry at the College of Technology, Manchester, and joined the firm of Messrs. Joseph Stubbs, Limited, where he spent many years in the foundry as a moulder and coremaker, etc. Mr. Stubbs served in the war as a gunner in the R.F.A., and at the end of the war returned to an executive position in the foundry of Messrs. Joseph Stubbs, Limited. Later he joined the board of directors and is now in charge of the foundry. He joined the Lancashire Branch in 1919 and was President in 1930 and 1931. He is also a member of the Manchester Association of Engineers. He is a member of the Executive Board of the National Ironfounding Employers' Federation and of the Executive Committee of the Manchester and District Ironfounders' Employers' Association.

PROCEEDINGS OF THE . . . INSTITUTE OF BRITISH FOUNDRYMEN.

VOLUME XXVII. 1933-1934.

Containing the Report of the Thirty-First Annual Conference, held at Manchester, June 5th, 6th, 7th, and 8th, 1934; also Papers and Discussions presented at Branch Meetings held during the Session 1933-1934.

Institute of British Foundrymen.

Head Office:
Saint John Street Chambers, Deansgate, Manchester, 3.
(Registered Office: 49, Wellington Street, Strand, London, W.C.2.)

LONDON: Printed by
"THE FOUNDRY TRADE JOURNAL,"
49, Wellington Street, Strand, London, W.C.2.

THE INSTITUTE OF BRITISH FOUNDRYMEN

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(Surviving Past-Presidents are ex-officio members of the General Council.)

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Victor Stobie, M.I.E.E., Langholm, South Drive, Harrogate. 1932.
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B. Hird, "Woodcot," Upper Cwmbran, near Newport, Mon.

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E. Longden, 11, Welton Avenue, Didsbury Park, Manchester.

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(Branches represented shown in brackets.)

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ITALY.

Dr. Ing. Guido Vanzetti, Via Bianca di Savoia, 10, Milan (115).

SOUTH AFRICA

A. H. Moore, Standard Brass & Iron Foundry, Limited Benoni.

AWARDS 1933-34

THE "OLIVER STUBBS" GOLD MEDAL.

1934 Award to Mr. V. C. FAULKNER,

"for his work in connection with the establishment of the Degree Course in Founding at the University of Sheffield."

MERITORIOUS SERVICES MEDAL.

1934 Award to Mr. J. J. McCLELLAND,

"as a recognition of his devoted services for many years."

DIPLOMAS OF THE INSTITUTE

were awarded to—

Mr. W. G. MORGAN, for his Paper on "Fettling-Shop Efficiency," given before the Birmingham Branch.

Mr. F. HUDSON, for his Paper on "Moulding-Sand Control," given before the Lancashire and London Branches.

Mr. A. LOGAN, for his Paper on "Some Aspects of Non-Ferrous Founding," given before the Lancashire Branch.

Mr. T. MAKEMSON, for his Paper on "Some Impressions of Czecho-Slovakian Foundries," given before the London Branch.

Mr. G. L. BAILEY, for his Paper on "Porosity in Non-Ferrous Castings," given before the London Branch.

Dr. A. B. EVEREST, for his Paper on "Potentialities of Cast Iron," given before the London Branch.

Mr. J. LONGDEN, for his Paper on "Grey-Iron Castings for Laundry Machinery," given before the Scottish Branch.

Mr. J. ROXBURGH, for his Paper on "Alloys in the Iron Foundry," given before the Sheffield Branch.

Mr. B. GALE, for his Paper on "Practical Considerations in a Small Jobbing Foundry," given before the Wales and Monmouth Branch.

THE OLIVER STUBBS MEDAL.

The Oliver Stubbs Medal has been awarded as follows:—

1922.—F. J. Cook, M.I.Mech.E.
1923.—W. H. Sherburn.
1924.—John Shaw.
1925.—A. Campion, F.I.C.
1926.—A. R. Bartlett.
1927.—Prof. Thomas Turner, M.Sc.
1928.—J. W. Donaldson, D.Sc.
1929.—Wesley Lambert, C.B.E.
1930.—James Ellis.
1931.—John Cameron, J.P.
1932.—J. E. Hurst.
1933.—J. W. Gardom.
1934.—V. C. Faulkner.

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The Institute of British Foundrymen

THIRTY-FIRST ANNUAL CONFERENCE, MANCHESTER

JUNE 5, 6, 7 and 8, 1934

The thirty-first Annual Conference of the Institute of British Foundrymen was held in Manchester from June 5 to 8, 1934, under the Presidency of Mr. Roy Stubbs (Manchester). The arrangements in connection with the conference were made by the Lancashire Branch and Mr. T. Makemson, the General Secretary of the Institute. The Chairman of the Conference Executive Committee was Mr. A. Phillips (immediate Past-President of the Branch), the other members being Mr. W. N. Cook (President of the Branch), Mr. R. A. Miles, Mr. Roy Stubbs and Mr. J. E. Cooke (Hon. Conference Secretary). The conference committees included a Ladies' Committee, of which Mrs. Roy Stubbs was Chairman, and there was an excellent programme for the entertainment of the ladies apart from the social functions in which both sexes joined, these latter including the annual banquet and dance, receptions and entertainments. The headquarters of the conference were at the Midland Hotel, Manchester.

In addition to the conducting of the formal business of the Institute and the meetings for the consideration of technical Papers, arrangements were made for visits to various large works in the Manchester district. The works visited by the members during the period of the conference were those of Messrs. Joseph Stubbs, Limited, at Openshaw (Foundries: textile machinery and general engineering castings): the Metropolitan-Vickers Electrical Company, Limited, Trafford Park (manufacturers of steam turbines, generators and all kinds of electrical plant, the works including the ironfoundry, where castings up to 60 tons are made, and the non-ferrous foundry); the Lancashire Steel Corporation, Irlam (blast furnaces, coke ovens, open-hearth steel plant, rolling mills and iron and steel foundry); Messrs. Tweedales & Smalley, Limited, Castleton, near Rochdale (textile machinery manufacturers, whose works include an ironfoundry); Messrs. Craven Bros., Limited, Reddish (makers of heavy machine tools, whose works include an ironfoundry, for castings up to 40 tons, and non-ferrous foundry), and Messrs. Leyland Motors, Limited, Leyland (builders of heavy motor vehicles, whose works include a steel foundry with electric furnaces and iron, non-ferrous and aluminium foundries).

On June 8, the last day of the conference, the members and their ladies enjoyed a visit by motor-coach to Llangollen, North Wales. After lunch at Llangollen they proceeded by barge along the canal to Berwyn, in the valley of the Dee, and later rejoined the motor-coaches and travelled to Chester for tea, returning to Manchester in the evening.

ANNUAL GENERAL MEETING

The Annual General Meeting of the Institute was held at the Midland Hotel on Tuesday evening, June 5. Mr. C. E. Williams, of Cardiff (Retiring President), was in the chair.

Greetings to Original Members

The Chairman, who said he had been reminded that he had attended the Institute's first meeting, said that some of the original members who were still living were unable by reason of age to attend the conference. It had been suggested by Mr. Primrose, therefore, that the greetings of the conference be sent to them, and the Chairman proposed that that be done. The resolution was seconded by Mr. J. S. G. Primrose, and carried. Mr. Primrose said he had derived great pleasure from corresponding with all the original members in order to obtain their photographs and signatures, which were contained in the conference souvenir booklet.

Minutes

The minutes of the preceding annual general meeting, held at Cardiff in June, 1933, were taken as read, and were confirmed and signed.

On the motion of the Chairman, seconded by Mr. F. J. Cook (Past-President), the annual report of the General Council for the session 1933-34 was adopted, without discussion.

ANNUAL REPORT

This report covers the period of twelve months ended April 30, 1934, and the accounts are for the year ended December 31, 1933.

Membership

Experience shows that trade conditions are usually reflected in the membership of Institutes such as this, after a period of two or three years, and there is a slight decrease of membership due to the conditions of trade which prevailed during the years 1931 and 1932. A recent influx of new members encourages the hope that this decrease will be neutralised in the course of the present year.

Tables I and II show the changes of membership, and an analysis of the present membership.

Obituary

It is with regret that the Council reports the deaths of ten members during the year, including those of Mr. F. Allan, President of the Newcastle Branch in 1931-32, and Mr. Stanley G. Flagg, of Philadelphia, a Past-President of the American Foundrymen's Association and an honorary member of this Institute. Mr. R. R. McGowan, a former President of the Scottish Branch, also passed away during the year.

Finance

It is satisfactory to note that the finances of the Institute are in a prosperous condition. Subscriptions have increased by approximately £60, and due to economical working, there has been a decrease in expenditure. The year's working shows an excess of income over expenditure of over £60. The cash at the bank, £336 4s. 6d., includes the sum of £74 11s. 9d., which has been transferred from the surplus funds in the hands of the Branches.

TABLE I.—*Changes of Membership.*

	Subscribing firms.	Members.	Associate members.	Associates.	Total.
At April 30, 1933 . .	49	748	962	135	1,894
Losses and transfers to other grades	2	76	97	43	218
	47	672	865	92	1,676
Additions and transfers from other grades . .	3	72	69	12	156
At April 30, 1934.	50	744	934	104	1,832

Cardiff Conference

The Thirtieth Annual Conference was held in Cardiff from June 20 to 23, 1933.

On Tuesday, June 20, ladies and members were entertained at a reception by the Lord Mayor and Lady Mayoress of Cardiff, and the Lord Mayor and other prominent citizens attended the opening meeting.

The authorities of the University College, Cardiff, also entertained the ladies and members at a reception.

TABLE II.—*Analysis of Membership, April 30, 1934.*

Branch.	Subscribing firms.		Members.		Associate members.		Associates.		Total.	
Birmingham	2	(1)	106	(102)	114	(125)	17	(20)	239	(248)
East Midlands	3	(4)	46	(46)	79	(93)	3	(4)	131	(147)
Lancashire	15	(13)	121	(114)	240	(238)	24	(23)	400	(388)
London	6	(5)	147	(149)	80	(79)	7	(10)	240	(243)
Middlesbrough			25	(30)	38	(36)	5	(5)	68	(71)
Newcastle	6	(7)	35	(44)	36	(41)	29	(54)	106	(146)
Scottish	6	(6)	87	(83)	173	(171)	10	(8)	276	(268)
Sheffield	6	(7)	84	(82)	70	(72)	7	(8)	167	(169)
Wales and Monmouth ..	2	(2)	26	(27)	33	(36)			61	(65)
West Riding of Yorkshire	3	(3)	35	(36)	60	(60)	1	(2)	99	(101)
Unattached..	1	(1)	32	(35)	11	(11)	1	(1)	45	(48)
	50	(49)	744	(748)	934	(962)	104	(135)	1,832	(1,894)

The figures in brackets are for the year ending April 30, 1933.

At the Annual General Meeting, Mr. C. E. Williams was installed President in succession to Mr. Victor Stobie.

The Council tenders its sincere thanks to the Lord Mayor, Alderman C. F. Saunders, J.P., the Lady Mayoress, Miss Muriel Saunders, and Prof. J. F. Rees, of the University College of South Wales and Monmouthshire, for their hospitality, and to Mr. J. Morgan Rees, President of the South Wales Institute of Engineers, and his Council, for so kindly placing their building at the disposal of the Institute for their meetings.

The thanks of the Council are also given to those firms who arranged visits for members and ladies to their respective works, and to the staffs of those firms; to the authors of Papers, and to those who subscribed to the Conference Fund or in any way assisted in the organisation. Thanks are specially due to the Chairman of the Reception Committee, Mr. Wm. Williams, to Mr. J. J. McClelland, the Honorary Conference Secretary, and to his daughter, Mrs. Rawden.

Technical Committee

The activities of the Technical Committee and its Sub-Committees which have been referred to in previous reports, have continued with considerable vigour. Further details are given in the special report of this Committee which follows this report.

Invitations

Messrs. F. W. Bridges & Sons invited the Council to luncheon, and the whole of the members to tea, at the Shipping, Engineering and Machinery Exhibition held at Olympia, in September, 1933. A large number of members accepted these invitations and the Council's thanks are hereby tendered to Messrs. F. W. Bridges & Sons.

The Council also wishes to thank the Birmingham Chamber of Commerce for their invitation to luncheon at the British Industries Fair on February 27. The invitation was accepted by a number of members of the Council.

Educational Activities

Considerable progress has been made in the preliminary work in connection with the proposed Degree Course in Founding at the University of Sheffield. A Sub-Committee of the Institute has held a number of meetings, and is at present engaged in soliciting the necessary financial support from the industry. A considerable amount of financial assistance has already been promised.

The General Council has also accorded its support to the scheme brought forward by the British Cast Iron Research Association, for the establishment of a British Foundry School.

The examinations in Foundry Practice and in Patternmaking conducted by the City and Guilds of London Institute were held for the third time under the revised arrangements, in April and May, 1934. The results will be issued in due course. The results of the 1933 examinations show that there was a considerable increase in the number of candidates taking the examinations in Patternmaking. There was also a slight increase in the number of candidates for the examination in the subject of Foundry Practice and Science. The numbers presenting themselves for the 1933 examinations were as follow:—

	No. of Candidates.	Pass 1st Class.	Pass 2nd Class.
Patternmaking— Intermediate Grade	36	11	10
Patternmaking— Final Grade ..	10	2	2
Foundry Practice and Science	51	13	15

Prizes were awarded as follow:—

Patternmaking: Intermediate Grade.—Mr. B. R. Pearson, Technical College, Coventry; Bronze Medal.

Patternmaking: Final Grade.—Mr. J. G. Rees, Sheffield Foundry Trades Society; Silver Medal and Buchanan Medal of the Institute of British Foundrymen.

Foundry Practice and Science.—Mr. T. W. Trayherne, Birmingham; Bronze Medal and Buchanan Medal of the Institute of British Foundrymen. Mr. G. T. Hampton, County Technical College, Wednesbury; Bronze Medal.

Buchanan Book Prizes were also awarded to Mr. J. L. Handley and Mr. G. T. Hampton.

National Certificates.—Forty-six National Certificates in Mechanical Engineering were endorsed in respect to special Foundry subjects by the Institute of British Foundrymen, making a total of nine Higher and seventy-nine Ordinary Certificates since the inauguration of the special endorsement of these certificates three years ago.

Awards of the Institute

Oliver Stubbs Medal.—The twelfth award was made in June, 1933, to Mr. J. W. Gardom, " for his distinguished services as Convener of the Technical Committee during the past year."

Diplomas.—Diplomas were awarded at the Cardiff Conference in 1933, to five members for Papers given during the previous year. The names of the recipients and the Branches before which the Papers were given are as follow:—

W. West, Birmingham and Lancashire Branches.
H. E. Beardshaw, Lancashire Branch.
E. J. L. Howard, Lancashire Branch.
R. Ballantine, Scottish Branch.
C. A. Howe, Wales and Monmouth Branch.

The announcement of the Diploma awards for the Session 1933-34 will be made at the Annual General Meeting on June 5.

Surtees Memorial Examination.—The 1934 examination was held by the Scottish Branch, and the successful candidates were:—

Andrew L. Mortimer—Gold Medal.
John M'Gregor—Silver Medal.

Overseas Foundry Associations

About twenty-five members and ladies attended the International Foundry Conference in Prague in September and afterwards made a tour of the industrial portions of Czecho-Slovakia.

A meeting of the International Committee of Foundry Technical Associations was held in Prague during the Conference period; the Institute was represented at this meeting by Messrs. J. Cameron, V. C. Faulkner and T. Makemson, who was present as Secretary of the Committee. Messrs. J. G. Pearce and T. Makemson were also present at the meeting of the International Cast Iron Testing Committee held during the same period.

The value of internationalism in foundry technique was recognised by President Masaryk, who honoured the Conference by receiving a small deputation of members of the International Committee. The Institute's international membership is indicated by the fact that no less than five members of the deputation of seven are members of the Institute, namely: Mr. J. Cameron, representing Great Britain; Mr. V. Delport, representing the United States; Prof. Pisek, Czecho-Slovakia; Mr. J. Leonard, Belgium; and Mr. T. Makemson.

The official exchange Paper to the International Conference at Prague was prepared by Mr. C. H. Kain. Mr. W. Y. Buchanan was the author of the Paper to the Polish Foundry Conference in June, and Mr. W. West prepared the Paper which was submitted on behalf of the Institute to the French Foundry Conference in November.

Exchange Papers will be presented on behalf of the Institute at forthcoming Conferences by the following members:—

International Conference, Philadelphia.—Dr. W. H. Hatfield.

French Foundry Conference, Nancy.—Mr. E. Longden.

Exchange Papers will be presented to our own Conference at Manchester in June next on behalf of the American, French and German Associations.

Branch Activities

The Institute has always recognised the value of the work of the Branches, and there is probably no other similar technical body which holds meetings in so many centres and whose Branches take so active a part in the conduct of the Institute's affairs. During the past year, meetings have been held regularly in about twenty cities and towns in various parts of the country and no less than one hundred and thirty Papers have been presented. Additionally, there have been several general discussions and the Presidential Addresses of the Branch-Presidents.

The General Council wishes to thank all these authors and the firms with whom they are associated for placing their experience at the disposal of the Institute and the industry in general. The Council also wishes to express its appreciation of the work of the Branch-Presidents and Secretaries and all who have assisted in the very large amount of detail work necessary in the organisation of the various Branches.

Employment Bureau

The Council is indebted to the proprietors of THE FOUNDRY TRADE JOURNAL for the continuance of the facilities which they have given for some years, whereby members of the Institute who desire employment are permitted to use the advertising columns of the JOURNAL free of charge. A considerable number of suitable positions have been filled as a result of these facilities.

British Cast Iron Research Association

Although the financial year of the British Cast Iron Research Association does not close until June 30, there is every prospect that the income and activity for the year will constitute a record and the contacts with the Institute have been fully maintained.

During the year the Association has brought forward an important proposal for the creation of a foundry high school which shall provide instruction of the highest order for those already engaged in the industry, and also to make Great Britain in this respect at least as well off as other countries, notably France and Germany.

Bye-Laws and Rules

The revised by-laws were approved by the Annual General Meeting in June last, and have been submitted to the Privy Council. The certificate of the Privy Council has not yet been given and in the meantime it is necessary to work to the existing by-laws.

General Council

Four General Council meetings and a large number of Committee meetings have been held at Cardiff, York, Birmingham and Derby. The average attendance at the General Council meetings was 45.

There have been eight meetings of the Technical Committee and Technical Council, and a large number of sub-committee meetings have been held. Additionally, there have been meetings of the Advisory Committees in connection with the City and Guilds of London Institute examinations, and the proposed Degree Course at the University of Sheffield.

Of the ten members of the General Council elected by ballot of the whole of the members, five retire each year; the five who so retire at the Annual General Meeting on June 5 are:—Mr. A. Campion, Mr. F. J. Hemming, Mr. B. Hird, Mr. J. R. Hyde and Mr. J. M. Primrose. All these gentlemen offer themselves for re-election.

The Council wishes to tender its very grateful thanks to Mr. W. B. Lake, J.P., Honorary Treasurer, whose interest on behalf of the Institute's finances has been invaluable.

Manchester Conference

The Thirty-first Annual Conference will be held at Manchester from June 5 to 8, when Mr. Roy Stubbs, President-elect, will be installed President of the Institute.

The report is signed by Mr. C. E. Williams, President; Mr. Tom Makemson, General Secretary.

BALANCE SHEET, DECEMBER 31, 1933.

LIABILITIES.

	£	s.	d.	£	s.	d.
Subscriptions paid in advance				97	2	6
Sundry creditors				429	9	9
The Oliver Stubbs Medal Fund :—						
Balance from last Account	209	9	2			
Interest to date	7	14	0			
Income Tax Refund ..	2	11	4			
	219	14	6			
Less Cost of Medal ..	9	0	0			
				210	14	6
The Buchanan Medal Fund :—						
Balance from last Account	120	18	10			
Interest to date	4	14	3			
				125	13	1
Sheffield University Fund ..				45	8	0
International Conference Fund :—						
Surplus included in General Investments				40	18	11
Accumulated Fund :—						
Balance at December 31, 1932	1,428	4	8			
Add : Excess of Income over Expenditure for the year ended December, 31, 1933	60	13	3			
				1,488	17	11
				£2,438	4	8

ASSETS.

Cash in hands of Secretaries :—

	£	s.	d.	£	s.	d.
Lancashire..	1	13	11			
Birmingham	28	12	10			
Scottish	14	0	2			
Sheffield	31	10	10			
London	23	17	6			
East Midlands	21	10	0			
West Riding of Yorkshire	13	11	3			
Wales and Monmouth ..	4	9	9			
Middlesbrough	3	11	6			
				142	17	9

	£	s.	d.	£	s.	d.
Sundry Debtors :—						
Subscriptions due and subsequently received				99	4	6
Due from Sheffield Council				3	17	6
Lloyds Bank Ltd.				336	4	7
Do. (Sheffield University Fund)				45	8	0
The Oliver Stubbs Medal Fund :—						
£342 5s. 7d. Local Loans £3 per cent. Stock at Cost	200	0	0			
Balance at Lloyds Bank Ltd.	10	14	6			
				210	14	6
The Buchanan Medal Fund :—						
£125, £3 10s. per cent. Conversion Stock at 78¼	98	6	9			
Balance at Midland Bank	27	6	4			
				125	13	1
Investments Account :—						
£650, 3½ per cent. War Loan at cost	630	8	4			
£300, 5 per cent. Conversion Stock, 1944/64 at cost	297	14	11			
£653 19s. Local Loans 3 per cent. Stock at cost	451	13	8			
				1,379	16	11
Furniture, Fittings and Fixtures :—						
Per last Account	104	17	7			
Less : Depreciation 10 per cent.	10	9	9			
				94	7	10
				£2,438	4	8

W. B. Lake, *Hon. Treasurer.*

Tom Makemson, *General Sec.*

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

J. & A. W. Sully & Co., *Chartered Accountants, Auditors,*
19–21, Queen Victoria Street,
London, E.C.4.

April 5, 1934.

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED DECEMBER 31, 1933.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Postages				111	11	2
Printing and Stationery including printing of "Proceedings"				664	17	10
Council Finance and Annual Meetings Expenses ..				122	7	11
Medal for Past-President ..				3	0	0
Branch Expenses :—						
Lancashire	146	11	1			
Birmingham	73	17	4			
Scottish	99	15	4			
Sheffield	56	19	2			
London	59	2	10			
East Midlands	44	18	7			
Newcastle	42	1	0			
West Riding of Yorkshire	25	8	9			
Wales and Monmouth ..	30	15	3			
Middlesbrough	32	19	3			
				612	8	7
Audit Fee and Accountancy Charges				12	12	0
Incidental Expenses				75	15	3
Loss on Sale of Badges ..				0	3	4
Salaries—Secretary and Clerks				669	12	5
Rent, Rates, &c., of Office, *less* Received				91	5	0
Subscription International Committee				5	0	0
Depreciation of Furniture ..				10	9	9
				2,379	3	3
Excess of Income over Expenditure carried to Balance Sheet				60	13	3
				£2,439	16	6

INCOME.

	£	s.	d.	£	s.	d.
Subscriptions Received :—						
Lancashire				482	9	6
Birmingham				282	9	0
Scottish				311	6	6
Sheffield				237	6	0

				£	s.	d.	£	s.	d.
Subscriptions Received (*continued*):—									
London							366	19	6
East Midlands							156	10	0
Newcastle							148	11	6
West Riding of Yorkshire							126	10	6
Wales and Monmouth							93	9	0
Middlesbrough							81	18	0
Unattached Members							42	0	10
							2,329	10	4
Add : Subscriptions in advance, 1932				89	15	6			
Do. due, 1933				99	4	6			
				£189	0	0			
Less : Subs. in advance, 1933	£97	2	6						
Do. due, 1932	62	9	6						
				159	12	0			
							29	8	0
							2,358	18	4
Sale of " Proceedings," &c.							4	11	4
Interest on Investments and Cash on Deposit							50	6	10
Income Tax Refund							6	15	6
John Surtees Medal Fund Surplus							19	4	6
							£2,439	16	6

Finance

Mr. W. B. Lake, J.P. (hon. treasurer), presenting the accounts and balance-sheet for the year ended December 31, 1933, and proposing their adoption, said the details of the accounts differed only slightly from those of the previous year. Printing costs had increased slightly, due to the expense of the draft copies of the Rules and the preparation of the Institute's booklet on Microstructures, but he commented that the money had been very well spent. There had been a slight decrease in the expenditure on postages and in the audit fee, the latter decrease being due to the fact that in 1933 there was no expensive legal work in connection with the recovery of Income Tax.

The net result was an excess of income over expenditure to the extent of £60 12s. 3d. The fact that, in spite of the great depression in the industry, the Institute had been able so to maintain its membership that it could show a credit balance on the year's work, was a great testimonial to the work of the Institute. There had been an appreciation of the Institute's investments. The amount paid for the various stocks held was £1,678 3s. 8d., and at current market prices those stocks were worth £2,037, so that the appreciation was roughly £300. Under all the circumstances, the position was satisfactory.

The motion for the adoption of the accounts and balance-sheet was seconded by Mr. A. Harley (Past-President), and carried.

Report of Technical Committee

Mr. J. W. Gardom (Convener of the Institute's Technical Committee) proposed the adoption of the Committee's third Annual General Report. He added that during the year the Committee had examined a report published by the British Cast Iron Research Association on the analyses of various metals, and was in favour of the adoption of that report by the Institute.

Commenting upon the devoted work of the members of the Technical Committee and its sub-Committees, he said that possibly it might be thought in some quarters that they were not doing much, and that if they gave only one hour per week to this work throughout the year it would amount to only one week's work in any whole-time research organisation. As an instance of achievement, however, he drew attention to the Technical Report produced by the Sub-Committee on Cast Iron, and said that if any research worker at a University could produce such a report in six months he would consider that he had done very well. It must be appreciated that the production of such a report must have entailed many hours of work.

Mr. V. C. Faulkner (Past-President), seconding the motion for the adoption of the Technical

Committee's Report, said he had attended one or two of the Committee's meetings, and although he played only a minor rôle, he had been very much impressed by its work. The fact which had impressed him mostly was the speed with which suggestions were put into practice; the lag between suggestion and accomplishment was of the lowest possible order.

The Chairman also paid a tribute to the wonderful work of the Committee, which was done voluntarily and gratuitously, and said that it was essentially the kind of work that the Institute wanted to do. All the members could read about the researches of the British Cast Iron Research Association and other bodies, but in applying the findings of such researches in actual practice in the foundry and connecting up with them the Committee was performing a useful function. He could not praise the Committee's work too highly.

The report was adopted, amid applause.

THIRD ANNUAL GENERAL REPORT OF THE TECHNICAL COMMITTEE

The reorganisation which was explained in detail in the last Annual Report has been in operation during the past twelve months and has been completely successful. The Technical Council, which consists of the members elected by the Branches, together with the officers of the Technical Committee and the conveners of sub-committees, has met four times during the year, on the same days as the meetings of the General Council, and has dealt with matters of general administration. The full Technical Committee, consisting of the Technical Council, the whole of the members co-opted on the sub-committees on account of their special knowledge and certain ex-conveners of sub-committees, has held four meetings on dates approximately midway between the Technical Council meetings. Such meetings have been held at Carlisle (twice), London and Birmingham. These meetings of the full Technical Committee afford a method of reviewing the work of the whole of the sub-committees and provide the necessary liaison. The total number of sub-committee meetings which have been held is about forty.

In the last Annual Report, reference was made to the Technical Exhibit organised in connection with the International Foundry Exhibition in April, 1933. The Committee continues to receive evidence of the value of this exhibit in the interest shown in the development of foundry technique.

Inquiry Bureau

The Inquiry Bureau was commenced in October, 1932, for an experimental period of twelve months. This period has now been continued indefinitely, as it was found that the Bureau was of real service to members, as it provides a definite means of answering inquiries regarding publications and other matters of a technical character, which were not dealt with previously by any special machinery. Since the establishment of the Bureau 40 inquiries have been answered.

Publication of Technical Data

In the course of their work, the various sub-committees have collected and tabulated a large amount of data bearing on their respective subjects and careful consideration is being given to a suitable method of making this data available to the members of the Institute. A certain amount of matter relating to the properties of cast iron is already available to members on application to the General Secretary.

The Technical Committee wish to bring to the notice of members of the Institute, and of the industry generally, the value of the publication on "Recommended Methods of Sampling and Analysis of Cast Ferrous Metals and Alloys," published by the British Cast Iron Research Association. The methods given in this publication have the approval of the Committee.

Attention, particularly of non-ferrous founders, is also directed to another publication, namely, "The Casting of Brass Ingots," by Dr. R.

Genders and Mr. G. L. Bailey. This book is published by the British Non-Ferrous Metals Research Association, and although concerned specifically with the manufacture of ingots, contains much information of value to founders of non-ferrous metals.

During the year the principal activities have been of a specialised character and have been carried out mainly by the various committees. Details of their work appear in the reports of these sub-committees which are appended to this report.

The Sub-Committee on Cast Iron has issued a booklet of Typical Microstructures of various types of cast iron. Copies may be obtained by any member of the Institute free of charge, additional copies may be had at the price of 2s. 6d.

At the Cardiff Conference held in June, 1933, a Paper by the Sands and Refractories Sub-Committee was presented entitled " Routine Methods of Testing Green Sand." During the past year the Sub-Committee on Cast Iron has carried out a large amount of experimental and investigation work on various phases of cast iron, including such subjects as porosity, contraction, the influence of phosphorus, etc. This work has been embodied in a report which will be presented by this Committee to the Manchester Conference in June next. These Sub-Committee reports follow the report presented by the Malleable Cast Iron Sub-Committee to the Newcastle Conference in 1932, and it is anticipated that further reports will be received at subsequent conferences from these and other sub-committees.

The Sub-Committee on Foundry Costing has made considerable progress under the convenership of Mr. Vincent Delport and is engaged actively in formulating proposals, which will be placed before the Institute in due course.

From time to time the Institute has been invited to put forward its views on draft specifications issued by the British Standards Institution and to participate in the work of other committees, both international and national. The Technical committee has now become the recognised medium through which the Institute participates in such work, and through which it is represented on these committees.

The Convener takes this opportunity of paying tribute to the devoted work done by the members of the committee and of the sub-committees. The members carry out a considerable amount of work in their own time and they attend meetings in various parts of the country, usually at the week-ends and at their own expense. The thanks of the Institute are due to them for their work for the benefit of the members as a whole and the industry in general. A considerable amount of time must necessarily elapse before work of this kind reaches a stage at which useful information can be published, sufficient work has already been published, however, to indicate that considerable progress is being made in almost every branch of modern foundry practice.

J. W. Gardom,
Convener, Technical Committee.

REPORTS OF SUB-COMMITTEES

Sub-Committee on Cast Iron

As this sub-committee has been responsible for the production of a Technical Report for the Manchester Conference, there is little to report beyond the work described therein. The sub-committee has co-operated in the work of the Technical Committee by attending to queries raised in the Inquiry Bureau and other matters of general interest.

The preparation of the Technical Report has involved many meetings of the Sub-Committee, special meetings having been held in addition to the usual quarterly ones.

P. A. Russell,
Convener.

Sub-Committee on Non-Ferrous Castings

Since the record report issued a year ago, the Non-Ferrous Castings Sub-Committee members have held three meetings and attended four Technical Committee meetings in various centres. Their chief work has centred round the selected alloys to be recommended to the British Standards Institution for the simplification of numerous commercial specifications dealing with leaded gun metals and leaded phosphor bronzes. Certain modifications both in the suggested composition ranges and also the physical properties to be expected from these have been decided upon as the result of tests made by the various members, but before these were finally declared in the Paper proposed for the next Conference, it was agreed to get evidence of other founders. With this end in view several collaborators have been selected, whose work is now in progress, and until this whole scheme can be correlated it was deemed inadvisable to frame a final report on this piece of work. One outstanding feature of the work so far covered has been the demonstration of the usefulness of the two types of standard test-bar selected two years ago.

Other aspects of the work undertaken by the sub-committee have been the condensation of the various tables of standard physical data collected and also the answering of several technical inquiries which have been passed to them by the full Technical Committee to deal with. In connection with the Melting Furnaces Sub-Committee, details of all types of furnaces suitable for melting non-ferrous metals have been tabulated and will form a basis of joint work with their sub-committee as their work expands.

J. S. G. Primrose,
Convener.

Sub-Committee on Malleable Cast Iron

Much work has been done during the course of the last twelve months, but as the investigations in hand have been of considerable magnitude none of the work has yet been completed.

An investigation is in progress in connection with the possibility of utilising a standard size test-bar, but specifying different test requirements satisfactorily to represent different sections of metal. This work has involved the preparation of large numbers of test-bars, and at the present time these bars are undergoing or about to undergo annealing treatment. The work should be brought to a conclusion within the next month or two.

An attempt to correlate physical properties of malleable cast iron with microstructure has been in progress for a considerable time, and this work has also involved the preparation of numerous test-bars. It is expected that this investigation will be brought to completion during next year.

The Committee has taken up the question of "Tolerances on Dimensions" of Castings, and much work has been done in investigating the accuracy to drawings and patterns obtained in normal practice. In this work the Committee has received the co-operation of the Steel Castings, Non-Ferrous and Grey Cast Iron Sub-Committees, and the whole of the data will shortly be drawn together, and it is hoped to make some publication on the subject.

A. E. Peace,
Convener.

Sub-Committee on Sands and Refractories

In June, the Paper entitled "Routine Methods of Testing Green Sands" was presented to the Cardiff Conference. After this, opportunity was given for discussing the relative merits of various methods of testing, the Sub-Committee put forward in September, 1933, definite recommended methods for routine testing of green sands as follows:—

Use the A.F.A. test-piece prepared in the standard A.F.A. rammer.

Determine the permeability by the A.F.A. method in the A.F.A. apparatus or Richardson's modification.

Determine the bond strength using the A.F.A. standard rammed test-piece crushed in the B.C.I.R.A. compression-strength testing machine.

Determine moisture in the Speedy Moisture (patent) moisture tester.

Firms and individuals throughout Great Britain have been invited to use the recommended methods in practice over a period of about a year with the object of reporting their experiences of the methods.

The Sub-Committee is now engaged in correlating tests with practice with a view to determining the relationship between the bond and "lift," also what amount of moisture, permeability and bond strength is best for each type of green-sand casting.

It is also investigating what modified methods are suitable for determining permeability and bond strength in dry moulding sands and core sands. The Sub-Committee has already agreed that the A.F.A. method of determining permeability in dry sands is satisfactory.

A suitable instrument for determining the mould hardness is being investigated, also the relationship between mould hardness and permeability in order to determine the link between standard tests for permeability and the permeability of the actual moulds.

N. D. Ridsdale,
Convener.

Sub-Committee on Melting Furnaces

The Melting Furnaces Sub-Committee has been continuing the work outlined in the last Annual Report. A report on the cupola furnace has been prepared and it is intended to amplify this by including recommended operating data for a 36-in. dia. (lined) cupola. With regard to non-ferrous melting furnaces, a schedule of the various types available has been drawn up, and it is proposed to collect operating data from published and other sources with a view to making a comprehensive report which will be of value to members.

At the request of the main Technical Committee and arising out of a discussion at one of the Branches, a questionnaire has been prepared and has been circulated to a number of foundries, on the subject of cupola linings and patching materials, with a view to obtaining authoritative data on the consumption of such material under different methods of cupola operation.

F. K. NEATH,,
Convener.

Sub-Committee on Steel Castings

The Steel Castings Sub-Committee has been investigating the casting of a valve, and eight firms have promised to assist and supply castings, some of which are completed.

These castings will enable the Sub-Committee to investigate moulding troubles, contraction and hot tears, together with the physical properties of the metals made under different processes. This will occupy a considerable time, and in the meantime we refrain from making any detailed report or conclusion.

R. J. RICHARDSON,
Convener.

Sub-Committee on Costing

The Costing Sub-Committee was definitely constituted in November, 1933, and immediately started its investigations.

Taking up the subject in relation to grey-iron foundries, it was decided at the first meeting that the system would be divided into four main divisions, as follows:—(*a*) Melting Department; (*b*) Moulding Department; (*c*) Core-making Department; (*d*) Cleaning and Finishing Departments. In addition, a number of auxiliary departments would also be considered.

The Costing Sub-Committee has agreed upon a number of suggestions covering the standard system of costs for the melting department, and it is felt that it would be very helpful if the proposed recommendations could be put before the foundry industry in order to obtain a reaction from those who show sufficient interest in the subject. It would thus be possible to obtain what might be valuable suggestions and constructive criticism, which would enable the Sub-Committee eventually to present a complete system embodying the best practice. As constituted at present, the Sub-Committee comprises five members who are fairly representative of various aspects of the grey-iron foundry industry, but suggestions from outside the Sub-Committee might fill certain gaps which may or may not exist in the proposed recommendations of the Committee.

A number of foundry owners have been asked to supply information concerning the system used in their works. From the replies which have been received, it would appear that a few very broad principles are more or less in use in all the foundries that have been approached, and these replies show that it would be difficult to compare costs accurately without a standard system that could be followed by the majority of foundries.

It is suggested that the best way in which to receive constructive criticism would be to submit before one or several of the Branches a short Paper summarising the proposed recommendations on melting costs. The Technical Committee and the General Council have approved of the preparation of such a Paper, and the Costing Sub-Committee hopes to be in a position to present it to the Branches after the month of November.

Vincent Delport,
Convener.

The Oliver Stubbs Gold Medal

The Chairman announced that the General Council recommended the award of the Oliver Stubbs Gold Medal for 1934 to Mr. V. C. Faulkner (Past-President) for the wonderful way in which he had steered the Committee (as Convener) which had been concerned with the establishment of a school of founding science in Sheffield. There were thousands of reasons why thanks were due to Mr. Faulkner for his work on behalf of foundrymen.

Mr. Faulkner said he was deeply moved by the kindness of the Institute in awarding him the Medal. Some 12 years ago he had had discussions with the late Mr. Oliver Stubbs as to the terms of the award, but had not dreamed at that time that he would ever be a recipient; he was indeed happy in the knowledge that he was to receive the award, by reason of his great respect for the name with which it was associated. The work which the Institute had been kind enough to recognise in this way had been very much a labour of love; other work that he had done, such as the preparation of the Bulletin, was much harder.

An Institute Medal

The Chairman said that the Oliver Stubbs Gold Medal was awarded for work done specifically in any one year. There were men, however, who by their continuous service accumulated a mass of credit over many years. In 1933, therefore, the Institute had presented a Medal to Mr. F. W. Finch (the Institute's first Secretary), and in 1934 it was decided to present a similar Medal to Mr. J. J. McClelland. (Applause.) The Chairman added that, as a resident of South Wales, where Mr. McClelland had done so much, he was delighted to be able to make the announcement.

Diplomas

The Secretary (Mr. Tom Makemson) announced that the following Diplomas had been awarded, for Papers read before the branches during the past session:—

Mr. W. G. Morgan: "Fettling Shop Efficiency."—Birmingham Branch.

Mr. F. Hudson: "Moulding Sand Control."—Lancashire and London Branches.

Mr. A. Logan: "Aspects of Non-Ferrous Founding."—Lancashire Branch.

Mr. T. Makemson: "Some Impressions of Czecho-Slovakian Foundries."—London Branch.

Mr. G. L. Bailey: "Porosity in Non-Ferrous Castings."—London Branch.

Dr. A. B. Everest: "Potentialities of Cast Iron."—London Branch.

Mr. J. Longden: "Cast Iron for Laundry Machinery."—Scottish Branch.

Mr. J. Roxburgh: "Alloys in the Iron Foundry."—Sheffield Branch.

Mr. B. Gale: "Practical Considerations in a Small Jobbing Foundry."—Wales and Monmouthshire Branch.

Election of President

The CHAIRMAN, proposing the election of Mr. Roy Stubbs as President of the Institute for the ensuing year—a task which he regarded as a privilege—said it was difficult to assess the value of friendship, but one of the outstanding characteristics of Mr. Roy Stubbs was that he was a friend of every foundryman. He (Mr. Williams) had found in him a true friend during his term of office, and in electing Mr. Stubbs the Institute would be electing the right man, who would stand by the Institute in the coming year. His name was a household word amongst the members, and it was indeed a pleasure to be able to propose his election.

MR. VICTOR STOBIE (Past-President), seconding, commented that Mr. Stubbs would be the youngest President the Institute had had for many years, and, like all who attained merited prominence in early years, he was undoubtedly one of great quality and a wise counsellor. He had the blood of Oliver Stubbs in his veins, but that was by no means the reason why he had come to the forefront; he had focussed the attention, the admiration and the esteem of all by his own unaided efforts. The Lancashire Branch, under his Presidency, had forged ahead, due to a great extent to the grit and determination with which he had conducted its affairs; that grit and determination, harnessed to the main body of the Institute, would produce wonderful results.

Amid enthusiasm the resolution was carried unanimously.

MR. STUBBS, responding, confessed that he was overwhelmed. At the same time, he was conscious of the very high honour conferred upon him, and was appreciative of the actions of those who had deemed him worthy of such a distinction. He was succeeding a long line of capable, energetic, sincere and prominent men in the industry, each of whom had added his own step of individuality in the march of progress that had brought the Institute of British Foundrymen to its present standing amongst Institutes not only of this country but of the world; and if he could add his little step forward in that march of progress he would be very happy. He tendered his sincerest thanks to all the Officers and members of the Institute for their kindness to him on this occasion, and to Mr. Williams and Mr. Stobie for their very gracious expressions of goodwill.

Vote of Thanks to Retiring President

Mr. Stubbs, taking the opportunity to propose a vote of thanks to the retiring President, said that Mr. Williams had placed the Institute under lasting obligations by the exceptionally active and constructive service which he had maintained continuously during his year of office. There was no doubt that the Institute had thereby gained greatly in prestige, and the members paid tribute to him, acknowledging their deep indebtedness for his wise counsel and tactful guidance.

Mr. J. E. Hurst (Vice-President), seconding, said he was voicing the opinion of all when he stated that no other President had wormed his way more quickly than had Mr. Williams into the esteem and real affection of every member of the Institute. One could feel assured that his year of Presidency would ever be remembered in the annals of the Institute.

The vote of thanks was carried with acclamation.

Mr. Williams, with his usual modesty, said that a President could do nothing without the aid and support of the Secretary, the Vice-Presidents, the Council and the Committees; he was just one of them. If he had been of any service to the Institute and if he had done any of the members any good he was indeed glad. During his Presidency he had made a great many friends, and he valued friendship very highly; we brought nothing into the world, and we could take nothing out of it but friendship.

Election of Senior Vice-President

MR. STUBBS, proposing the election of Mr. J. E. Hurst (of Dronfield, Sheffield) as Senior Vice-President, remarked jocularly that he would not mention all that he knew of Mr. Hurst; he was a man known internationally, however, for his researches into the mysteries of cast iron. He had delivered numerous lectures—some of which the hearers agreed with and some of which they did not—and had written various text books which were regarded as classics. The members could be sure that under his (Mr. Stubbs') able guidance Mr. Hurst would make quite an efficient Vice-President. (Laughter.)

MR. C. D. POLLARD, who claimed the privilege of seconding the proposal, said that some people had honour thrust upon them, whilst others sought it. Mr. Hurst was not in the latter category, and he would honour the Institute by becoming its Senior Vice-President, and eventually, the members hoped, its President. As a member of the Sheffield Branch, Mr. Pollard assured Mr. Hurst of the whole-hearted support of that Branch.

The resolution was carried with enthusiasm.

MR. HURST, responding, said he regarded his election more in the nature of a compliment to the Sheffield Branch. It had already been indicated by Mr. Pollard that the members of the Branch were conscious of the honour done to them, and they hoped in due course to welcome the Institute to Sheffield. He would do all in his power to maintain the traditions of the Vice-Presidency and the Presidential Chair.

Election of Junior Vice-President

MR. J. CAMERON, J.P. (Past-President), proposed the election of Mr. H. Winterton (Scottish

Branch) as Junior Vice-President, a task which gave him the greatest pleasure. He recalled that 10 or 12 years ago there had been tremendous difficulty in getting men to take office, and added modestly that he himself would not have been President but for that state of affairs; Mr. Oliver Stubbs had practically taken him by the ear and had made him accept the office, and there was no opposition. The Institute was to be congratulated, however, on the fact that to-day there are plenty of good men ready to take office, with the responsibilities attached thereto. Nowadays the Branch Councils were asked to nominate candidates for the Vice-Presidency, and it was the task of the Past-Presidents to make a selection and to place their decision before the Council. This year the task had been very difficult. Each district should have the right to provide a President from time to time.

Mr. Winterton was no stranger to the Institute; he had joined only a year after it was formed, and had been a good friend ever since. His sons and Mrs. Winterton were good friends and workers, and there were members of his staff who were good workers also. He was the nominee of the Scottish Branch, which was for the second time nominating an Englishman. The Branch had tried that experiment in the case of the late William Mayer, and it was so successful that one felt sure the Institute would again accept the proposal. Mr. Winterton would worthily maintain the traditions of the office, and after he had passed through the Presidential Chair, as it was hoped he would do, he would still maintain his interest in the Institute.

Mr. Sharp, seconding, said all who knew Mr. Winterton would appreciate his geniality and his capacity for friendship, and that he was well fitted for the Vice-Presidency.

The resolution was carried with acclamation.

Mr. Winterton expressed his thanks and hoped sincerely that he might give satisfaction to his many friends in the Institute. As far back as 1905 he was nominated a member of the Institute—then known as the British Foundrymen's Association—he was elected early in 1906, and since then his interest in the Institute had increased year by year. He would endeavour sincerely to support Mr. Stubbs and Mr. Hurst. Another reason he was glad to be able to take office was his conviction that research and the gathering together of those connected with the various branches of the iron foundry trade must be for the good of iron founders generally; he looked upon his election as a further indication that the members of the foundry industry realised that the whole must work together in order to achieve success.

Auditors

On the motion of Mr. V. C. Faulkner, seconded by the Chairman, Messrs. J. and A. W. Sully & Company (chartered accountants) were re-elected auditors for the coming year.

Assumption of Presidential Duties

The Secretary announced that, inasmuch as the Annual General Meeting was being held before the official opening of the conference by the Lord Mayor of Manchester, Mr. Williams had been asked the fulfil the duties of President until after the official opening of the following morning.

Election of Members of Council

It was announced that as the result of the ballot for the election of members of Council to fill vacancies, the following were elected:—Messrs. A. Campion, J. W. Gardom, B. Hird, J. R. Hyde, J. M. Primrose and E. Stevenson. Five were elected for two years, and Mr. Hyde for one year; the latter filled the vacancy due to Mr. Winterton's elevation to the Vice-Presidency.

Membership

Mr. A. Sutcliffe made an appeal that the Institute should increase its efforts to attract greater numbers of practical moulders into its ranks. He pointed out that castings were made on the foundry floor, and not in the laboratory.

Mr. Stubbs' Welcome

Mr. Roy Stubbs extended to all members of the Institute a very sincere welcome to the City of Manchester, and expressed the hope that they would avail themselves to the full of Lancashire's characteristic hospitality.

Presentation of Presidential Badges

Following the business of the Annual General Meeting, the members joined their ladies at the informal reception and entertainment. There a very happy little ceremony took place, for collarettes were presented for the use of the President, the wife of the President, and for the Vice-President. The first was the gift of the Lancashire Branch, the second was the gift of the ladies of the Lancashire Branch, and the third was presented by Mr. and Mrs. Williams.

Mr. A. Phillips (Chairman of the Conference Committee) presented to Mr. Williams, on behalf of the Lancashire Branch, the badge to be used by Presidents on occasions when the usual chain and badge of office was too cumbersome. When the Lancashire Branch was honoured, he said, by the decision to hold the 1934 conference in Manchester the members had wished to mark the occasion in some suitable manner, and, having obtained the necessary permission from the Institute, had subscribed the money to provide a collarette to be worn by the Institute's Presidents. At a recent meeting it was the unanimous feeling that the Branch would be honoured if Mr. Williams were the first President to wear it; he had been an outstanding President, and it was hoped that he would live for many years to see it worn by his successors.

Mr. Williams accepted the collarette on behalf of the Institute, and expressed his warm thanks for having been given the opportunity of wearing it, if only for a few hours. The large Presidential Chain and Badge, he said, was properly worn at functions of the Institute, and it was delightful that the Lancashire Branch should have hit upon the idea of providing a distinctive badge which could be worn by a President when representing the Institute at the functions of other bodies, where it would be out of place to wear the large Chain and Badge.

Mrs. Stubbs, presenting to Mrs. Williams the collarette provided for the use of the President's wife, said that when the Ladies' Committee had heard that a collarette was to be presented to the President, they had decided to provide one to be worn by the wife of the President when supporting her husband. They asked her to accept the collarette, with their good wishes and their love; she had charmed everyone by her personality, and it was hoped that her successors would fill the position with equal dignity.

There was great applause when Mrs. Stubbs, in making the presentation to Mrs. Williams, kissed her affectionately.

Mrs. Williams felt deeply the specially graceful gesture on the part of the ladies of the Lancashire Branch in offering it to her in the first place, and she was indeed proud to wear it. She acknowledged also the pleasure she had derived from visiting various branches of the Institute, the members of which were particularly happy and friendly, and expressed the hope that Mrs. Stubbs would derive equal pleasure.

On behalf of Mr. Williams and herself, Mrs. Williams then presented to Mr. Stubbs a collarette to be worn by Vice-Presidents of the Institute. They felt that the Vice-President should have a distinguishing decoration, and it was presented as an earnest of their hope for great things to come.

Mr. Stubbs, in accepting it, said he appreciated that he had been made the custodian of a very wonderful gift, and that Mr. and Mrs. Williams had tendered a substantial compliment to the Institute. It would perpetuate the memory of Mr. Williams' Presidency and of the conference held in Cardiff in 1933, and all who were given the honour of wearing it would think most generously of his and Mrs. Williams' kindness. He personally was proud indeed to be the first to wear it, and to have the opportunity of expressing the Institute's gratitude.

A Civic Welcome

The members and their ladies assembled at the Midland Hotel on Wednesday morning for the official opening of the conference by the Lord Mayor of Manchester (Alderman Joseph Binns, M.B.E.), supported by Mr. B. Mouat Jones, D.S.O., M.A. (Principal of the Manchester College of Technology).

MR. WILLIAMS (retiring President) introduced the Lord Mayor, who, appropriately enough, was a patternmaker, so that his presence was doubly appreciated.

The LORD MAYOR extended to the members and their ladies a hearty welcome to the city, and expressed the hope that the Conference would be in every way a success; he congratulated them also upon the fact that they were enjoying bright weather and upon the programmes arranged both for the ladies and the gentlemen, which indicated that they would enjoy a very happy time.

Though not a member of the Institute, he was a patternmaker by trade; also, occasionally he had had the misfortune to take charge of foundries, but, being a mild and gentle patternmaker in the early days, his methods were not quite forcible enough to project into the men under his charge that energy which would have made his management more effective. In his apprenticeship days it was recognised that if one wanted definite purposeful language whereby to put some vim into the men one could always find it in the foundry! As a patternmaker, he had taken a keen interest in metallurgy; he remembered the Institute being started in Manchester in 1904, for he was then a student in metallurgy (laboratory and practical) at the Manchester College of Technology; he believed that the class on iron founding at that College was the first in the United Kingdom. In 1904 he had passed through his final term in the metallurgical section and also the iron founding classes.

Lancashire and Professional Societies

He was proud of the Institute's association with Manchester; during the past year he had attended some 70 or 80 dinners and luncheons as the guest of associations which had met in Manchester, and had found that so many of the bodies that were formed to co-ordinate the activities of specific industries or professions —from the chartered accountants to the undertakers—were founded in that city. This circumstance had arisen, he claimed, from the fact that South-East Lancashire was the first district in which many industries were developed intensively. The metal trades, the machine building trade, the development of power engines, had all come forward very rapidly in South-East Lancashire, and the necessity for organisation was proved in the first instance in a definite manner by labour. Later, the advantages of such organisation had caused the professional classes to consider the matter. The British Foundrymen's Association was formed in 1904.

He congratulated the Institute upon the arrangement of its printed matter, and said he had never seen anything better done by any of the other associations; it showed that its members, belonging to a calling which in the early days was referred to as that of the sandrats, were anxious to acquire fundamental knowledge and to see that the whole industry was so co-ordinated and regulated that the maximum efficiency would be attained. When he had been closely associated with the foundry industry it had in very few instances possessed those qualifications, but to-day it had sprung right to the forefront. Its members interested themselves not only in the ordinary productions of their establishments, but also in the fundamental education of the younger men. It was necessary to instruct them in the root principles, to give them an idea of the natural laws which required consideration to a greater degree in the foundry than in the majority of the engineering sections of the trade.

Advancement in Foundry Knowledge

More than 35 years ago he had read a book on foundry practice, in which it was stated that if a moulder were to be successful he must consider certain natural forces which he could not balance up and work out in a mathematical sum and so arrive at a right valuation of his risks. In those early days the loam moulders, the men responsible for the laying out of the bed and for putting in the right amount of backing to allow the gases to escape when a heavy casting had to be made, did their work with calm confidence, and invariably they were successful. But in order to achieve that success they must have had an idea as to the amount of pressure that would be exerted upon the mould sides by the escape of the gases when the molten metal was poured into the mould, and if the walls had not the strength necessary, or if the boxes were not such as to afford a big margin of safety, the results would be disastrous, probably to the workmen, and certainly to the employers, for the castings would be lost. But nowadays the difficulties had been largely minimised by the fact that very often the men in charge had a thorough knowledge of stresses and strains, a good knowledge of the erosion process in metals, a better knowledge of the mixing of sands and of their solidity and of getting away the gases and air that must exude from the mould in the process of casting. He was proud to know that such a tremendous advance had been made.

When at the Metropolitan Vickers works during the previous week it had been his special pleasure to go into the foundry and to ask Mr. Jolley the extent of the improvements which had been achieved since the days when he himself was closely associated with foundry work, and had found that there were very marked differences. Changes were being made perhaps more rapidly in the foundry trade than in any other section of the engineering trade. He instanced the development of the metal mould, the more complicated moulds, and the more general use of mixtures of metals. He was in possession of three or four of the pocket books which were kept by foremen in the old days for their own private use; in those days the correct proportions of metals for different purposes were not ascertained generally, and the notebooks kept by the foremen allowed them to retain what they had called the secrets of the success of their foremanship. That attitude had ceased, however, and we were developing processes satisfactorily by the only sure means, *i.e.*, by the application of science.

Finally, the Lord Mayor wished the Institute every success in its efforts to develop the industry, in the interests of both employers and employed, to a high standard of efficiency and accuracy, so that it would continue to prosper and help Great Britain to uphold her traditions of best workmanship and of greatest satisfaction to her customers.

Presentation of Oliver Stubbs Medal

In presenting to Mr. V. C. Faulkner the Oliver Stubbs Gold Medal, the Lord Mayor recalled that he had had the pleasure of knowing Mr. Oliver Stubbs; he expressed the hope that Mr. Faulkner would continue his labours on behalf of the Institute, whose influence would continue to expand.

MR. FAULKNER said he was indeed proud to receive the Medal, which commemorated a name famous and honoured in the annals of iron founding; and he would not be regarded as conceited when he said that if his old friend Mr. Stubbs were still living he would be exceedingly pleased to see the Medal presented to an old friend, for it formed another concrete link between them.

Mr. Faulkner also took the opportunity to acknowledge his sincere gratitude to his

Directors for their enthusiasm in facilitating any work he was able to do to help the Institute, and to his staff, who were always willing to undertake work thrown upon them by reason of his absence on Institute business.

A Tribute to Mr. McClelland

As the Medal which the Institute has awarded to Mr. J. J. McLelland, for his continued good work on its behalf, was not available for presentation at the Conference, the Lord Mayor shook hands with him in congratulation and wished him well in the future.

Mr. McClelland expressed his gratitude to the members of the Institute as a whole for the honour they had conferred upon him, and particularly to the members of the South Wales and Monmouthshire Branch Council, who had been most persistent in their efforts to ensure that he was so honoured. His position at the moment was somewhat unique, for he recalled that he was apprenticed to the foundry trade in Manchester more than 50 years ago. It was there that he had first learned the elements of the sand-rat trade, and he was glad to hear the splendid compliment paid by the Lord Mayor to those associated with him in that trade. Indeed, he was proud to be described as a sand-rat, for the sand-rat, so called, was engaged in a business which required the application of intelligence as well as physique.

A Further Expression of Welcome

Mr. B. Mouat Jones, D.S.O., M.A. (Principal of the Manchester College of Technology), extended a welcome on behalf of the educational institutions of Manchester. It was a particular pleasure, he said, to be able to do so, for the Institute of British Foundrymen had shown great interest in educational affairs; and if it shared the experience of other professional bodies its educational activities would extend more and more and would absorb a very great deal of its energy. Another reason why he was particularly glad to offer a welcome to the Institute was that the local Branch had held its meetings regularly over a period of 20 years at the College of Technology—from 1913 until 1933. It was a matter of some regret to him that the Branch had found it necessary to change its habitat; but when he had been told the reason for the change it had seemed to him so overwhelmingly cogent that he had not the heart to demur. The College of Technology did not possess a licence for the sale of alcoholic liquors—and the marvel was, not that the Branch had decided to hold its meetings elsewhere, but that it had remained at the College for 20 years! However, he was glad that the Junior Section, which had commenced to hold meetings at the College in 1924, was still meeting there, and he hoped a very long time would elapse before its members contracted that "thirst" for knowledge and experience which had constrained their elders and betters to seek new pastures and fresh water holes!

A still further reason why he was extraordinarily glad to welcome the Institute was that its newly-elected President, Mr. Roy Stubbs, was, like the Lord Mayor, an old student of the College; it was always a source of very great pride to be able to point to old students who had attained positions of eminence, and to take all the credit for their having got there! If Mr. Stubbs felt that he owed any debt to the College he could be assured that that debt had been more than amply repaid by the very great kindness and generosity of his firm, Messrs. Joseph Stubbs, Limited, which had always been an extraordinarily good friend to the College.

The College had always been in very close contact with the foundrymen of Manchester and district. In 1898—36 years ago—the foundrymen's classes were first started, and they had been carried on ever since; he hoped they would continue to develop and to maintain contact with the foundrymen. As the Lord Mayor had pointed out, in these days the relationship between the art and practice of founding became more and more and day-by-day interlinked with the fundamentals of metallurgy, and one would like to think that the local Branch of the Institute would make further use of the Metallurgical Department of the College.

A Vote of Thanks

On the motion of MR. WILLIAMS, seconded by MR. STUBBS, a hearty vote of thanks was accorded the Lord Mayor and the Principal of the Manchester College of Technology for their expressions of welcome and goodwill, after which the Lord Mayor and Mr. Jones withdrew.

Installation of President and Vice-President

MR. WILLIAMS then formally invested Mr. Roy Stubbs with the Presidential Chain and Badge of office, and also handed to him the new collarette and replica of the badge to be worn on subsidiary occasions. He wished Mr. Stubbs the greatest success in his year of office.

MR. STUBBS then formally occupied the chair. He expressed the hope that he might carry the chain and badge with the same dignity as had Mr. Williams, and that he would be able to add lustre to the office.

In presenting the Past-President's badge to Mr. Williams, he said it was not only in finished undertakings that the Institute honoured him, but in the portent of still further achievements; it was hoped that the possession of the badge would inspire him in working out further benefits for the Institute. The good that he had done would live after him, and with cumulative value to the foundry industry. The members hoped that as the years receded this token would be treasured not alone for its significance; it carried with it the members' hopes for the continued health, happiness and prosperity of Mr. Williams and of those whom he held dear.

MR. WILLIAMS expressed his thanks, and added jocularly that its presentation carried with it a feeling of great relief.

The collarette for the use of the wife of the President was then formally presented by Mrs. Williams to Mrs. Stubbs, to whom wishes for her future happiness were expressed. Mrs. Stubbs very feelingly returned thanks.

The PRESIDENT then invested Mr. J. E. Hurst with the collarette to be worn by the Senior Vice-President, and invited Mr. Hurst and Mr. H. Winterton formally to occupy the Senior and Junior Vice-Presidential Chairs.

Greetings from Overseas

The following cablegrams were received from foundrymen's organisations overseas:—

From the American Foundrymen's Association:

"Please convey heartiest good wishes, American Foundrymen's Association, success Institute of British Foundrymen Conference. May their work furthering world advancement in foundry industry be stimulated, and far-reaching benefits be extended through participation large number British foundrymen in fifth International Congress in Philadelphia, October. Anticipate great pleasure in welcoming officers and representative members of that splendid group this fall.

FRANK J. LANAHAN, President."

From the French Foundry Association:

"Association Technique de Fonderie send cordial salutations to British colleagues and best wishes for the success of the congress.

M. L. F. GIRARDET, President."

Apologies for Absence

Apologies for absence, and expressions of good wishes for the success of the conference were received from Mr. F. P. Wilson and Mr. S. H. Russell (Past-Presidents), Mr. F. W. Finch (first Secretary of the Institute), Mr. Walter Flavell, Mr. J. B. Johnson, Dr. P. Longmuir, and many other members.

Visitors from Overseas

A hearty welcome was extended to Dr. Ing. Heinrich Nipper (of the Technical High School, Aachen, Germany), and to Mr. Williams, a steel founder from Calcutta.

The PRESIDENT then delivered his address.

PRESIDENTIAL ADDRESS

Mr. Williams and Gentlemen,—The measure of human progress, by which we gauge the difference between the centuries just passed and those of ancient times, is not the status of the isolated individual, but rather the amount by which the condition of the great multitude has been raised by the increase in prosperity, leisure and opportunity for happiness—by the increased facility the average man has for improving the position of those whom he loves and who are dependent upon him. If this be the measure of progress, then industry, of which we are all a part, has had more to do with progress than any other single factor.

If this be true, what is the position of our own calling in this picture?

When a mould is made, cast, the casting is taken down, fettled, and a finished casting produced, something absolutely new has been created. The pattern may be old, the design may be obsolete, but the object produced never existed before. When our foundries close to-night, the world is richer than it was when the sun rose this morning by the product that has been made. The foundry is not rehashing that which has been. It is creating something that is new; something to help the future of the race.

Notwithstanding that it is so old, we are beginning to realise that our industry is so complicated that we know little or nothing about it. Any man who handles molten metal is daily confronted with problems which tax to the utmost his ingenuity. A few years ago we used to judge pig-iron by its fracture. Then we called in the chemist, only to find that he did not tell us the whole story. Spurred on by the demands of society for a better and better product, we turned to the microscope and to instruments of which our fathers knew nothing. With them we began to explore our sands, our facings and our metals, only to find undreamed of mysteries challenging our intellect and demanding our best effort for their solution.

This Institute was born because it was realised that it is much better that men in an industry should help each other, rather than fight each other. It was born because men began to see that no matter how much an individual thought he knew about his own business, there was always someone who could tell him something which would be of advantage to him. It was born because the industry realised that with the tremendous problems before it, solutions could only be obtained by marshalling the best ability and the best brains for the attack. For after everything else has been said, the real object of this organisation is simply to discover the truth.

As is well known, the casting industry is an old one, dating back to prehistoric times. From these beginnings, castings of grey iron, of so-called semi-steel, chilled iron, malleable iron, carbon and alloy cast steels, and a multitude of brasses and bronzes, have been developed to a high state of perfection. In recent years these have been followed by the newer nickel-copper alloys, such as Monel metal, tin-nickel-copper alloys for greater hardness, silicon-copper, and steels of nickel-chromium, chrome-tungsten, chrome-molybdenum, and various others of the more highly corrosion-resistant type.

While the casting industry has developed commercially to gigantic size, castings of a large variety of shapes and sizes being available for various purposes, other products—forgings, stampings and welded products—some of them made by methods scarcely known even ten years ago—have come in to meet the multitudinous needs of present-day industry.

The revolution has not been confined to this, but has had a much broader scope, involving also, apparently to a much greater extent than before, the attitude of people toward life, toward fulfilment of desires, personal or otherwise, and especially in the willingness to pay liberally for the fulfilment of these desires. The increased leisure resulting from the use of machinery which has minimised the need for manual labour has increased the means for employing leisure, such as the motor car, the "talkies," the wireless, etc.

High-Temperature Demands

A new factor, or rather one that has become magnified, has hastened developments which create uncertainty as to the ultimate status of some of these products—castings, forgings, welded assemblies, etc. This factor is the higher temperature desired for the chemical and mechanical processes which to-day are so much more efficiently making steam and electrical power, products for our motor cars, tractors and other machines, coke for smelting of materials, etc.

Undoubtedly, the higher temperatures and pressures have overawed designing and operating engineers, who, in a very proper effort to ensure safety in operation, have demanded perfection in castings. The recent development of the X-ray method of testing, along with the "marvellous" development of welding "advertising," have temporarily put iron and steel castings at a disadvantage.

It would appear that, if an equally vigorous campaign had been pursued by the producers of high-class castings, the advocates of forgings, of rolled products and of welded structures, would not have enjoyed all the advantages their publicity methods have gained for them.

Whilst problems due to metal cooling, solidification, shrinkage, grain formation, etc., still exist, the foundry product of to-day has been brought to a very high quality from the standpoint of operating permanence and safety.

The welded product, too, is subject to the working of natural laws, and the welding expert has his troubles, and often his unsatisfactory product. Forgings and rolled products are in much the same category as to the possibilities of flaws and weakness.

Thus it would appear that the castings industry awaits a champion!

It is not the function of this Institute to conduct extensive research; its function is to make available to members the results of the research of others. Research, as we know it to-day, is largely the very careful study of minute problems. It is intensive, whereas the broad divergence in the interests of our members force us to deal with more general questions. It is very expensive; but if we are to be of value to the small units of our industry, our subscriptions must be kept on a nominal plane. We have opportunities to join with other organisations in co-operative investigations for the solution of certain problems, and we can quite properly avail ourselves of every such opportunity to be of benefit to our members, but we should not assume that every research problem in the industry is ours, and that anyone else who assumes to solve one is usurping our prerogative. But one of the glorious things about our great industry is the fact that, generally speaking, those units which have the resources or the ability to discover new facts, or improve old processes, are more than willing to share that knowledge with those not so fortunate, conscious they advance only as the entire industry advances. There is no single problem of the business or economic world which does not have to be met at some time by one or all of our members.

The Scope of the Institute

Should our Institute assume the responsibility of solving all the problems of our industry, which is equivalent to solving all the economic problems of industrial society? Is it humanly possible that any one organisation can accomplish such a task? Will we best serve the interests of our members by "gadding about " all over the place, or by concentrating to secure solutions of particular problems?

There are many lines of endeavour in which the interests of all our classes are fairly identical; there are some in which the interests of competing classes are sharply antagonistic. We must agree that everything which improves the quality of the product of a foundry or a class of foundries by making that product of greater use to the human race, is beneficial in the long run to the entire industry, even though it be temporarily detrimental to the welfare of those members who refuse to change old methods in the light of new knowledge. But we must not engage in any activity which seeks to increase the business, or the interests, or the prosperity of any one of the classes at the expense of any of the rest of them. So far as possible we must serve the interests of all jointly, if we are to retain their interest and their co-operation.

We are, primarily, a technical Institute, engaged in studying and improving the product of our industry by taking some of the " guess " and uncertainty out of foundry operations. We are not a trade association concerned with commercial considerations, with merchandising problems, successful largely as their competitors succeed. To make technical information available to all members is the primary function of this organisation.

Nor is the task to be lightly assumed. The greatest menace to the success of the foundry industry lies within it, and does not come from the outside. The successful casting of metals is an exceedingly complicated art; the difficulties of making sound castings are great; the variables in the process, especially in making jobbing work, are numerous and hard to eliminate. Too often the designer, or the customer, considers the purchase of a casting of any sort as being more or less of a gamble, to be avoided if possible. Many times a sales department has reports that a customer who formerly used iron castings has been influenced by a low price or other considerations, and has purchased from a company who furnished an inferior product, with the result that the customer re-designed his machines and eliminated iron castings. In the long run society will use that product which has best served its purpose. The real job of this Institute is to help the industry to furnish a product that will the better serve society's needs.

Kaleidoscopic Industry

In the foregoing I have no desire to be dogmatic. Problems of business are full of constantly-changing variables. They cannot be solved either by slide rules or formulæ. I have attempted to set down principles which, to my mind, underlie successful progress. As problems arise these principles must be interpreted to meet them, for the problems are often complicated and lie so close to the border-line between what is wise and what is unwise that a satisfactory solution can only be obtained by very careful judgment.

As we review the accomplishments of science and industry during the first part of this century, we can only be gratified to note that the foundry industry is keeping pace with the rapid strides that have been made in the application of the developments in chemisty, in specialisation —resulting in increased efficiency with its accompanying lessening of the strain on labour—and in the elimination of both physical and human waste.

We are living in a machine age, an age that is slowly but surely utilising the resources of this great nation, through the application of improved technique, in a way that is giving society the highest benefit for the least expenditure of both time and money. Science has been applied to all types of industry, resulting in the elimination of blundering and mismanagement.

Twenty-five years ago we would not have had the courage even to imagine the changes that have been wrought in both production and distribution methods.

It was not so very long ago that scientific methods were considered too much in the realm of theory to serve as an aid to industry. Yet to-day science is the chief ally, the very basis of industrial methods. But the technique of science has changed to a degree that parallels the changes in industry.

Instead of individualism in production, we have co-operation. Instead of haphazard trial-and-error methods, we have a sound scientific background. Instead of slow, tedious, hard work, we have machines, developed to an efficiency that the human factor could never attain.

Visualise a few of the results—the telephone, the motor car, the aeroplane, the radio. These comprise but a mere handful, important because of their commonness. The thousands of improvements in factory methods that enable these and hundreds of other specialising elements to be constructed so that they can be placed within the easy grasp of the average man, cannot even be considered here.

As members of the Institute of British Foundrymen, we can accept our share in these marvellous achievements. The foundry industry is keeping pace with the times. Applied science, through the aid of the chemist and the engineer, is keeping our business on a par with all others.

Machinery for Advancement

New methods have been evolved to meet the production requirements placed upon our industry by the development of the automobile and other commodities. Improved alloys, simplified methods, new machinery, concerted effort and many other factors—all have been constantly in the throes of change and development to meet the increasing demands of the times.

These examples merely serve to indicate how we are answering the demands of the day. The successful foundryman is one who has the ability to assimilate present-day knowledge and put it into practice in terms of present-day needs. The detail man is essential to business, but the detail man does not supply the motive power that lies behind the industry.

Applied science is a modern thought. It is still more modern when applied to the foundry industry, for in spite of the progress we have made, we are young in the application of the practices of this machine age. We are having our whole economic plan altered. Those who can meet this situation will build for themselves a business raised upon a foundation that can never crumble.

New Tools Available

The greatest change in the industry has taken place in the foundry department, and the end is hard to foresee, because each new development seems to lead to new opportunities. The mechanical sand-handling and conditioning systems, mould conveyors and casting-cooling conveyors have become fairly established in the modern foundry, and it takes no prophet to foretell that within a very few years even the smaller foundries will find the sand-handling system as much a part of their equipment as the cupola itself.

On the face of it, this idea might seem impractical to those who are using two or three or more grades of moulding sand to suit their variety of castings. In time, competition may force some of these foundries into more specialised lines, but experience shows that one grade of sand may suit a much greater variety of castings than is generally believed possible.

There has been a great improvement in ordinary cast iron over the last five or six years. We have learned to produce iron consistently within very close limits in respect to Brinell hardness, tensile strength and machinability.

The rapid mechanising of foundry operations naturally had a pronounced effect on maintenance organisation. Where maintenance could be handled a few years ago by fitters and millwrights, to-day we require an engineering department and the leadership of trained engineers.

Unlike some other branches of industry, a foundry occupying the front rank has to develop the greater part of its new equipment, at least to the point where it can be turned over to some equipment builder. To accomplish this a thorough knowledge of foundry operations is necessary.

Due to the sand, dust and hot iron that are ever present, the wear on equipment is very heavy. Through strengthening of weak parts and the use of dustproof ball or roller bearings, we are constantly improving our conditions. Much, however, remains to be accomplished before we get our equipment as free from breakdowns and interruptions as some other industries.

Mechanisation

May I now for a moment or two deal with the question of mechanisation? We often hear people deploring the loss of craftsmanship, a loss which is supposed to be the result of mass production. Another statement that is frequently made is that the machine-made article, which is rapidly displacing the hand-made one, has been the means of lowering the quality of workmanship. May I take these two points and review them from certain angles to show how perfectly futile both views are.

In the first place, I want to repudiate the idea that the machine-made article is inferior to those made by hand. This idea is so entirely opposed to facts that wherever it persists, then you may be sure there is an unbalanced mentality. Since the introduction of the machine there has been a steady and continual improvement in the standard of output of every commodity that helps to make life brighter. Running parallel with this improved output we have had at all times an improved standard of quality; a quality in the majority of cases which can only be achieved by the use of the machine. We have the well-known fact that one of the earliest difficulties of Watt in bringing out his steam engine was the failure of his attempts to bore the cylinders, and it was not until Wilkinson invented his boring machine that Watt was successful with his steam engine. Since that day this condition has been multiplied innumerable times. Anyone who knows the foundryman's business knows that our present position could never have been achieved at all without the use of the machine, and in many cases where we could have got something of the same kind, the cost would have been so extraordinarily high that we should never have progressed, simply because the market would not have been there for our goods.

It is a mistake also to think that mechanisation tends towards the elimination of either the artist or the craftsman. For instance, most of you have seen recent reproductions of the work of artists who have long been dead. These reproductions may take the form of etchings, or of coloured pictures done by the three- or five-colour process. Now it is a well-known fact that many of these reproductions are more nearly true to scale and to colouring than were the originals. The men who are doing the preliminary work for these processes are artists in the true sense, exactly as were those who made the original drawing or painting, but the mechanisation of production has made it possible to place copies of these works into the homes of the masses instead of confining the work to either the homes of the rich or to picture galleries.

In what way has mechanical process done anything to reduce the importance of the artist? Looked at from the point of view of payment for work done, there never has been a time when the artistic sense of conception and execution gave greater monetary returns to the artist than is the case to-day. If, then, the work of the artist is made available for more people to enjoy, and if, further, the artist is better paid than he used to be, how can it be said that mechanisation is gradually eliminating both the artist and the craftsman? It is not true, gentlemen, and the statements, when they are made, arise from lack of balance on the part of those who make such statements.

On craftsmanship alone, and confining it to our own business, there is no foundation in the statement that there is lack of craftsmanship.

There is, however, a displacement of craftsmanship owing to the rearrangements in the methods of doing the work. We can now, when the work is of a repetition character, eliminate the skill of the craftsman in the foundry, but in such cases we need his help in the tool room. I want everyone to realise this fact, that somewhere in our organisation we ought to be building up craftsmen all the time. We are. We take an unskilled man; we put him on a moulding machine, if we are wise we train him along certain lines. Eventually that man, who was once a labourer, will become a skilled moulder. Skilled probably along a narrow line, but with the skill that is higher than could possibly exist if his training were made more general.

To-day is the age of the specialist, and while there are some people who are foolish enough to think that specialisation in the foundry deadens the mentality, such people are back numbers, and if they would only examine their own mentality, they would be rather surprised at their lack of balance.

Recruitment Problems

It is the habit of foundrymen, as well as those engaged in other industries, when a number of them get together, to discuss their troubles at length. They usually begin by saying that the industry is going to seed in general, and then take up their problems in detail. They recount various troubles—arising from the low prices which prevail in the industry, the intense competition amongst themselves and the complications brought on by the advance of competing processes—they bring up the impossibility of getting good moulders, and deplore the passing of foundry craftsmanship.

Even those foundrymen who have established their plants on a production basis, with a large proportion of machine work, continue to be handicapped by the lack of men to supervise and lay out the work.

It is commonly held that modern young men are weak, lazy and effeminate, that all of them want to work in banks or insurance offices, or do something which permits them to sit at a desk and wear a white collar. It is pointed out that all are afraid to soil their hands, and that they think about nothing except amusement and the lighter forms of enjoyment.

The so-called old-style young man—stout, bright, alert—is said to have passed out of the picture. It would appear that no young man can be induced to enter the foundry trade under any circumstances whatsoever.

Much of this kind of discussion is based on facts. It is true that very few boys are going into the foundry industry at the present time. It is unfortunate, of course, that young men do not rush into foundries; but is it not equally true that foundrymen as a rule make no effort to attract young men?

I have seldom heard any of them make definite plans for solving the problem. They assume that the fault lies entirely with the young men, and few of them have conceived the idea that possibly foundry management is partly at fault. And yet, no industry and no organisation can remain secure which does not constantly attract young blood to itself.

A strong human element must always be fundamental to every industry. We may build the finest foundries in the world, equipped with the newest and best furnaces and cupolas, the best of moulding machines, the most efficient sand-handling equipment; but unless this wonderful plant is operated by first-class foundrymen it will not succeed.

It is true that self-trained men have successfully operated old-fashioned foundries in days gone by, but the very complexity of our modern equipment, and the multiplicity of our requirements, call for a training unknown in former times. While our fine modern equipment is of great help to all of us in the foundry industry, it will not do away with the necessity for careful and intelligent training. Man is still superior to the machine—man still controls the machine; the machine does not control the man.

Modern engineering, with its sand-handling equipment, is constantly lightening the load, and modern thought is constantly improving conditions of labour. We have an industry full of problems and full of interest, which recognised and properly interpreted to youth, will do much to counteract this feeling.

Variables to be Reconciled

Where can you find an industry whose roots go back so far into the foundation of society as the casting of metal? What other industry presents so many problems to the inquiring mind —problems of mechanics, problems of physics, problems of chemistry and metallurgy, problems of gases, problems of fluids, and problems of solids, and of the forming of one from the other?

What other industry retains so much of individualism? The production of a jobbing casting, at least, is an art instead of a stereotyped process, more like the painting of a picture or the chiseling of a statue than the dull mechanical process existing in some trades. In what other industry do we so easily feel the pleasure of creating that which is new, that which because of our efforts exists now, but has never existed before.

If we who live by the industry have never appreciated its romantic side, why should we feel surprised that youth, which sees it superficially, should miss it? Why should we blame the young man for our failure to point out to him the worth-while parts of the industry in which we are engaged?

It is no doubt true that modern methods of manufacturing, including the foundry, have substituted machines for hand skill in many directions. At the same time, it is true that in every industry and in every foundry, high-grade men are required to supervise, direct and lead the work, and the need for such high-grade men is even greater now than it was in the old-style foundry.

It is also true that in our jobbing foundries there will always be quantities of work in which the machine can be used only to lighten physical labour, and where the skill of the trained artisan must always be relied upon to produce satisfactory results.

Dearth of Young Foundrymen

Where are our young foundrymen? There are very few. The best foundrymen are of middle age or older, and yet no industry can continue unless it builds up a generation of young men.

We must bring large numbers of young men into this industry, we must show them its attractive features, we must train them into the knowledge and skill which we possess—or we shall find ourselves falling behind in our ability to satisfy the increasing demands necessary to meet society's onward progress.

What have we done to attract young men? As an organised industry, we have done little or nothing. I doubt whether we have yet appreciated the necessity of doing anything, nor have we recognised this as a definite obligation on ourselves or our industry. Moulders have come to us, in the past, as easily as the air we breathe. We have not realised that this condition might not always continue.

I gladly acknowledge that there are some notable exceptions, some individual foundries and local associations which have embarked upon training programmes that are a distinct credit to them. As an industry we have not approached the realisation that the public judges the value of a calling by the time and effort it takes to master it.

I do not believe that the youth of to-day is essentially different from the youth of any other day. He realises that he must face different conditions, and he naturally expects to face them in a different manner, but there are still large numbers who realise that they were not born to be kings—who are quite willing to become good craftsmen if we but approach them in the proper manner and show them an opportunity in accordance with modern conditions.

I am not only urging the training which will qualify boys for positions as foundry executives, but also that which will produce good mechanics, thoroughly-skilled moulders, or coremakers, or patternmakers, or cupola operators. To accomplish this, we must recognise the need, we must believe in the work and the value of the results we are going to attain, and we must really want to do it and not feel that we have been pushed into it, or we shall not be able to interest the boys and make them enthusiastic about it.

To be successful in this work, a company must organise on the same principle that it organises to buy its raw materials or develop its cost figures or to handle metallurgical research problems. It must set as its goal the training of certain young men, the making in this particular department, not of moulds, but of moulders.

Just how the details should be accomplished, I leave to those who have devoted more time to the study of this subject that I have been able to do. But I am quite sure that, in general, the time has come when we must devote thought to this question, and that when we tackle it with the energy and the intelligence of which the industry is capable, we shall not have to ask "Where are the young craftsmen?" in vain.

However, I think we all appreciate that a youth in his teens, under proper guidance, would naturally develop into a better workman. We believe this, and are backing up this belief. We have trained a number of boys during the past few years, we have a number now in training, and we also employ a number who are out of their "time."

We sometimes hear men of intelligence ask the question "Why train apprentices to-day in the foundry when machine methods destroy the opportunity to absorb the skilled men?" My answer is that if we ever needed men of mechanical ability and practical training in the foundry, we need them now.

Competition was never keener than at the present time. New processes are making inroads into the foundry industry and call for keen, intelligent men to raise the standards of the foundry in every particular, and place it in its proper place in the manufacturing group.

After all, in our basic industry, the manufacturing cycle usually begins with castings. If we can, by using intelligent methods, produce something superior to that which was in times past the source of so much trouble and economic loss, we shall at least have made our contribution to the progress of the age.

Some of us, after an active career in many different directions, are in a position to advise and guide those who are starting out with their future still to make, and are willing to help all we can, by personal advice, anyone who is interested in his own future. When, in retrospect, I think of the many changes that the average young man has to make before he finds his level and becomes satisfied that he has entered upon an activity which warrants the application of the best that is in him, I often wonder whether the present younger generation is willing to recognise, at least in a general way, the value of the advice that the older generation is capable of giving.

The Work of the Institute

I want to say just a word on the character of our Institute, for organisations of this kind do have character, irrespective of presidents who come and go, like the changing seasons. I have been a member of a good many organisations, but never one the members of which were of a higher character or so conscientiously devoting their time and the best of their ability to the interests of the organisation. There is a close association between foundrymen and the representatives of the equipment manufacturers, but I have never heard one of the latter advocating a policy which might be of disadvantage to the foundry industry. Their action has indicated that they feel that their own interests can best be advanced by that which best advances yours.

I have never known an organisation in which I felt that those who represent the members in executing their work were functioning with higher ideals or with a more earnest desire faithfully to discharge the trust placed in them.

In conducting the affairs of your Institute there is a vast amount of detail to be accomplished. Each President realises fully the correctness of this statement. I cannot refrain from expressing my sincere admiration of the work of your Secretary, Mr. Makemson, and his very able staff. This may seem like a formal courtesy, but I am only voicing a sincere conviction resulting from some years' close contact and observation of this work. I have seen so many instances of administrative ability, sound business judgment and straightforward dealing coupled with fine diplomacy that I would be remiss if I did not direct your attention to it.

I wish also to take this opportunity of expressing my appreciation of the interests and co-operation of all the Past-Presidents who have so graciously given of their time to help whenever called upon, and who are so well qualified by their broad business experience and by their intimate knowledge of the affairs of this Institute to give advice and counsel. We are indeed fortunate to have so many Past-Presidents who continue to take an active interest. I shall deem it a personal obligation to continue an active interest and helpful participation in the affairs of the Institute after my official contact ceases and I sincerely trust that such humble effort as I may be able to make will be productive of at least a slight increment of progress and growth.

The Institute of British Foundrymen has constantly aided the industry in developing new methods of meeting new conditions. It has enabled knowledge to be disseminated for those who would take it. It has been the clearing house for a grouping of ideas to which all might contribute and from which all might benefit.

Our task is a never-ending one. Although marvellous changes have been wrought in production, although unimagined results are being attained, although the technique of distribution has reached a peak never before realised, actually, only a start has been made along the road of industrial progress. Through careful and keen observation, through scientific experiment and the subsequent gathering of data, through the application to our industry of the improvements thus discovered, and above all through intelligent co-operation, we may hope to achieve in times yet to come a large measure of the success that should be ours.

Civilisation will continue to progress. Science will be for ever discovering new processes, and production and distribution techniques must continue to evolve.

To us falls the burden of seeing that the foundry industry, functioning as it now is upon a solid economic basis, will continue to meet the demands of the times.

It is a wonderful thing to be connected with industry in this great industrial world, where each man is honestly striving to make money for himself and those dependent upon him, conscious, however, that the only way in which he can attain this goal is by rendering to society a service by which he gives it more than he gets back. It is a wonderful thing to be connected with an industry which is so old that we cannot find where it began, and yet which is so young, so inexperienced, so unknown that it challenges the best of our executive ability, the best of our engineering skill, the best of our scientific research. It is a significant thing to be connected with a great organisation of this kind, where men are meeting together, each one to help himself by helping his competitor, where men are willing to devote their time, their work and their money in an effort to make of their industry an instrument which shall be of greater worth to the world and produce more happiness for the children of God.

On the motion of Mr. C. E. Williams (Past-President), a hearty vote of thanks was accorded the President.

The Foundry Course at Sheffield

The President, dealing with the establishment of the Degree Course at Sheffield, said that the Institute had always taken a prominent part in promoting technical education for the foundryman, and suggestions had been made frequently as to the desirability of establishing a Degree Course in the science and technique of foundry practice. The Sub-Committee of the Institute, which had been at work for a considerable period, had collected promises of sufficient financial support to enable such a course to be inaugurated at the University of Sheffield. That course was an established fact, and would commence next autumn.

It consisted of a four-years full-time course leading to the Degree of Bachelor of Metallurgy (Founding). The industry was indebted to Prof. J. H. Andrew (Prof. of Metallurgy, Sheffield University), who was responsible for its inauguration and for the preparation of the syllabuses, copies of which would be available for distribution at the Conference, and he would be in charge of the course.

Increasing numbers of graduates, continued the President, were being absorbed into the industry, but up to the present they had usually taken their degrees in Metallurgy or Engineering. In future they would be able to take a degree in Founding.

It should be understood that this course was of a national character, and was open to students from all parts of the country. It was hoped that members of the Institute would make known the inauguration of the course, endeavour to attract suitable students to it and to increase the financial support which had already been promised.

Greetings to Original Members

Of the 16 original members of the Institute who are still living, 7 were present at the meeting, and the President extended to them the congratulations of the Conference. They were Mr. C. E. Williams, of Cardiff (Past-President);

Mr. F. J. Cook, of Birmingham (Past-President); Mr. J. T. Goodwin, of Chesterfield (Past-President); Mr. J. J. McLelland, of Bilston; Mr. T. W. Markland, of Bolton; Mr. K. M. Burder, of Loughborough; and Mr. W. H. Meadowcroft, of Burnley.

The remaining original members, to whom the meeting sent messages of congratulation and good wishes, in accordance with the resolution adopted at the Annual General Meeting, were:—Mr. F. W. Finch, of Gloucester (the Institute's first Secretary); Provost James Galt, of Paisley; Mr. R. W. Kenyon, of Accrington; Dr. Percy Longmuir, of Sheffield; Mr. D. Aston, of London; Mr. Jas. Chadwick, of Bolton; Mr. James Smith, of South Shields; Mr. W. H. Sherburn, of Warrington; and Mr. W. R. Wilson, of Liverpool.

The meeting then proceeded with the reading and discussion of the following Papers:—

"Report of the Work of the Cast Iron Sub-Committee of the Technical Committee," introduced by Mr. P. A. Russell, Convener.

"Contribution to the Study of Graphite Formation and Structure in Cast Iron, and Its Influence upon the Properties of the Cast Metal," by Dr. Ing. Heinrich Nipper.—(German Exchange Paper.)

The Conference adjourned at 12 noon, and members and ladies lunched together at the Midland Hotel.

Works Visits

During the afternoon parties of members visited the following works:—

Messrs. Joseph Stubbs, Limited, Openshaw.

The Metropolitan-Vickers Electrical Company, Limited, Trafford Park.

The Lancashire Steel Corporation, Limited, Irlam.

Parties of ladies visited the Handkerchief Works of Messrs. Tootal, Broadhurst, Lee & Company, Limited, and Messrs. Richard Haworth's Mills, Salford.

ANNUAL BANQUET AND DANCE

The Institute's annual banquet and dance was held on the evening of Wednesday, June 6, at the Midland Hotel. The President and Mrs. Stubbs received the members and guests, who included the Rt. Hon. the Lord Mayor of Manchester (Alderman Joseph Binns, M.B.E.) and the Lady Mayoress, the Rt. Hon. the Lord Stanley of Alderley, Mr. J. S. Peck (Metropolitan-Vickers Company, Limited), Mr. Sterry B. Freeman, C.B.E., M.Eng. (chairman, North-Western Branch, Institution of Mechanical Engineers), Mrs. M. E. Stubbs (chairman of Messrs. Joseph Stubbs, Limited), Mr. W. N. Cook, B.Sc. (President of the Lancashire Branch), Mr. A. Phillips (chairman of the Conference Committee), Mr. J. E. Cooke (Hon. Conference Secretary), Mr. T. Makemson (General Secretary of the Institute), Mr. C. E. Williams (Immediate Past-President) and Mrs. Williams, Mr. F. J. Cook (Past-President), Mr. J. Cameron (Past-President) and Mrs. Cameron, Mr. J. T. Goodwin (Past-President) and Mrs. Goodwin, Mr. V. C. Faulkner (Past-President) and Mrs. Faulkner, Mr. V. Stobie (Past-President) and Mrs. Stobie, Mr. J. E. Hurst (Senior Vice-President) and Mrs. Hurst, Mr. H. Winterton (Junior Vice-President) and Mrs. Winterton. A number of representatives of allied bodies were also the guests of the Institute.

The Toasts

The loyal toast having been honoured,

The Rt. Hon. the Lord Stanley of Alderley, proposing " The City and Trade of Manchester," said it would be invidious to contend that the toast was the most important to be honoured that evening, and he would not make the contention, because by so doing he would invoke serious rebuffs from subsequent speakers; but if it were not the most important it was at least a very important toast. When a small boy he had been taught that Manchester was the second greatest city in the British Isles. He did not know whether that was still true as regards size, but he had no hesitation in saying that, for a multitude of reasons, Manchester was not the second greatest city in the British Isles, but the greatest. Two of those reasons were implied in the very name of the toast; Manchester was the greatest from the point of view of a "city," a word which implied civic pride, and in many ways it was the greatest of our trading centres. It was the fourth largest port in the Kingdom—and its seaborne trade was but a tithe of the whole of its trade. If the figures of the total trade of Manchester, both seaborne and internal, were available, he believed it would be found that Manchester was the greatest trading city in the country; and that, he would like to believe, meant that it was the greatest trading city in the world.

Trade and Tariffs

But, alas, the trade of Manchester is not now what it was. There were many reasons and factors operating, some of them being under our control. The city of Manchester was perhaps most remarkable for its enterprise in having built at the end of the last century the Manchester Ship Canal, and its cost, he believed, was upwards of twenty million pounds sterling. Its object was to enable us to render goods, and all the necessities of life, as cheap at the point of consumption as at the point of production, or almost as cheap, to bring wealth (by which he meant goods) from the four corners of the world to Manchester as cheaply as possible. For many years the Manchester Ship Canal had fulfilled that object in the most admirable fashion. But, alas, during the last few years trade in this country, as, indeed, all over the world, had been slipping from us, with the result that the sound common sense, that rock bottom of commercial integrity which had existed in Manchester, began to seek anew for different gods to worship, and we had the melancholy spectacle of goods being made cheap at the point of production—which in this case was Manchester, the centre of one of the largest industrial areas of this industrial nation—and then rendered more expensive by artificial means. We had set up around our shores an army of officials, of red tape, men who, for aught he knew, had bayonets, swords, revolvers and guns—the Inspectors of His Majesty's Customs—and on everything that came through the Manchester Ship Canal, and which the citizens of Manchester wished to make cheap, we raised artificial barriers to make them again more expensive. We had, indeed, overcome the great obstacles of nature. We had built railways and great roads, we had tunnelled through mountains, we had improved our fuel and had made more efficient ships, with the end of cheapening goods and rendering wealth more available to our people; and at the same time we placed man-made artificial barriers in the way. That was why the trade of Manchester was not so healthy as he wished to see it.

The Foundry Industry and Cotton

Manchester was the centre of the cotton industry; but it was also far more than that. Manchester and the country around it was, to use a vulgar phrase, the guts of the whole works, and the foundrymen and engineers were representative of that guts. How could we spin cotton without looms and other machinery, and how could we create machinery without the foundryman to cast it? The fact that the first meeting of the Institute was held in Manchester, in 1904, indicated that Manchester then, as now, was in the forefront of industrial development in this country. Manchester had realised what a future lay before her in the foundry business. It was true to say that, without the foundrymen, industry would founder; indeed, it could be said that the foundrymen's business was the foundation of all industry.

In short, one found in Manchester an active-minded body of citizens, thinking constantly of the benefit of the greatest number of the inhabitants. They were well to the fore in all modern developments. Constantly he had cause to thank Manchester for its foresight in establishing an admirable airport.

Finally, Lord Stanley coupled with the toast the name of the Lord Mayor, and commented upon the great ability with which he led the progress and the civic pride of the city.

The **Right Hon. the Lord Mayor of Manchester**, responding, first voiced the pleasure it afforded him to welcome the members of the Institute to the City of Manchester, for they represented an industry which rendered considerable service in the city, and it was the industry in which he had first endeavoured to make his fortune. Unfortunately, he had become a Lord Mayor instead, and the disastrous consequences of personal ambition would be appreciated.

As a Manchester-born man, however, he was proud of the achievements of the men of that city. The founder of the atomic theory was John Dalton, who was a teacher at Owen's College and a respected member of the Manchester Literary and Philosophical Society; John Dalton had fixed a basis upon which scientists could calculate to a closer degree than they had ever done before the possibilities of natural resources and the powers that came about by true chemical combination and dissection. Again, Joule had laid down a mechanical law which stood to-day. At the University and Owen's College there was pride in the achievements of the long line of men who had been pioneers—men such as Prof. Lord Rutherford, who was endeavouring to find an even smaller fundamental than the electron.

But he regarded Manchester also from another point of view. He believed, as did Lord Stanley, that Manchester would go forward again, and he was not so despondent about the present situation as were many people. A few of the industries of Manchester were fairly active. The engineering industry had become considerably better than it was six months ago; the textile industry was not slumping terribly at the moment, though it was bad. There were other industries which were doing fairly well, and, given an opportunity, by the removal of some of the restrictions which had been mentioned, he claimed that Manchester would very largely come into its own again during the period of the next three years; at least, he hoped so.

Sheffield University Foundry Course

There were many reasons why he was glad to be present at the Institute's dinner. He recalled that in 1898 he was a student at the College of Technology, where there were classes on iron-founding—the first in Great Britain, he believed. He was proud to be able to say that since then the Institute had come into being, and that similar institutions had been inaugurated in the various sections of the engineering and other industries. The result was that to-day we were becoming the most scientifically organised people in the world. Information obtained in one direction was commonly distributed to those interested for the purpose of raising our industries to a higher level than they had occupied before. The opportunities for using the universities had become more common in all scientific industries, and he was proud that the Institute had decided to set up a Degree Course in Founding at Sheffield, because in his opinion the foundry craft was a high scientific profession. The dangers that had existed at the time he had started in the industry had been largely diminished by reason of scientific investigation, and foundrymen undertook their work with a measure of knowledge which led to the finest results and raised everything to a much higher pitch of perfection than formerly. Manchester, as a large foundry centre, was pleased to welcome the Institute, particularly with Mr. Roy Stubbs as President. He was a member of one of the oldest foundry families in Manchester—and the Lord Mayor recalled that he had known the three brothers for many years. Messrs. Joseph Stubbs, Limited, had always had the respect of the men when negotiating, and when there was any trouble they had fought the matter out and had shaken hands afterwards.

Finally, the Lord Mayor expressed the hope that the Institute would continue to help forward the education of future foundrymen, so that the country would rise to greater skill and greater eminence and maintain its great share in the control of the world's work.

Mr. J. S. Peck, who had accepted at short notice the task of proposing the toast to the Institute, owing to the fact that Mr. E. J. Fox, who had intended to propose it, was prevented by illness, suggested that the gathering might send to Mr. Fox a word of goodwill and an expression of the hope that he would soon be restored to health.

(This suggestion was heartily approved.)

Continuing, Mr. Peck said that as he looked around at the prosperous people seated at the tables he felt that he had made a mistake in his choice of profession! As an engineer, he had always been in close proximity to a foundry. Thus he could appreciate the troubles and difficulties of the foundryman, and he could also appreciate the difficulties, the expense and the delays to which the engineer was put when the foundry delivered defective castings to the machine shop! But so seldom did the machine shop receive castings filled with blowholes that perhaps, when such castings were received, the people in the machine shop were a little more critical than they should be when they remembered the moulders' difficulties.

Competition from Weldings

But a serious competitor to the foundrymen had arisen; those who had visited the Metropolitan-Vickers works that day and had seen the enormous progress that was being made with fabricated steelwork would appreciate it. It was developing at a very rapid rate indeed, and if he owned a foundry he would find a corner in which to put down a fabricating department, a small one to start with, so that he could test out the possibilities of fabrication, and, if it did develop to the extent that appeared probable to-day he would be able to share in the development. He did not consider for a moment, of course, that the foundry had finished, because there would always be a demand for certain types of castings, whatever developments were made in weldings. It had been his experience that no industry so firmly established as was the foundry industry ever succumbed quickly. For example, we had been told that the electric locomotive would soon supersede the steam locomotive; yet the introduction of the electric locomotive had acted merely as an incentive to the designer of the steam locomotive to effect improvements, and he had improved the steam locomotive almost beyond recognition. The steam turbine had to a certain extent superseded other types of prime mover, but the reciprocating engine was still being built in large numbers; and he was told also that more candles were being manufactured to-day than was the case a hundred years ago. Competition tended to increase efficiency. He believed that, whatever the competition might be, a strong and virile organisation such as the Institute of British Foundrymen would rise to meet it, no matter from what part of the world it might arise.

We were entering on a period of better times, and he ended by wishing prosperity to all, and to the Institute in particular. He coupled with the toast the name of the President.

The **President**, who was greeted with prolonged applause when he rose to respond to the toast, first expressed the Institute's thanks to Mr. Peck for having suggested sending a message of goodwill to Mr. Fox; indeed, it was the intention to do so. The President added that he had been looking forward to hearing Mr. Fox say that he came to this function not as an ironfounder but as a manufacturer of pig-iron. He was disappointed, also, that he had not the opportunity to tell Mr. Fox that Messrs. Joseph Stubbs, Limited, had bought pig-iron from his company in 1896 at 47s. a ton, or to try to convince him that if he could offer similar iron to-day at the same price the miserable ironfounder could make some profit, and the Stanton Iron Company would treble its profits within the next twelve months.

One was impressed with the thought that all thoughts for the future were based on helping the industry, and he believed the 31 years of service rendered by the Institute to British foundrymen placed an obligation of membership upon any man who expected to make founding his life work. All were welcome; the members realised that the Institute had a proud record of accomplishment, and if this fact were broadcast many of the thoughtless ones would realise that the Institute was entitled to their support. It seemed that there should be an increased membership in the future, and that the Institute would then accomplish even far more than in the past. All the existing members, by their willingness to give of themselves without stint and by their unselfish devotion to the interests of the Institute and of the industry, had made association with them a very great privilege. His plea was that they should avail themselves fully of the facilities which the Institute had to offer, and help it to grow and become more useful by their participation, interest and effort.

It would be churlish on his part if he did not express very sincere gratitude to the chairman of the company, with which he had the honour to be associated, and also to his co-directors, for their kindness to him, because without their support, both moral and physical, he would not have been able to occupy the proud position of President of the Institute. Therefore, he paid tribute to them, and he also expressed grateful thanks to the members of the staff, because the periodical absences from the business, which his Presidential office would entail, would throw extra work upon them.

Finally, the President voiced his personal thanks and those of the Institute to Mr. Peck for the kind manner in which he had proposed the toast.

The Visitors

Mr. W. N. Cook, B.Sc. (President of the Lancashire Branch) proposed a toast to "The Guests," and spoke of his good fortune in occupying the presidential chair of the Branch at this time, for it carried with it the privilege of proposing the toast. A conference such as this, he continued, would be impossible without the co-operation of many people, not the least of whom were the Lord Mayor and other leading citizens of the city and the executives of the principal works in the district. It was a pleasure to entertain these gentlemen and their ladies and to convey to them in person the Institute's deepest thanks for their valuable co-operation. The Institute had been honoured both in the morning and in the evening by the presence of the Lord Mayor, in spite of his multitudinous duties, and it was an added pleasure that the Lady Mayoress was able to accompany him. The Lord Mayor understood the industry thoroughly, and perhaps one might take the opportunity to point out that the Institute would be delighted indeed to enrol him as a member if at any time he should decide to return to the industry.

Mr. Cook also paid a tribute to Lord Stanley, whose distinguished father and illustrious grandfather were honoured not only in the Manchester district, with which they were so intimately associated, but throughout the country, for their services had earned them the respect of the country as a whole. Everyone was glad that Lord Stanley was following so worthily in their footsteps, and it was fitting that he should have proposed the toast to the city, for he had already shown himself willing to take an active part in the governing thereof, and it was hoped that his services, so willingly offered, would be willingly accepted.

Again, the Institute was deeply indebted to Mr. Peck, who had at short notice accepted the task of proposing a toast. He was a noted electrical engineer, and a director of the branch of the Metropolitan-Vickers Electrical Company, Limited, at which some of the members had been entertained so magnificently. Another honoured guest was Mr. Sterry B. Freeman, representing the Institution of Mechanical Engineers, one of the largest and most important of all the engineering and scientific societies. He had achieved no mean fame as a marine engineer. It was also a pleasure to welcome the representatives of various firms which had co-operated to make the conference so great a success, and they included Mrs. M. E. Stubbs, the chairman of Messrs. Joseph Stubbs, Limited; and the representatives of kindred associations and societies.

The name of Mr. Freeman was coupled with the toast.

Mr. Sterry B. Freeman, C.B.E., M.Eng., M.I.Mech.E. (Chairman, North-Western Branch, Institution of Mechanical Engineers), responding to the toast, said he was speaking, for the first time in his life, to a "mixed constituency." Speaking of the Institute, he commented on the fact that it was remarkably well run, and said that whereas things which were left to run themselves ran down-hill, this body was going up-hill, under the care of its officials. Its guests would carry away happy recollections of the delightful manner in which they had been entertained.

It was said that the raw material of the foundrymen was liquid iron, but it was obvious that another raw material they dealt in was brains; and, as the ladies were present, he would like to add that another raw material was sense. We had seen a good deal of brains, sometimes rather over-developed, among the intelligentsia, the people having all brains and no sense; inasmuch as the ladies were present on this occasion, one felt there was a balance which was sometimes lacking.

This concluded the speeches, and the remainder of the evening was devoted to dancing, which continued until a late hour.

Thursday, June 7

The Conference was resumed at 9.15 a.m. and the following Papers were read and discussed:—

Session A, under the chairmanship of the President.

Resumed discussion on Dr. Nipper's Paper.

"Oven-Drying of Cores and Moulds," by E. G. Fiegehen.

"Recent Developments in British Synthetic Moulding Sands," by J. J. Sheehan.

"The Use of High-Duty Cast Iron in the Manufacture of Textile Machinery," by M. Roeder.—(French Exchange Paper.)

Session B, under the chairmanship of the Senior Vice-President, Mr. J. E. Hurst.

"Studies on Cast Red Brass for the Establishment of a Basic Classification of Non-Ferrous Ingot Metals for Specification Purposes," by C. M. Saeger.—(American Exchange Paper.)

"Studies in Cast Bronzes," by F. W. Rowe.

The Conference adjourned at 12 noon, members lunching together at the Midland Hotel.

During the afternoon, parties of members visited the following works:—

Messrs. Tweedales & Smalley, Limited, Castleton.

Messrs. Craven Bros., Limited, Reddish.

Messrs. Leyland Motors, Limited, Leyland.

The ladies took part in a whole-day excursion to Southport.

SOCIAL ACTIVITIES

On Thursday evening, June 7, a dance was held at the Grand Hotel, at which over 200 members and ladies were present. At intervals, Mr. Graham Adams, the Manchester entertainer, performed amusing conjuring tricks, and gave a wonderful memory exhibition.

During an interval, the President, Mr. Roy Stubbs, took the opportunity of acknowledging the services which had been rendered in connection with the organisation of the Conference. He said that, in forming a Conference Executive Committee, it was very important to have the right man as chairman, and they had been fortunate in that Mr. A. Phillips had served in this capacity. Splendid service had been given by other members of the Committee, Messrs. W. N. Cook and R. A. Miles, and they were particularly indebted to Mr. J. S. G. Primrose, who had prepared the excellent souvenir booklet.

Work of the Ladies' Committee

The Ladies' Committee had worked assiduously, and had had complete charge of the ladies' programme. Furthermore, they had made a very graceful gesture in presenting the badge for the use of the wife of the President. Considerable assistance had been rendered by the general secretary and his staff, and they were also indebted to Mr. Ben Haigh, who had devoted a portion of his holidays to rendering secretarial assistance. He also felt that he must pay tribute to the devoted work of his wife, Mrs. Stubbs had been an admirable chairman of the Ladies' Committee, and he, personally, owed very much to the encouragement and support which she had given to him during the period of preparation of the Conference.

Presentation to Mr. and Mrs. Cooke

Finally, it was with the greatest pleasure that he extended the thanks of everyone present, to Mr. J. E. Cooke, the Conference secretary, Mrs. Cooke and Miss Joyce Cooke. Mr. Cooke, his wife and daughter, had carried out the secretarial work, much of which was unseen. They had done it with praiseworthy devotion, and it had been carried out exceedingly efficiently. No one could express the Institute's indebtedness to them for the valuable part they played in the organisation of the Conference. On behalf of the Conference Committee, the President then presented a clock to Mr. and Mrs. Cooke as a slight recognition of the appreciation that was felt for their services, and as a memento of the Conference.

Mr. J. E. Cooke, who was received with loud applause, thanked Mr. Stubbs for his very kind remarks regarding the work of himself, wife and daughter, and thanked the Conference Committee for the very handsome memento. Such work as they had been able to do for the Conference had been a real pleasure, and the Conference would always be a very happy memory.

Mr. R. A. Miles proposed a vote of thanks to Mrs. Stubbs for the work which she had done as chairman of the Ladies' Committee, and to all connected with the organisation of the Conference. Mrs. Hogg seconded the vote of thanks, and remarked upon the interest Mrs. Stubbs had always shown in the work of the Lancashire Branch, and also of the Burnley Section of the Branch.

In responding to the vote of thanks, Mrs. Stubbs paid a special tribute to the assistance and co-operation that she had received from Mrs. J. E. Cooke, secretary of the Ladies' Committee.

Whole-Day Excursion to Llangollen

Friday, June 8, was devoted to a whole-day excursion. The party left Manchester by motor-coach, and travelled by way of Northwich, Tarporley and Whitchurch, to Llangollen in North Wales, luncheon being served at the Hand Hotel.

After luncheon, the party made their way to the boat landings on the canal, and proceeded to the source of the canal at Berwyn, a distance of about two miles, in horse-drawn barges. The canal at Llangollen is certainly an artificial waterway, but bears no resemblance to the type of waterway that one usually visualises as a canal. It is cut out of the hillside, is lined with trees, and commands most entrancing views of the Valley of the Dee. After leaving the barges, a short walk brought the party to an artificial waterfall, known as the Horse Shoe Falls, which is situated in one of the most beautiful parts of the Dee Valley. The coach journey was resumed at this point, and gradually climbed up the Horse Shoe Pass, the summit of which is about 1,100 ft. above sea level, then commenced the long gradual descent over the moors to the city of Chester. On arrival at Chester, tea was served at Bolland's Cafe.

Mr. C. E. Williams, Ex-President, said that, as the immediate Past-President of the Institute, he probably had a clearer recollection than the other Past-Presidents of the work involved in the preparation of a large conference, and on behalf of the visitors he wished to tender to the Conference Committee and to the Lancashire Branch the sincere thanks for all they had done in organising the Conference, and hearty congratulations upon the success of their work.

The Lancashire Branch as a whole, and their ladies, had co-operated in an admirable manner. He felt, however, that special thanks were due to the President, Mr. Roy Stubbs, to the President of the Lancashire Branch, Mr. W. N. Cook, to the secretary of the Lancashire Branch, Mr. J. E. Cooke, and to his wife and daughter. He also acknowledged the valuable work which had been done by Mr. Makemson, the General Secretary, and by Miss Crook and Miss Walmsley of the general office.

The vote of thanks was carried enthusiastically with loud applause, and Mr. W. N. Cook responded on behalf of the Lancashire Branch.

After tea a short time was spent in exploring the ancient city of Chester, and the party then returned to Manchester.

PAPERS PRESENTED AT THE MANCHESTER CONFERENCE

A REPORT OF THE WORK OF THE CAST IRON SUB-COMMITTEE OF THE TECHNICAL COMMITTEE

The Cast Iron Sub-Committee of the Technical Committee is the only sub-committee that has had any comparative predecessor in the Institute, for it followed the Test-Bar Committee, which had so ably drawn up the B.S.I. Specification 321/28 for grey-iron castings involving the use of round test-bars, varying in diameter with the section of the casting represented, and had also investigated and reported upon the Fremont Test.

On the formation of the Technical Committee, the first natural action was to take up the question of specifications and tests. During its first year of activity this sub-committee devoted its attention mainly to the collection and co-relation of existing specifications. The collection of specifications proved a difficult matter, but from those that were collected it was evident that the adoption of the then comparatively new B.S.I. 321/28 specification was far from general. Several specifying authorities were persuaded either to change their specification to conform with the B.S.I. 321/28 or to sanction this as an alternative to their own specification. Since then the question of specifications has not received much attention from the sub-committee, but this subject will be reverted to at the end of this Report.

During its early days the sub-committee drew up a list of the published physical properties of cast iron, including specific gravity, specific heat, thermal conductivity, coefficient of expansion and electrical conductivity. In June, 1932, this report was made available to members.*

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* Available to Members on application to the General Secretary

On completion of the first year's work the sub-committee was enlarged and proceeded to ask itself in what directions it might prove of most value to the grey-iron industry. It was decided to pursue investigations on the following four subjects:—

(1) To investigate the theory that had been expressed in various quarters that the properties of cast iron in relation to strength and soundness were at their worst when the phosphorus content was approximately 0.4 to 0.6 per cent., or, in other words, a "dangerous range" existed at this composition.

This subject opened up the very general one of porosity and strength of cast iron in relation to its constituents, and this has occupied most of the attention of the sub-committee, thus forming the major part of the report.

(2) To compile a series of photomicrographs representative of various grades of cast iron which might be used as a reference standard by metallurgists throughout the Industry.

The first part of this work has been completed in collaboration with the British Cast Iron Research Association, and the "Typical Microstructures of Cast Iron, Series I," was issued to members of the Institute in December, 1933.* Prior to the publication of this booklet, a great deal of discussion took place in the Technical Committee as to the desirability, or otherwise, of issuing details of the analyses and physical properties of the specimens illustrated. The committee decided that it would be very misleading to state any particular composition or strength for any one structure, as the structure is also dependent upon the history of the sample with reference to original materials, melting methods, section of casting, etc.

(3) To attempt to evolve rules for the contraction of cast iron according to composition, section and pouring temperature.

It was found that there was great difficulty in accurately measuring slight differences in contraction and, with the exception of work on long

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* Available to Members on application to the General Secretary.

bars referred to in the body of this report, this subject could not be carried any further at present.

(4) To examine existing methods of wear testing with a view to recommending a standard form of test.

The sub-committee have given constant thought to this problem, the principal obstacle to its solution being the lack of an exact definition of wear, which word covers a multitude of phenomena differing in essential details.

A preliminary examination of existing methods revealed that so many factors were involved, and that conditions of wear were so varied, that a standard test was not desirable or practicable at the present time. The data collected for this examination were published in the form of a Paper.[1]

The sub-committee feels that the difficulty of imitating practical conditions in laboratory tests, and the length of time necessary to obtain results, make the problem of wear testing more difficult than a first consideration would seem to indicate. It has been suggested that a detailed consideration of the stress conditions between wearing faces will be necessary before much progress can be made in explaining the varying results which are obtained, and that attention will have to be paid to the definition of wear.

(5) Recently an investigation has been started on the subject of carbon pick-up in the cupola. This is still in its preliminary stages, but sufficient data has already been produced to open up a very useful line of work. Details of the experiments so far carried out are given in this report.

Porosity and Strength of Cast Iron—Preliminary Work

A preliminary examination of the question as to the existence of a "dangerous range" of phosphorus failed to reveal any published expression of opinion on the subject. The works of Wüst,[2] Mackenzie[3] and Hamasumi[4] all reveal that the strength of cast iron is maintained up to 0.3 per cent. P, after which there is a gradual falling-off of strength. Bolton,[5] in his summary of the effect of phosphorus on cast iron, does not give any indication of a dangerous range. Molineux,[6] when discussing cast iron for cylinders, stated that he has had satisfactory results in cylinders with chilled bores with irons of the following composition:—T.C., about 3.2; Si, 1.4 to 2.0; Mn, 0.5; S, 0.1 max.; and P, 0.4 to 0.5 per cent. In the discussion on this Paper it was agreed that P 0.4 to 0.5 per cent. had been successfully used, but that the normal Continental practice was to use 1.2 per cent. P and American practice to use 0.2 per cent. P. This latter statement is confirmed by Bolton.[5]

F. J. Cook, however, asked by the sub-committee for his views, gave some examples of faulty castings that had been cured by raising the phosphorus from 0.5 per cent. up to 0.7 or 1.0 per cent., or by reducing it to 0.3 per cent. These troubles were principally concerned with hair cracks, and he was unable to state whether the carbon had been automatically varied with the phosphorus or not. He also stated that in some crucible-melted tests on straight blast-furnace iron, a drop in the properties occurred at 0.5 per cent. P, quite out of line with the rest of the series, though this phenomenon did not show when the tests were repeated with a refined pig-iron.

It was decided that experimental work should be carried out to determine the relationship between composition and strength and porosity. In this connection it must be stated that the porosity investigated was that which occurs as irregular internal voids in a casting, of the type illustrated in Fig. 6, and must not be confused with other phenomena which are sometimes loosely classified as either drawing or porosity, viz., gas holes (as illustrated in Fig. 2, top specimen), external shrinkage or piping (as illustrated in Fig. 3), gas generated from entrained slag, or general openness of grain due to the presence of very coarse graphite throughout the casting.

The first necessity in carrying out these tests was to find a satisfactory porosity test. The first experiment was with a double cylinder, cast solid and bored so as to leave a standard thickness of metal between the bores at a spot where porosity was most likely to occur,[7] as it did. It was hoped that a quantitative measure of porosity might be obtained by observing the rate of leakage from one bore to another. From this point of view it proved to be a failure, as all the samples tried either gave no leak at 500 lbs. per sq. in. pressure or leaked so rapidly at low pressures that it was impossible to obtain comparative measurements.

It was reported to the sub-committee that attempts to measure porosity by measuring the rate of flow of gas through a disc of metal failed in a similar way, the discs being completely gastight if observable porosity was absent, although with exceptionally thin sections leakage of gas via the graphite flakes was obtainable.[8] This latter, however, was not within the scope of the present investigation. Efforts to explore porosity by specific-gravity tests on grey cast iron also proved fruitless.

The familiar K test-piece[9] was found to be insufficient as most samples failed to show any porosity on fracture, and an enlarged form of this was used in the shape of a T casting. This was adopted as the standard porosity test throughout the experiments detailed below, though it has the disadvantage that the porosity can only be measured by comparative observation and cannot be quantitatively determined. The dimensions of this test-piece are given in Fig. 1. A further porosity test was evolved by sectioning actual castings of cylinder heads, and, for clarity of results, this method has proved to be the most satisfactory of all, and, where available, these are illustrated in preference to the T-tests.

The investigations of the sub-committee have followed two definite lines, one set of experiments being made on irons where all the elements were fixed, with the exception of the one under investigation, whilst other series were investigated in which the total carbon was increased as the phosphorus was decreased, which is the normal effect when mixing hematite irons and phosphoric irons in different proportions. The conclusions to be drawn from the former method are naturally more easy to follow.

Attention was drawn to the risk of conflicting results being obtained on account of varying casting temperatures and mould conditions. Throughout the experiments these were kept as constant as possible in any one series, the casting temperatures in Series I to VII being controlled at a constant figure by an optical pyrometer read by the same operator throughout.

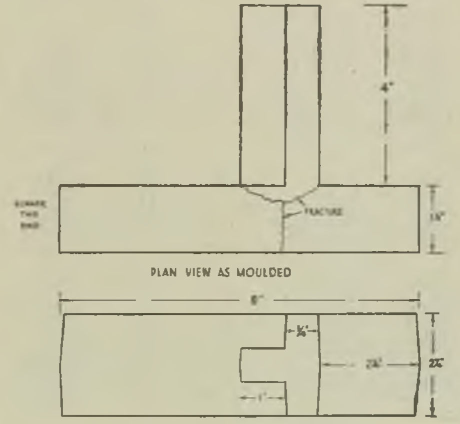


Fig. 1.—Test for Porosity

To ascertain the seriousness of the risk of the experiments being vitiated by varying casting temperature, a set of four cylinder heads were cast from the same ladle of metal at decreasing temperature. These are shown sectioned in Fig. 2. The specimen cast at the lowest temperature (so low that the casting would hardly run) shows a bubble of entrained gas, but otherwise the difference between the observable porosity is insufficient to upset the data obtained from this test.

Tests made on the usual cone test-piece showed that the pouring temperature affected the external sinking of the metal, but not the internal

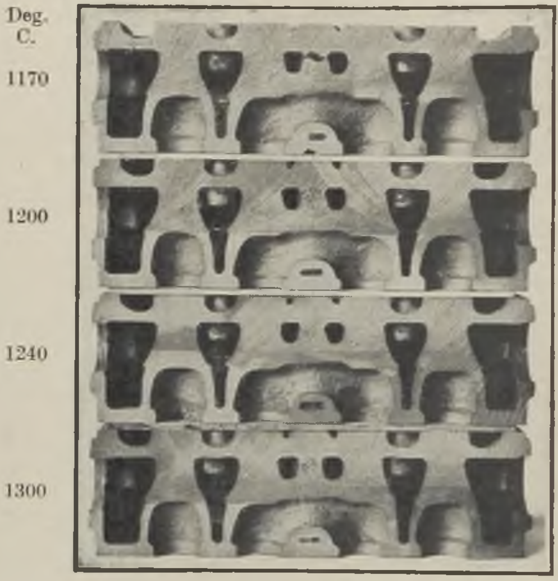


Fig. 2.—Influence of Pouring Temperature on the Porosity of Cylinder Heads. T.C. 3.2; Si 2.0; Mn 0.46; S 0.08 and P 0.40 per cent. The temperatures given were read on an optical pyrometer and no correction factor has been applied.

porosity, and T-tests confirmed this. These results are shown in Figs. 3 and 4. The cones, when sectioned, showed no signs of internal porosity. Incidentally, this set of experiments shows that the cone test is unsatisfactory for routine foundry control, as the volume of sink varies more with the pouring temperature (which

Fig. 3.—Effect of Pouring Temperature on Shrinkage. The samples have been cast at decreasing temperatures and (above) is a sectional casting of No. 4.

is so difficult to control exactly) than with the changes in composition of the metal.

A close examination of Hailstone's work[6] on the influence of pouring temperature revealed that there was little evidence of low pouring temperatures giving increased porosity as it is defined in this Report, but that the incidence of gas-holes became very pronounced. All porosity tests, whether T-bars or cylinder-head castings, in these series of experiments were made without feeder heads so that no complication occurs in that respect.

Experimental Work

At the initiation of these investigations the sub-committee found that one of its members was engaged on a research into the effect of phosphorus in cast iron, now completed and published.[7] The sub-committee were in touch with the progress of this research and particular attention was paid to such parts of it as might throw light on the problem in hand. Parts of this research are referred to in this report as:—

Series I, the general composition of which was T.C. 3.3, Si 2.1, Cr 0.3 and phosphorus varying from 0.07 to 1.1 per cent.

On completion of this work the same member undertook the preparation and examination of a further six series (this time without the presence of chromium) as follows:—

Series II.—T.C. 3.6, Si 2.0, phosphorus varying from 0.25 to 1.0 per cent.

Series III.—T.C. 2.6, Si 1.9, phosphorus varying from 0.18 to 0.75 per cent.

Series IV.—T.C. 2.6, P 0.8, silicon varying from 2.0 to 3.2 per cent.

Series V.—T.C. 2.6, P 0.06, silicon varying from 2.0 to 3.2 per cent.

Series VI.—Si 1.9, P 0.86, total carbon varying from 2.8 to 4.0 per cent.

Series VII.—Si 1.9, P 0.16, total carbon varying from 2.8 to 4.0 per cent.

On each of these series porosity tests in the form of cylinder heads and T-bars were taken,

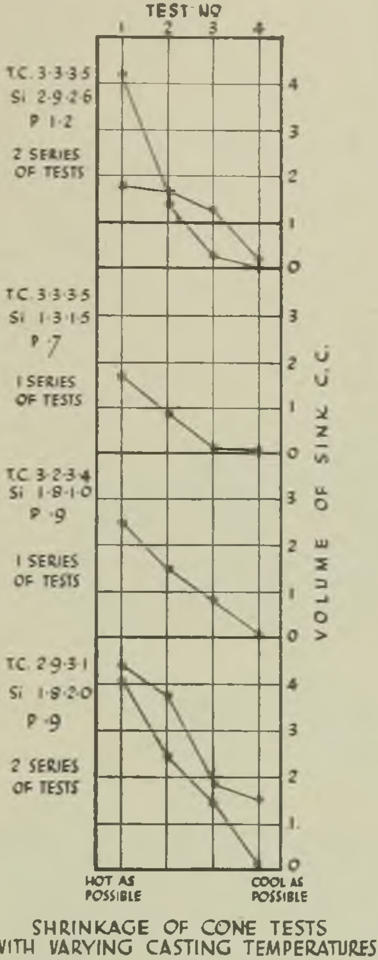


Fig. 4.—Effect of Pouring Temperature on Shrinkage. Graphs of Shrinkage of Cone Tests with Four different Types of Iron.

also transverse and tensile tests on "S," "M" and "L" bars. The metals for Series I, II and III were cupola-melted in a small experimental cupola, ferro-phosphorus being added to a suitable base iron. Series IV, V, VI and VII were crucible-melted, IV and V by the addition of ferro-silicon to a suitable base iron, VI and VII by mixture of a low- and a high-carbon hematite, the same quality low-carbon hematite being used throughout. The analysis of each cast was taken and came very closely within the common standard, and need not be given *in extenso.*

Some of the results on Series II and III were given in a Paper[10] to the French Foundry Conference in November, 1933, but the results on the other series have not hitherto been published.

At the same time, another member was carrying out a research into "The Influence of Phosphorus on the Properties of Hardened and Tempered Cast Iron." This work has also been completed and published.[11] Again the sub-committee were in touch with the author during the progress of his experiments, and such of the data obtained that is included in this report is classed as

Series VIII, having Si 2.4, Cr 0.6, with phosphorus increasing from 0.04 to 1.6 and total carbon decreasing from 3.8 to 3.4 per cent. Other members of the Sub-committee made further series as follows:—

Series IX.—T.C. 3.0, Si 1.2, Ni 2.0, phosphorus varying from 0.17 to 1.0 per cent.

Series X.—Si 2.35, total carbon decreasing from 3.7 to 3.2 per cent., while phosphorus increased from 0.06 to 1.13 per cent. All these series were crucible-melted, Series VIII being made by the melting of hematite and phosphoric irons in separate crucibles and mixing the metal in varying proportions. Series IX was made by the addition of ferro-phosphorus to a suitable base iron, and Series X by melting together suitable amounts of hematite and phosphoric irons of known composition, each set of tests being poured from a separate pot.

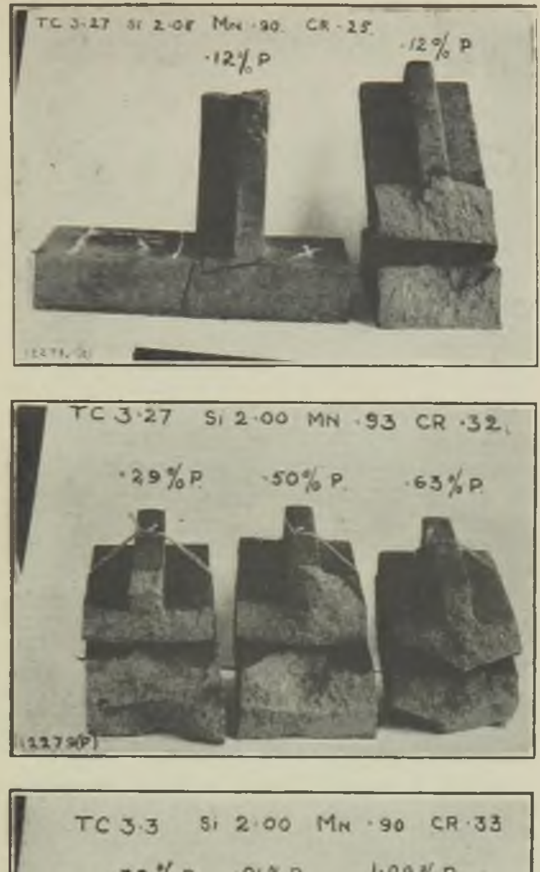


FIG. 5.—SERIES I. T-TESTS SHOWING THE INFLUENCE OF PHOSPHORUS ON FRACTURE.

Porosity Tests

The results of porosity tests on the above series were as follow:—

Series I.—These tests showed soundness up to 0.3 per cent. P and a gradual increase in porosity beyond (Fig. 5).

Series II.—The T-tests showed soundness up to 0.3 per cent. P and a gradual increase of porosity beyond.

The sectioned cylinder heads all showed slight porosity, increasing with rise in phosphorus, though there seemed to be a definite step in the increase as the phosphorus was increased from 0.42 to 0.52 per cent. (Fig. 6).

Series III.—The T-tests showed soundness up to 0.73 per cent. P. Slight porosity appeared after this, increasing with phosphorus.

The sectioned cylinder heads were all sound (Fig. 7).

Series IV.—The T-tests showed slight porosity with 2.40 per cent. Si and above, whilst the cylinder-heads had very slight porosity with 2.4, 2.62, and 2.88 per cent. Si, whilst the others were all sound (Fig. 8).

Series V.—Both the T-tests and the cylinder heads were all sound (Fig. 9).

Series VI.—The T-tests showed increasing porosity, which was very slight with 2.8 and 3.08 per cent. T.C., whilst the cylinder heads with 2.8 per cent. T.C. showed slight porosity; that with 3.08 per cent. T.C. was sound, but there was increasing porosity thereafter (Fig. 10).

Series VII.—The T-tests showed increasing porosity. The cylinder heads with 2.81 per cent. T.C. were sound, but there was increasing porosity thereafter, but much less than was exhibited by Series VI (Fig. 11).

Series VIII.—No porosity tests taken on this series.

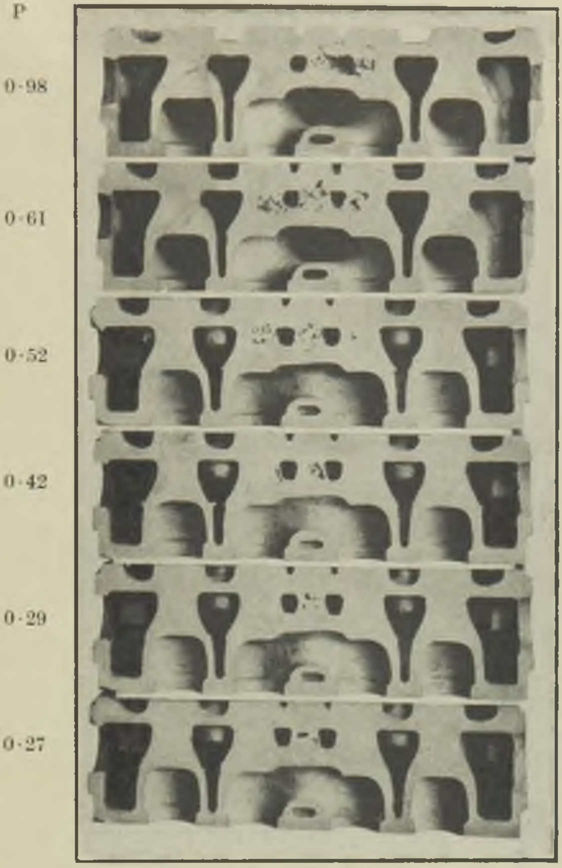


Fig. 6.—Series II. Sectioned Cylinder Heads. T.C. 3.6; Si 2.0; Mn 1.9 and S 0.045 with increasing Phosphorus.

Series IX.—In the T-tests no porosity was exhibited by any of the samples.

Series X.—In the T-tests porosity was present in samples 3, 4 and 5, but absent in samples 1, 2 and 6 (Fig. 12).

Conclusions from Porosity Tests

The evidence of all these tests is that total carbon and phosphorus are very important factors in controlling porosity, and are interrelated. If a perfectly sound casting be the only consideration, it is apparent that the best way is to employ low total carbon (about 2.6 per cent.), in which case the phosphorus and silicon may vary within fairly wide ranges without incurring porosity. Low total carbon irons

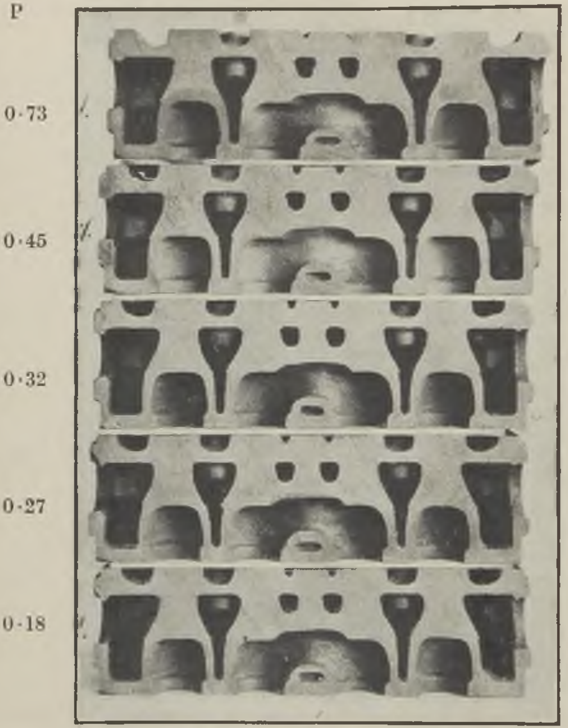


Fig. 7.—Series III. Sectioned Cylinder Heads T.C. 2.6; Si 1.9 · Mn 0.9; S 0.04 with increasing Phosphorus.

are, however, notoriously difficult to handle in the foundry, their high freezing points and great liquid shrinkage giving difficulty in obtaining castings that are sound in other respects.[12] The high shrinkage of the irons employed in Series II as against Series III is illustrated in Fig. 13.

The evidence of all the tests shows that soundness can be maintained if total carbon be increased up to about 3.3 per cent., providing that the phosphorus be kept below 0.3 per cent. Irons of this type are much more easy to handle in the foundry, and thus provide a much more satisfactory way of overcoming porosity. Only slight porosity is incurred if carbon is increased up to 4 per cent. with phosphorus below 0.2 per cent. The effect of silicon from 2.0 to 3.2 per cent. on low carbon irons has been demonstrated to have little effect on porosity, particularly in combination with low phosphorus.

The sub-committee does not wish these statements to be taken as meaning that the only way to eliminate porosity is to use materials of the compositions given, for it is well aware of the fact that castings free from porosity are produced daily in other compositions. The sub-committee is, however, unable to resist the conclusion from this and other experimental work, that the composition, in so far as total carbon and phosphorus are concerned, is of the utmost importance in controlling porosity, and that a greater range of silicon and carbon variation is permissible when using low phosphorus irons than when using high phosphorus irons.[7]

It is pointed out that in the above conclusions porosity has been the sole consideration, and such factors as hardness, etc., may sometimes rule out the employment of irons of the type suggested.

With regard to the "dangerous range," so far as porosity is concerned, the advantages of phosphorus being below 0.4 per cent. are abundantly illustrated, but the only evidence of an improvement with phosphorus rising above 0.6 per cent. is in Series X, in which there is a

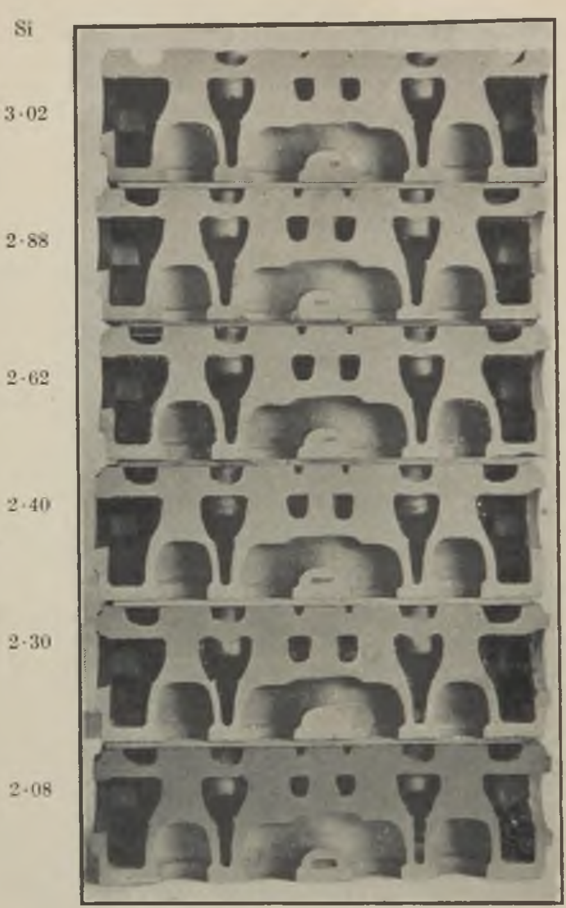


Fig. 8.—Series IV. Sectioned Cylinder Heads. T.C. 2.6; Mn 0.9; S 0.025 and P 0.8 with increasing silicon.

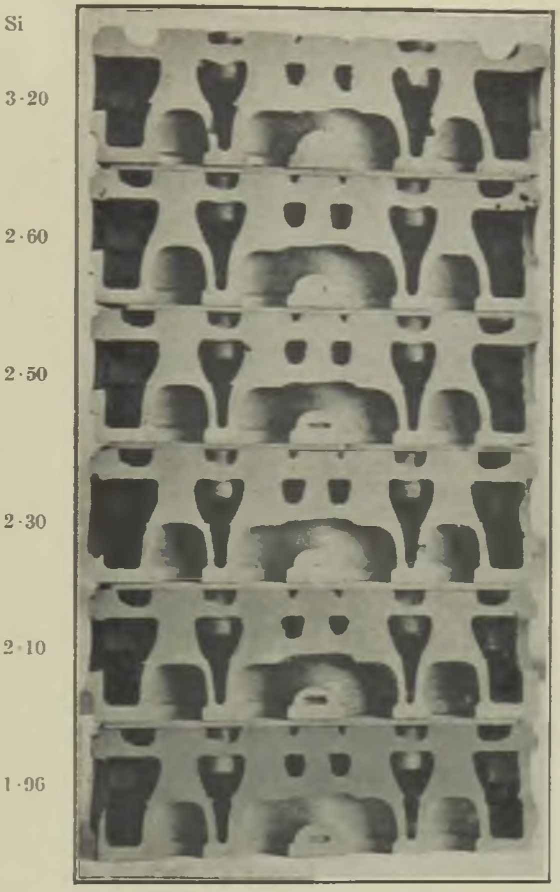


Fig. 9.—Series V. Sectioned Cylinder. Heads T.C 2.6; Mn 0.90; S 0.025 and P 0.06 with increasing silicon.

reduction in total carbon with the increase of phosphorus, and it is almost certain that the improvement is due to the fall in carbon more than counteracting the rise of phosphorus.

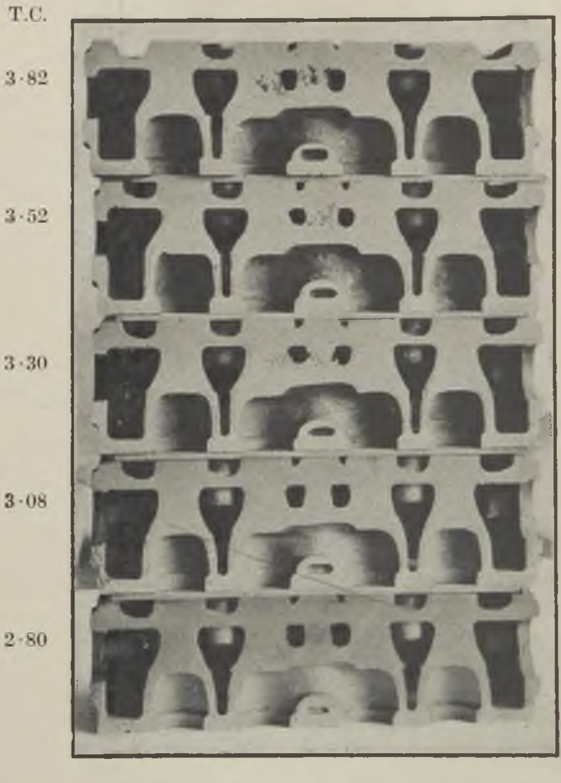


Fig. 10.—Series VI. Sectioned Cylinder Heads. Si 1.9; Mn 1.0; S 0.02 and P 0.86 with increasing Total Carbon.

Physical Tests

The physical tests were carried out as a subsidiary part of the porosity investigations, so that the experiments were not necessarily conducted on lines best calculated to produce the most informative results.

The results of the physical tests on all these series are shown graphically in Figs. 14 to 23. The transverse tests are expressed as transverse rupture stress throughout, and have in all cases been corrected for bar size. Nearly all the results plotted are the average of duplicate tests, and the points in the graphs are linked for the sake of identification. The same notation is used throughout, and all graphs are

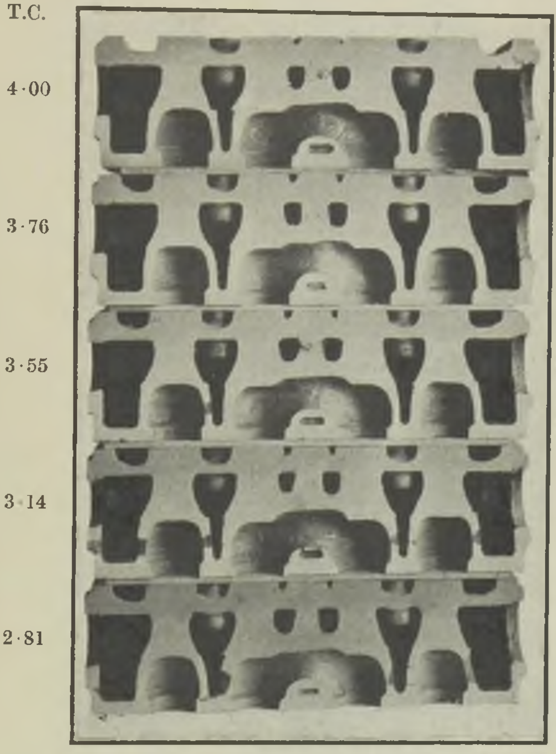


Fig. 11.—Series VII. Sectional Cylinder Heads. Si 1.9; Mn 1.0; S 0.022; P 0.16 with increasing Total Carbon.

T.C. 3.61 ; P 0.06.
T.C. 3.70 ; P 0.28.
T.C. 3.64 ; P 0.44.
T.C. 3.37 ; P 0.58.
T.C. 3.40 ; P 0.89.
T.C. 3.21 ; P 1.13.

Fig. 12.—Series X. T-Tests. Si 2.35; Mn 0.7, and S 0.05 per cent. with varying carbon and phosphorus.

plotted to the same scale so that one set of results can be readily compared with another.

In Series VIII, the tensile strength was calculated from ring tests, and the Brinell hardness was taken with a Firth hardometer 2 mm. ball 30 kg. load, all other Brinell tests being taken on the centre of the broken test-bar using a 10 mm. ball with 3,000 kg. load.

The sub-committee cannot explain the high values obtained in the transverse tests of Series I for the " M " bars with phosphorus above 1 per cent. These particular results were confirmed by repetition, but no corresponding increase is observed in the S. & L. transverse bars or in any of the tensile bars.

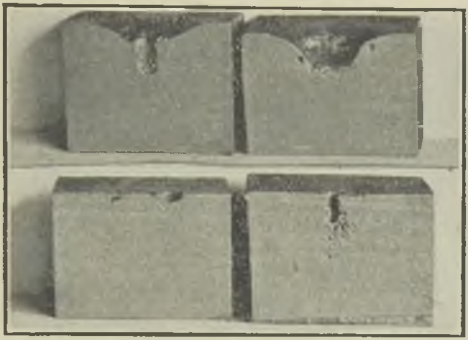


Fig. 13.—Blocks showing Liquid Shrinkage. *Top.*—T.C. 2.6 ; Si 1.9 ; Mn 0.9 and S 0.045 per cent. *Bottom.*—T.C. 3.6 ; Si 2.0 ; Mn 1.9 and S 0.04 per cent

Conclusions from Physical Tests

Tensile Strength.—Total carbon is the most important factor in controlling tensile strength, and figures taken from the graphs at a constant phosphorus show appreciable reductions in strength as the carbon increases from 2.6 to 3.6 per cent., though the reduction is not so marked in the higher phosphorus irons as it is in the low phosphorus irons. Similarly the effect of increasing phosphorus is to decrease the strength of the iron, this effect becoming less with increased carbon until, with carbon about 3.6 per cent., phosphorus has little effect on the strength. Thus irons having the greatest tensile strength are those having low carbon and phosphorus, carbon being the more important.

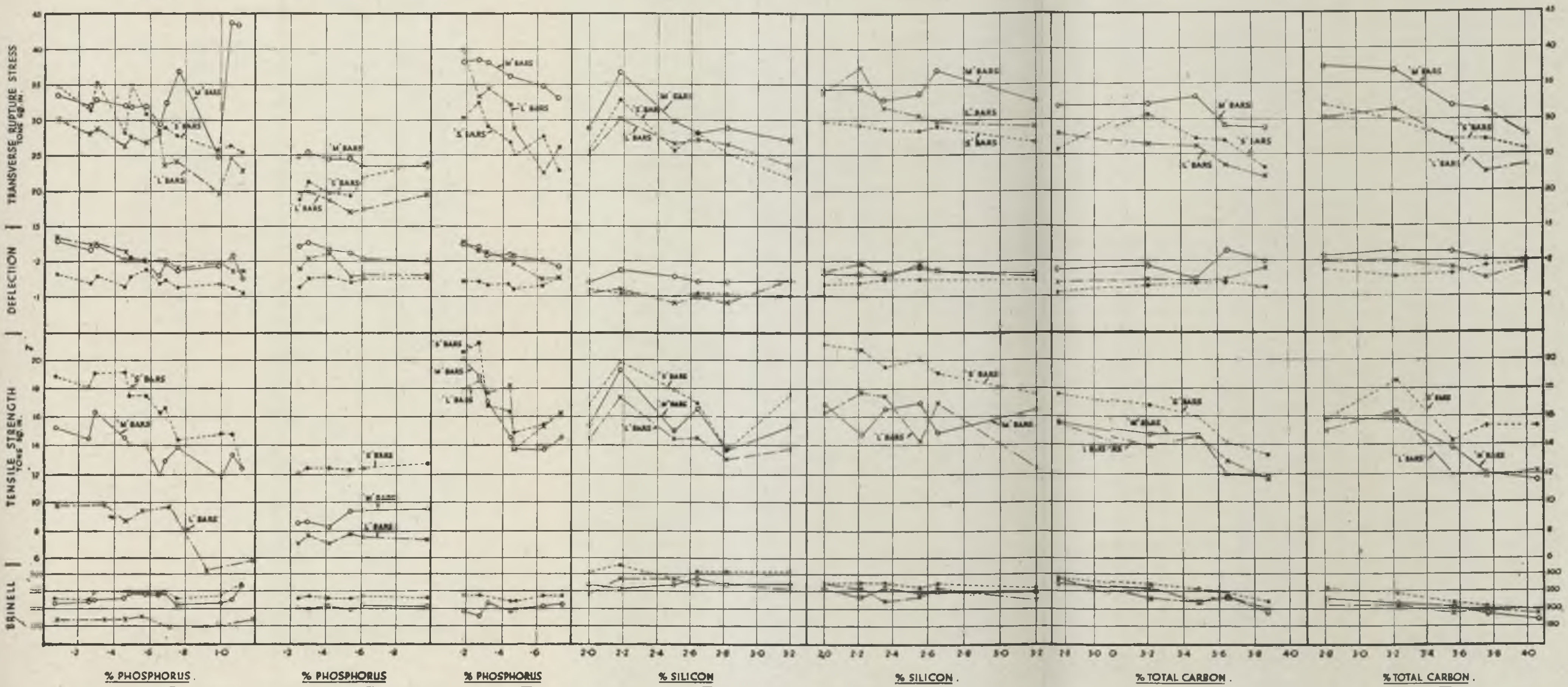
Transverse Strength.—In the transverse tests a very similar effect is noted with increasing total carbon and similar reductions occur. In these tests the effect of phosphorus is, however, more marked. Taking a broad view of the results, low phosphorus irons have a higher transverse rupture strength than the higher phosphorus irons irrespective of the carbon, though the lower the carbon the greater the difference. Thus again, low carbon, low phosphorus irons have the greatest transverse strength, but in this case phosphorus is a rather more important factor than carbon.

Deflection in Transverse.—Phosphorus appears to be the deciding factor in this connection, deflection decreasing with increasing phosphorus in all cases. Total carbon appears to have little effect.

Brinell Hardness.—Brinell hardness rises with decreasing total carbon, and also, though to a lesser extent, with increasing phosphorus.[13]

It is obvious that the graphitisation of the iron plays an important part in the strength, etc., of irons, and this is influenced to some extent by factors other than those disclosed by analysis, differing results being obtained with irons of the same analysis. The sub-committee has had evidence in these tests that where a different brand of pig-iron was accidentally introduced, results were obtained quite out of step with the remainder of the series, although analysis disclosed no difference. Thus in experiments involving the mixture of two different types of pig-irons, the effect of the introduction of a second pig with different graphitisation

FIG. 14. FIG. 15. FIG. 16. FIG. 17. FIG. 18. FIG. 19. FIG. 20.



SERIES I
T.C. 3.3; Si 2.1; Mn 0.87; S 0.046; Cr 0.3 with increasing Phosphorus.

SERIES II
T.C. 3.6; Si 2.0; Mn 1.9; S 0.045 with increasing Phosphorus.

SERIES III
T.C. 2.6; Si 1.9; Mn 0.9; S 0.066 with increasing Phosphorus.

SERIES IV
T.C. 2.6; Mn 0.9; S 0.025; P 0.8 with increasing Silicon.

SERIES V
T.C. 2.6; Mn 0.9; S 0.025; P 0.06 with increasing Silicon.

SERIES VI
Si 1.1.9; Mn 1.0; S 0.022; P 0.9.86 with increasing Total Carbon.

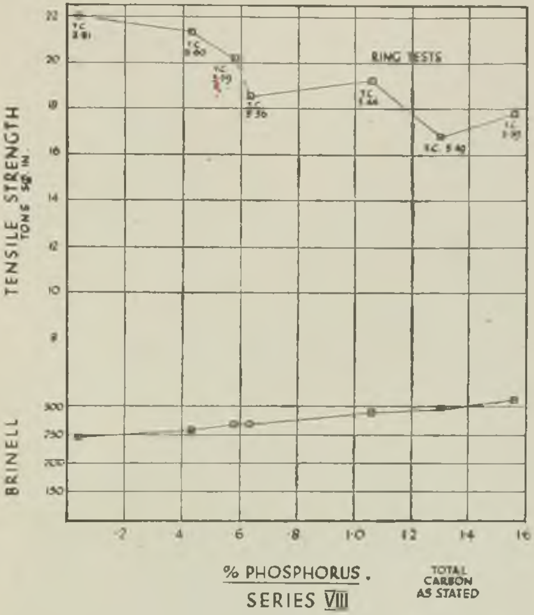
SERIES VII
Si 1.9; Mn 1.0; S 0.022; P 0.16 with increasing Total Carbon.

FIGS. 14 TO 20.—INFLUENCE OF INCREASING PERCENTAGES OF CONSTITUENTS ON THE MECHANICAL PROPERTIESES OF CAST IRON.

To face page 98.

properties may entirely offset any results anticipated from the change of analysis. (See Series X.)

In the above conclusions it must be borne in mind that, on the whole, irons with silicon about 2 per cent. have been under examination,

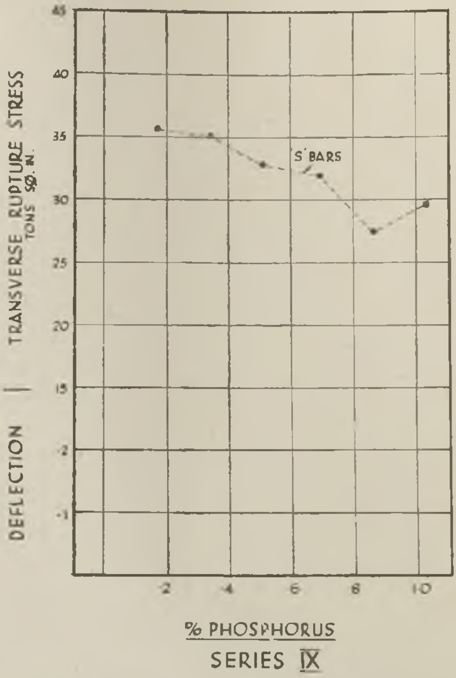


Si 2.4; Mn 1.0; Cr 0.6 with increasing Phosphorus.

FIG. 21.—INFLUENCE OF PHOSPHORUS ON THE TENSILE STRENGTH AND BRINELL HARDNESS OF CHROME CAST IRON (CENTRIFUGALLY CAST).

and so these conclusions do not necessarily apply to irons of different silicon content, etc., except that it has been demonstrated that silicon from 2.0 to 3.2 per cent. has little effect on low carbon irons. (Series IV and V.)

With regard to the "dangerous range" and physical properties, it is agreed that with certain carbon contents the strength of cast iron is maintained up to 0.3 per cent. P with a falling off thereafter. There is some slight evidence of a slight increase of strength with phosphorus above about 0.8 per cent.



T.C. 3.0; Si 1.20; Mn 1.1; Ni 2.0 with increasing Phosphorus.

Fig. 22.—Influence of Phosphorus on the Transverse Strength of Nickel Cast Iron.

It is obvious that in any discussion as to the existence of a dangerous range, total carbon must be borne in mind, and the sub-committee is of the opinion that any experiences of bad results having been obtained by reducing phosphorus from 0.7 to 0.5 per cent. are due to the incidental increase of carbon induced by the employment of low phosphorus irons, and where these troubles have been obviated by still further reducing the phosphorus to 0.3 per cent., the improvement is due to the phosphorus *per se.*

The committee have not investigated the hair crack troubles referred to by Cook, but no difficulty with this was experienced in any of their experiments. The experience of members of the sub-committee has been that these troubles are more related to casting strains, particularly those produced by thin flashes, and are not materially affected by the composition of the metal except to the extent that if the composition is such that the iron will chill white in the thin section of the flash, this trouble is greatly increased. The evidence with regard to the effect of phosphorus on chill is rather conflicting.[7, 13]. However, in view of the fact that neither high carbon hematites nor thin flashes were concerned in the instances given by Cook, it is difficult to give any explanation of this evidence of a " dangerous range."

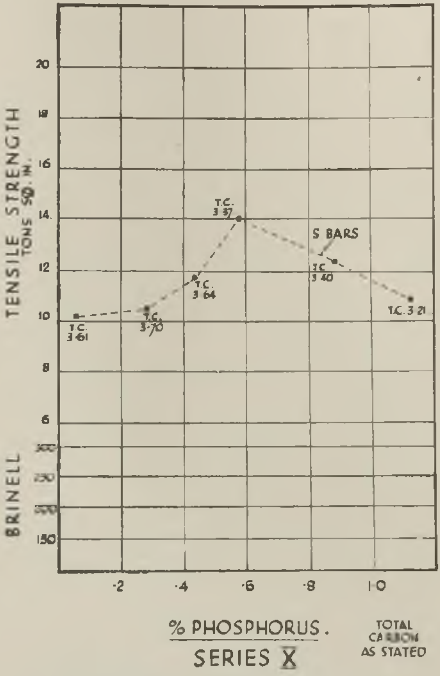
Contraction

The sub-committee came to the conclusion that it was impracticable to study the influence of analysis, section and pouring temperatures on the linear contraction of cast iron for the following reasons:—(1) Variations of contraction are so slight that it is impossible accurately to measure differences in bars of about 12 in. length, and longer bars are difficult to make as routine.

(2) Unless tests made in different foundries are made under exactly similar conditions of moulding, such as sand moisture, ramming density, section of chill yoke used, etc., the results will vary.

(3) The principal element in controlling contraction is the graphite, and it is well known that similar analyses and moulding conditions do not produce the same graphitisation of raw materials of different history.

A member undertook to investigate the contraction of bars 4 ft. and 12 ft. long at differing pouring temperatures and with different compositions. This was done by ramming up patterns of 1 in. sq. steel bar between machined



Si 2.35; Mn 0.7; S 0.05 with increasing Phosphorus.

Fig. 23.—Influence of Phosphorus and Carbon on the Tensile Strength of Cast Iron.

chills 12 in. × 4 in. × 2 in., two patterns in a box. The bars were run direct in the centre with relief risers near each end. The contraction was measured both by wedge before withdrawing from the mould, and by comparing with the length of the original pattern, only a slight difference being noted between the readings obtained by both methods.

The results are set out in Table I.

It would appear that temperature influences are not too marked until a very low point is reached. When metal was poured at a temperature bordering on freezing, a badly distorted casting resulted.

From the variations in the figures, the sub-committee's difficulties in obtaining accurate measurements on shorter bars will be appreciated.

Carbon Pick-Up

To explore the effect of different qualities of coke on carbon pick-up, certain experiments have been made. Three different grades of iron were melted in a small experimental cupola with three different grades of coke. Cupola conditions were kept constant in each melt, a constant weight of coke being used and the return coke deducted to arrive at the consumption. Five cwts. of pig-iron were melted in each test, the metal being tapped in three taps and each tap analysed. There was little variation between the analyses of the taps, and the average gains and losses are given.

The results of these experiments are set out in Table II. The sub-committee does not wish to comment on them at present, as they feel that further confirmatory work is required with other types of cupolas before definite conclusions can be drawn, but they publish them to show that a very useful line of investigation is being pursued and that there are possibilities of determining the relation of carbon pick-up to the shatter value and reactivity of coke.

B.S.I. Specification 321/28

This specification having been in force more than five years, the sub-committee feels that the time is now ripe for reviewing its position. The sub-committee has done no work in connection with this, but it is suggested that this is the next problem that should be undertaken, and

TABLE I.—*Contraction related to Composition and Casting Temperature.*

T.C.	Analysis.					Approx. pouring temp. deg. C.	Contraction ins. per ft. (Average of 2 bars).	
	C.C.	Si.	Mn.	S.	P.		12-ft. bar.	4-ft. bar.
A 3.30	0.62	2.03	0.72	0.110	0.79	1,400	0.150	0.155
A 3.30	0.62	2.03	0.72	0.110	0.79	1,350	0.150	0.158
A 3.30	0.62	2.03	0.72	0.110	0.79	1,325	0.153	0.155
C 3.20	0.65	1.50	0.70	0.090	0.80	1,350	0.158	0.158
C 3.15	3.15	0.75	0.70	0.110	0.80	1,350	0.237	0.241
C 3.15	3.15	0.75	0.70	0.110	0.40	1,350	0.227	0.250
A 3.45	0.35	2.75	0.95	0.090	1.45	1,350	0.148	0.156
A 3.60	0.45	2.15	0.75	0.080	0.05	1,350	0.142	0.139

NOTES.—A = Actual analysis. C = Calculated analysis. Optical pyrometer used.

Cokes used in Carbon Pick-up Experiments.

Cokes used.	Moisture.	Ash.	Volatile.	Sulphur.	Shatter.	
					2 in.	1½ in.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
No. 1..	Less than 1	9.2	1.25	0.56	80	85
„ 2..	„ 1	9.2	1.25	0.56	89	93½
„ 3..	„ 1	6.1	2.50	0.75	91.9	94·7

(Shatter figures are the amounts remaining on a sieve of the mesh stated after 4 drops of 6 ft.)

certain points are included in this report in the hope that the discussion will express the feeling of foundrymen in general, and give the sub-committee a lead as to the prosecution of its future work.

Table II.—*Analysis Variation with Different Cokes.*

Original pig-iron.	Gains or losses with coke.		
	No. 1.	No. 2.	No. 3.
T.C. 2.50	+ 0.417	+ 0.320	+ 0.183
Si 2.54	− 0.107	− 0.114	− 0.187
Mn 0.94	− 0.170	− 0.147	− 0.214
S 0.05	+ 0.021	+ 0.017	+ 0.010
Coke consumption, lbs.	158	156	138
Time of blow, mins.	36	30	25
T.C. 3.00	+ 0.080	+ 0.103	+ 0.050
Si 2.35	− 0.284	− 0.124	− 0.264
Mn 1.00	− 0.214	− 0.210	− 0.27
S 0.054	+ 0.017	+ 0.019	+ 0.013
Coke Consumption lbs.	166	158	136
Time of blow, mins.	30	27	30
T.C. 3.21	+ 0.110	+ 0.040	+ 0.016
Si 2.47	− 0.130	− 0.184	− 0.21
Mn 1.20	− 0.183	− 0.174	− 0.23
S 0.048	+ 0.006	+ 0.006	+ 0.004
Coke consumption lbs.	164	166	136
Time of blow, mins.	32	30	30

The principal comments that the sub-committee wishes to make, and upon which it desires discussion, are:—

(1) The sub-committee wholeheartedly approves of the principle of varying-size test-bars to represent varying sections of castings, and notes with gratification that the new American specification has adopted this principle.

(2) Certain practical difficulties have arisen in breaking the bars. In the transverse test, trouble is experienced through the round bars rolling if not perfectly straight or round, and

faulty deflection readings are obtained by the high loads necessary for the large bars, causing the knife edges to dig into the bar. Difficulties are encountered in breaking the "L" tensile bars, as not many machines are equipped with suitable grips for holding large bars, and with the advent of high-strength irons many machines are incapable of applying the necessary stress.

(3) The sub-committee feel that the time has now come for a further grade of higher strength to be included.

It is unfortunate that the grades have been labelled "A" and "C," for it is difficult to see how a suitable designation for an improved grade can be introduced into the present specification. The American and German specifications provide for irons of much higher strength, and the designation of the various grades permit of further additions as and when necessary.

(4) The extent to which the specification has been adopted is disappointing, and propaganda must be developed to encourage its use.

(5) The sub-committee have definitely adopted the method of expressing transverse strength as transverse rupture stress (modulus of rupture),[14] and hopes that this will ultimately become common amongst specifying authorities. In order to facilitate the conversion of transverse test results into transverse rupture stress, factors have been calculated to give the correct figure for bars which vary within ±0.1 in. of the correct size, and are set out in Appendix I. This Appendix also gives the factors for calculating the rupture stress of rectangular bars.

(6) The physical tests given earlier in this report are interesting in that they give tensile and transverse results for all sizes of bar on a wide range of irons. The low value for the transverse rupture stress of "S" bars as compared with the "M" and "L" bars which is brought out in these graphs will have to be investigated.

In conclusion, the committee wish to thank the following firms for giving facilities for carrying out the experiments, etc., detailed in this report:—

Bradley & Foster, Limited.
Craven Bros., Limited.
Keighley Laboratories, Limited.
Leyland Motors, Limited.
Mond Nickel Company, Limited.
S. Russell & Sons, Limited.
Sheepbridge Stokes Centrifugal Castings Company, Limited.

They are also indebted to the Rugby College of Technology for carrying out some of the tensile tests on the "L" bars, and to the British Cast Iron Research Association for access to their Library for certain published data.

BIBLIOGRAPHY

1 Neath, I.B.F. "Proceedings," vol. xxvi, p. 526.
2 Wüst and Stotz, "Ferrum," vol. 12, 1914–15, p. 89.
3 Mackenzie, "Transactions A.F.A.," vol. 34, 1926, p. 986.
4 Hamasumi, "Tokio University Scientific Report," vol. xiii, 1924.
5 Bolton, "The Foundry," August and September, 1933.
6 Molineux, I.B.F. "Proceedings," vol. xx, p. 427.
7 West, I.B.F. "Proceedings," vol. xxvi, p. 392.
8 Piwowarsky and Esser, "Die Giesserei," 1929, 16, 838.
9 Hailstone, "I.S.I. Carnegie Scholarship Memoirs," Part 1, 1913, v, 51; Part 2, 1916, vii, 55.
10 West, "Bulletin de l'Association Technique de Fonderie," December, 1933, p. 514.
11 Hurst, J.I.S.I., No. 1, 1933.
12 West, I.B.F. "Proceedings," vol. xxv, p. 409.
13 Everest and Hanson, J.I.S.I., vol. cxvii, No. 1, 1929.
14 Pearce, J.I.S.I., No. 2, 1928.

APPENDIX

Factors for determining Transverse Rupture Stress from Breaking Load on Round Test-Bars according to B.S.I. Specification 321/28.

Rupture Stress =

$$\frac{\text{Breaking load} \times \text{Distance between supports}}{0.392 \times \text{Diameter}^3}$$

The factors given below are for the three sizes of test-bar and the rupture stress is determined as follows :—

Breaking load in tons × Factor = Rupture stress in tons per sq. in.

L bar. Nominal dia. 2.2 in. tested on 18 in. centres.		M bar. Nominal dia. 1.2 in. tested on 18 in. centres.		S bar. Nominal dia. 0.875 in. tested on 12 in. centres.	
Actual diameter at fracture in ins.	Factor.	Actual diameter at fracture in ins.	Factor.	Actual diameter at fracture in ins.	Factor.
2.100	4.96	1.100	34.4	0.775	65.7
2.110	4.89	1.110	33.6	0.785	63.2
2.120	4.82	1.120	32.7	0.795	60.8
2.130	4.76	1.130	31.9	0.805	58.5
2.140	4.69	1.140	31.0	0.815	56.3
2.150	4.62	1.150	30.2	0.825	54.2
2.160	4.55	1.160	29.4	0.835	52.4
2.170	4.48	1.170	28.7	0.845	50.7
2.180	4.42	1.180	28.0	0.855	49.0
2.190	4.36	1.190	27.3	0.865	47.3
2.20	**4.30**	**1.20**	**26.6**	**0.875**	**45.7**
2.210	4.24	1.210	25.9	0.885	44.2
2.220	4.19	1.220	25.3	0.895	42.8
2.230	4.14	1.230	24.7	0.905	41.4
2.240	4.08	1.240	24.1	0.915	40.0
2.250	4.03	1.250	23.5	0.925	38.7
2.260	3.98	1.260	22.9	0.935	37.5
2.270	3.92	1.270	22.4	0.945	36.3
2.280	3.86	1.280	21.8	0.955	35.2
2.290	3.81	1.290	21.4	0.965	34.1
2.300	3.77	1.300	20.9	0.975	33.1

For square or rectangular test-bars the formulæ for the conversion of breaking load into rupture stress are :—

For 2 in. × 1 in. bars on 36 in. centres :

Corrected load (in cwts.) × 0.675 = Rupture stress (tons per sq. in.).

For 1 in. × 1 in. bars on 12 in. centres :

Corrected load (in cwts.) × 0.9= Rupture stress (tons per sq. in.).

The breaking load should be corrected for actual size of bar at fracture in accordance with the following formulæ :—

For 2 in. × 1 in. bars on 36 in. centres :

$$\text{Corrected breaking load} = \frac{4 \times \text{Actual breaking load.}}{\text{width at fracture in in.} \times (\text{depth at fracture in in.})^2}$$

For 1 in. × 1 in. bars on 12 in. centres :

$$\text{Corrected breaking load} = \frac{1 \times \text{Actual breaking load.}}{\text{width at fracture in in.} \times (\text{depth at fracture in in.})^2}$$

CAST IRON SUB-COMMITTEE OF THE TECHNICAL COMMITTEE OF THE INSTITUTE OF BRITISH FOUNDRYMEN.

P. A. Russell, B.Sc., *Convener.*

L. W. Bolton, A.M.I.Mech.E.
A. B. Everest, Ph.D.
B. Hird.
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E. Longden.
F. K. Neath, B.Sc.
W. West.
A. S. Worcester.

J. W. Gardom, *Convener, Technical Committee.*

DISCUSSION

MR. A. CAMPION, after an expression of commendation of the report, said it dealt with a large number of subjects, though some were not dealt with completely; it was all to the good, however, that the Committee should publish information from time to time in order to stimulate interest, and should submit its work to discussion with a view to obtaining tips and suggestions for further work. Mr. Campion's object in speaking was not to criticise the report but to make a few suggestions to the Committee as to directions in which it might amplify its present findings and perhaps in other cases review them.

He supported heartily the suggestion, with regard to tests, that the British Standard Specifications should be adopted in all cases as far as possible. Reference was made in the report to the difficulties experienced with the larger size of bars; but, as one who had carried out many hundreds of tests on such bars and had done some of the original Test-Bar Committee work, he had not experienced difficulties due to the knife edges digging into the bars, and he suggested that it was simply a question of the radius of the supports and of the presser foot. Neither had he experienced the difficulty of bars rolling out of position when placed on the supports.

Phosphorus in Light Castings

The main portion of the report dealt with the question of phosphorus in iron, and although there was much that was beyond dispute, some further work was required in certain directions to confirm some of the statements made. In the first place, the question of phosphorus had to be considered in relation to the castings being made. In light castings, such as gutters and rain-water goods, phosphorus did not matter, and a very high phosphorus content was permissible; but in heavy castings, which had to withstand high-pressure water or air tests, phosphorus became a serious problem, and it was necessary to limit the content to a low figure if the castings were to be sound. There was more in it than merely the relation between the total carbon and the phosphorus; one should consider all the elements present in any particular iron and the relation of one to the other. The Committee had dealt with carbon and phosphorus chiefly, but had mentioned only the total carbon; but it was necessary to consider not only the total amount but the condition and the distribution of the carbon present, especially the graphite.

Low-Carbon Content and Rotary Furnaces

Mr. Campion did not agree that there was necessarily difficulty in handling low total-carbon irons. In cupola melting there might be some trouble, owing to the difficulty of superheating to a sufficiently high temperature and for a sufficient length of time; but we were not confined to cupolas for melting nowadays. With the advent of the rotary furnaces of the Sesci and Brackelsberg type one could superheat the metal very highly, and submit it to that superheat for almost any length of time. He had had more than two years' experience of working a furnace of the Brackelsberg type, and there was not the slightest difficulty in handling irons with a carbon content as low as 2 per cent. This matter had to be considered seriously as affecting the physical and molecular condition of the metal. He was carrying out an extensive research into the qualities and properties of rotary-furnace melted and cupola-melted metal; the results were not yet complete, but he hoped to publish them in a Paper before the Scottish Branch of the Institute during the coming session. Through the kindness of Glasgow friends, facilities had been placed at his disposal, and the results obtained already indicated that it was necessary to modify our views as to the effect of the elements present in cast iron, both on the physical properties and the soundness of the metal.

Short Freezing Range Materials

A paragraph in the report, to the effect that if a perfectly sound casting were the only consideration the low total carbon irons could be employed, was rather puzzling. He had thought the ideal in all cases when making a casting was to secure the greatest possible soundness. Therefore, he asked for some further explanation of that result. Then it was stated in the report that the low total carbon irons were notoriously difficult to handle, on account of their high freezing points. That, he suggested, was a mis-statement; the trouble in dealing with these irons was not due to the high freezing points but the short freezing ranges. The modern trend in securing high strengths and sounder metals was in the direction of shorter freezing ranges, and in order to be able to handle them one must secure the required fluidity by superheating.

Phosphorus Limit for Soundness

Mr. J. G. Pearce (Director, British Cast Iron Research Association) congratulated the Committee on its extremely comprehensive report. Discussing the so-called dangerous range for phosphorus, he said there never had been any real theoretical reason to suppose that any dangerous range existed, and he personally had always attributed such troubles as had arisen in this connection to the difficulty of melting together, say, hematites and high-phosphorus irons to give a medium-phosphorus content, especially in indifferent melting furnaces. The point was, he suggested, that it was very difficult under those conditions to secure homogeneity. But that was no explanation of the points which Mr. Cook had raised originally, and which undoubtedly were important. There always had been cases in which quite successful medium-phosphorus irons had been made without any of these difficulties. The conclusions from the tests suggested that in order to secure soundness, *i.e.*, the freedom from inter-granular porosity, the carbon content should be below the eutectic value; and in these particular irons, which of necessity required about 2 per cent. silicon, that practically fixed the phosphorus limit for soundness. In the lower-silicon irons, which could be used quite safely in thicker sections, the phosphorus content could be increased without involving the risk of porosity. Sometimes in practical problems some very rough rule was adopted in order to keep this point in mind. One such example was that the phosphorus and silicon together should not exceed 2½ per cent. That again emphasised the fact that if the silicon content increased, the phosphorus content must be decreased, and *vice versa*. The danger lay, in fact, in having carbon in excess of the eutectic value for the silicon and phosphorus content.

Carbon Pick-up

With regard to carbon pick-up and reactivity tests, in 1929 a very capable German investigator had found very little relation between coke reactivity values and the results of gas analyses from the cupola; in fact, he had found that cokes of differing reactivity values but of similar composition and properties had given practically the same melting results in the cupola and the same results with respect to gas analysis.

The caution displayed in the report in many cases, particularly with respect to contraction and carbon pick-up, eloquently emphasised the difficulty which investigations of the kind dealt with presented. The difficulty was rendered still greater when such work was done in individual plants where the conditions inevitably varied from point to point throughout the industry. The Committee was fully justified in adopting its very cautious attitude.

The 321/28 Specification

Discussing the 321/28 Specification, Mr. Pearce said that in testing the 2.2-in. bar he had found the supports and the loading point, even when very fully rounded, digging into the bar. But very careful measurement had shown that the amount of error introduced by that into the deflection measurement was not very considerable; he had investigated the matter in connection with a number of large bars and had found that it was not really serious. Whilst he would not regard that as an argument for abandoning the round bar, he did consider that the use of the big bar was one of the matters which should have first attention when the Specification was reconsidered. The original test-bar Committee had always regarded it as anomalous, and had recognised that sooner or later it would have to be modified radically.

Phosphorus Content and National Resources

Mr. John Shaw, who also congratulated the Committee on its very valuable work, said there was little doubt that, under the conditions obtaining and with the type of casting examined, total carbon and phosphorus were the dominating elements to control the form of porosity investigated. It must be remembered, however, that the greater part of British pig-irons contained phosphorus from 0.8 per cent. to 1.5 per cent. Were we to accept it as proved that castings of unequal thickness could not be made from these irons, free from porosity, except by making large additions of either steel scrap or hematite and so reducing the phosphorus to approximately 0.3 per cent.? In order to reduce the phosphorus content from 1 to 0.3 per cent. there must be an addition of about 60 per cent. of steel or hematite to the charge. Either would have a large effect on the total carbon. Many castings with irregular sections had to withstand a water test, but the price prohibited the use of refined pig-irons therein. In any case, all castings should be sound. If the Committee would investigate the possibilities on this point it would be very helpful.

Turning to the physical tests, he deprecated strongly the common practice of casting the large L bar from a mixture which was suitable only for thin castings. No other single factor had done more to prejudice engineers against the use of cast iron than had the supposed abnormal drop in strength per sq. in. with increase in section. As an example, he referred to Fig. 14, where there was a decrease from 19 tons on the S bar to below 10 tons on the L bar. It would be just as truthful to say that when using a mixture suitable for a 3-in. thick casting that would give either a mottled or white S bar, with a consequent drop in physical properties; that cast iron increased in strength per sq. in. with increased thickness and was unsuitable for thin castings, because it was brittle and unmachinable. If one wished to investigate the effect of phosphorus on an iron for thick castings, one should use a suitable base material to start with. He uttered a warning, also, against drawing definite conclusions from the use of ferro-phosphorus to make the additions, because it was his personal experience that a different structure was obtained by this method.

Problem of Carbon Pick-up

In tackling the problem of carbon pick-up the Committee was doing useful work, but the problem was full of difficulty. MacKenzie, in his Paper before the Institute in 1927, had stated that temperature and time of contact with carbon were two of the principal points in connection with carbon pick-up. There was a tendency for all mixtures to come to the same carbon content, dependent on type of coke and blast. Also, depending on the type of coke, carbon pick-up would continue after each successive melting until equilibrium was reached. With high-carbon pig-iron an actual loss was sustained until equilibrium was arrived at. The question of a hot hearth was of vital importance. The bed might be well burned through, but the hearth might remain comparatively cool, due, say, to being idle over the week-end, extra daubing or wet bottom sand.

Foreign Specifications of Cast Iron

Coming to Specification 321, he said that whilst there might be a desire to add another grade of higher strength, the weakness of the Specification, in the opinion of many people, was the large variation of thickness covered by the 1.2-in. diameter bar. This was the result of a compromise to meet the capacity of the many testing machines in use at the time the Specification was drafted. Many now felt that the introduction of a bar of $1\frac{5}{8}$-in. dia. would give a more correct idea of the structure and strength of casting about that thickness. Admittedly, it was foolish to sacrifice the principle to the machine. Dealing with the references to German and American specifications, he said the former, whilst recognising the principle of fixing the diameter of the test-bar so that it would bear some near relation to the thickness of casting it represented, stopped short at the 1.2-in. dia. bar. This represented all castings more than 1 in. thick. The American tentative specification A48-32T varied from the British, for the large bar was fixed at 2-in. dia. and tested at 24-in.

centres. The span was increased to give a truer measure of the deflection. But some recent work by MacKenzie on the effect of difference in span had shown that there was little difference on the 2-in. bar between the 18-in. and 24-in. span, and it would appear that the Americans had merely harassed themselves by using a more cumbersome bar.

Again, the Americans had graded their material in terms of minimum tensile strength. Starting at 20,000 lbs. per sq. in., they had run up, with increments of 10,000 lbs., to 60,000 lbs. per sq. in. No difference was made between the S and L bars in this respect. The transverse tests were optional, but might be specified. The idea behind the alteration was that the customer might specify a definite strength, for which a price would be quoted accordingly. How far this would work out in practice remained to be seen, however; probably the engineer would require the high-test material, whilst the buyer would want to pay the lower price.

The Committee had definitely adopted the method of expressing transverse strength as transverse rupture stress. How far this would be acceptable to inspectors and engineers was open to question; they generally wished to see the actual breaking load, without going to the trouble of converting it into something else. There was an example of this kind in the recently-attempted introduction of the 24-hr. clock. Another objection to the method was the possibility of the same modulus figure being asked for from the L bar as from the S bar. If cast iron were a homogeneous material, that would be reasonable.

The Danger Range in Phosphorus Content

Mr. F. J. Cook (Past-President), after commending the work of the Sub-Committee, said he had never stated dogmatically that there was a danger range at about 0.5 per cent. phosphorus content because he had never been able to satisfy himself that it existed or that there was a reason for it. But during the last forty years he had experienced very remarkable troubles with castings, particularly in the development of hair cracks, where there was 0.5 per cent. of phosphorus in the composition, and they had been eliminated, so far as he could judge at the time, by raising the phosphorus content. The argument he had had in mind was that the troubles were due to contraction strains, and that by increasing the phosphorus one decreased strains of that description. Those experiences he had referred to the Committee, and he had no fault to find with the conclusions arrived at, that no reason could be found as to why this particular trouble should occur. He also did not know the reason. But when there were many examples, over a period, which had exhibited this particular trouble and where it had been made to disappear immediately, one had to see how far there was anything in it. The question had arisen in two ways—how far phosphorus affected the porosity of a casting and how far it affected the physical strength. He had merely stated the facts and had suggested that there was probably some definite reason for the particular change referred to. He believed it was Bolton, in America, who had pointed out that there was a distinct change at 0.5 per cent. phosphorus, that at below 0.5 per cent. it was mainly as a solid solution, but some of it was as a compound, whereas above 0.5 per cent. it existed entirely as a compound. If that were true—and Mr. Cook could not believe it altogether—it indicated that there was some change at that particular point. He did not believe that phosphorus *per se* was wholly responsible for the variations in the strength of a casting; the factor that mattered was the total carbon, *i.e.*, the balance of the total carbon and the silicon, or how near was the approach to the eutectic point. He believed he had proved many times that round about, or just below, the eutectic point it did not matter at all how much phosphorus was present; he had proved it in large Diesel-engine pistons, of 22 and 24 in. dia., in which, it was usually considered, phosphorus was absolutely detrimental. The phosphorus was only detrimental, he believed, when the carbon was off the range of the eutectic, or when there was not a balance between the carbon and phosphorus, and he had proved it by raising the phosphorus content in the pistons referred to. He had aimed at 1.5 per cent., but had obtained about 1.4 per cent. If the theory with regard to high phosphorus content were true, then those pistons ought to have cracked within about half an hour, but in fact they had been at work since about the middle of the war period. Again, he had proved that with 1 per cent. of phosphorus in the mixture one could produce castings of 18 or 19 tons tensile if one maintained the balance referred to; otherwise, the phosphorus became dangerous. Therefore, he suggested that the Committee should consider further the carbon content as well as the phosphorus content.

Convener's Reply

Mr. P. A. Russell (Convener of the Sub-Committee), replying to the discussion, assured Mr. Campion that the Sub-Committee had been thoroughly aware of the importance of the size and distribution of the graphite, and had endeavoured to overcome difficulties in this respect by maintaining the conditions as standard as possible, by using the same grade of pig-iron and the same melting processes as far as possible. Indications were given as to where irons were cupola-melted and where they were crucible-melted, and it was a fact that the tendencies exhibited were very much less marked in the crucible-melted series than in the cupola-melted series; the curve was very much steeper in the case of the cupola-melted than the crucible-melted iron. In the section of the report dealing with conclusions from physical tests, the Sub-Committee had covered the point particularly with regard to physical properties.

With regard to the request for a definition of "porosity," he said the Sub-Committee had had to define it largely by what it was not, and he believed the definition given was the best that could be arrived at for the form of porosity examined—that which occurred as irregular internal voids in a casting, of the type illustrated in Fig. 6.

The Sub-Committee had done no macro-etching.

He agreed with Mr. Campion about the importance of superheat and the importance of the low-total-carbon irons. The remarks of Mr. Campion bore out the Sub-Committee's contention that if the total-carbon content were low, one need not bother about phosphorus, and that at well below the eutectic the phosphorus did not matter.

With regard to the statement in the report, that if a perfectly sound casting were the only consideration the low-total-carbon irons could be employed, and Mr. Campion's criticism that a perfectly sound casting should be the only aim, Mr. Russell said that surely there were considerations other than perfect soundness in certain classes of castings, particularly those which were not exposed to severe conditions. Some castings, though not definitely free from porosity, were quite good enough for their duty. The Sub-Committee's point was that it was useless introducing a number of difficulties for the foundry by insisting upon perfectly sound castings in every case if soundness were not definitely necessary.

Replying to Mr. Pearce, he said the Sub-Committee had had in mind all along the importance of the eutectic point, and he had been to much trouble in an endeavour to correlate all the data to the eutectic point, but it had resulted in a hopeless tangle, and the Sub-Committee could not correlate it definitely to the eutectic point alone; there seemed a definite break at 0.3 which was not connected solely with the eutectic.

The remarks concerning carbon pick-up would be referred to the Sub-Committee for consideration, and the references to the specifications had also been very helpful.

The reference by Mr. Shaw to the predominance of high-phosphorus pig-irons in Britain

TABLE A.—*Initial Pouring*

	Green sand.		
Casting section :	¾ in.	1 in.	2 in.
Temperature of test section immediately after pouring deg. C. —	1,100	1,140	1,160
Temperature of solidification, deg. C.— Beginning	1,100	1,125	1,110
Final	1,085	1,100	1,100
Time of solidification after pouring in minutes— Beginning	Nil	½	1
Final	2¾	4	9
Cooling time in minutes to reach carbide change point— Beginning	13½	16½	33
Final	18	21½	43
Temperature of carbide change point, deg. C.	720	750	730
Cooling time in minutes to reach 600 deg. C.	24	32½	58½
Analysis— T.C.	3.46	3.53	3.53
C.C.	0.60	0.65	0.55
Si.	1.69	1.41	1.64
Mn.	0.87	1.24	0.86
S.	0.125	0.101	0.129
P.	0.40	0.27	0.28

NOTE.—All gates and risers normal

Temperature, 1,340 *deg. C.*

		Dry sand.				
3 in.	4 in.	¾ in.	1 in.	2 in.	3 in.	4 in.
1,180	1,190	1,100	1,150	1,160	1,200	1,210
1,110	1,120	1,090	1,120	1,130	1,150	1,120
1,100	1,100	1,070	1,100	1,100	1,100	1,100
2	2	½	1	1	2	3
13½	20	3	4	8½	13	18
48	72	12½	16½	30	51	63
61½	81	17½	22½	41	65	92
730	740	718	750	740	740	745
86	115	24	35½	57	100	138
3.55	3.20	3.53	3.48	3.64	3.54	3.49
0.55	0.53	0.65	0.58	0.55	0.55	0.67
1.5	1.83	1.69	1.50	1.36	1.55	1.73
1.09	1.16	0.90	1.16	1.36	1.22	1.17
0.185	0.102	0.125	0.115	0.093	0.137	0.092
0.28	0.30	0.49	0.47	0.27	0.33	0.24

to general foundry practice.

was appreciated, and it was necessary to bear in mind that we must use the high-phosphorus irons if we could. He believed the solution lay in employing low-carbon contents with the high-phosphorus contents.

One was inclined to agree with Mr. Cook that possibly the development of hair cracks was related to contraction, the phosphorus having some effect upon that contraction; but the Sub-Committee had been unable to investigate the point.

Vote of Thanks

Mr. J. E. Hurst (Senior Vice-President), speaking as an individual member of the Sub-Committee, expressed appreciation of Mr. Russell's convenership. No one who was not a member of the Sub-Committee, he said, could really appreciate the extraordinary amount of work that Mr. Russell had done, not only in organising meetings in all parts of the country, but also in summarising the work and in preparing the present report. It was hoped that the production of the report would be regarded by him as some compensation for his work.

Mr. W. West (also a member of the Sub-Committee), who seconded, said that Mr. Russell had attended every meeting, and, judging by the volume of correspondence between himself and the members, he must have spent a great deal of time in the compilation of the information forwarded to him.

The vote of thanks was accorded with acclamation.

Effect of Pouring Temperature

Mr. F. Hudson (member) wrote that there were two points in this excellent report upon which he wished to comment. In the first place, regarding the effect of pouring temperature on shrinkage, he had been interested in this matter for some time, and the experimental results published in Table A might help to shed additional light on this subject. In conducting these tests the object was to obtain some idea as to the effect of green- and dry-sand moulding upon the properties of various sectioned castings.

Apart from the results obtained in this direction, it is interesting to observe that when using an initial pouring temperature of 1,340 deg. C. the actual temperature of the green-sand casting with $\frac{3}{4}$-in. section is 1,100 deg. C., the beginning of solidification for iron of the composition used. This result was quite unexpected and illustrates the large temperature drop between pouring temperature and true casting temperature. He suggested that this point should receive further consideration in any future study of this question. It clearly indicated the futility of results based on pouring temperature alone.

The second point concerned test-bars and B.S.I. Specification 321/28. In the transverse test on the largest size bar the capacity of many machines was insufficient to effect fracture, and it would be a good thing if the breaking centres could be extended to permit of lower breaking loads being applied, and a correction factor determined for the correction of such results for direct comparison with the existing standards. If such a factor could not be arranged, then he would suggest a definite alteration in the specification on this point.

The L-Bar Deemed Unsuitable

Mr. R. G. Tucker wrote that he had read the report with considerable interest, particularly as he had been a member of the Cast Iron Sub-Committee in its earlier stages. He was glad to see how the work had developed and he wished to congratulate the members on this report of their work.

The bulk of the report was occupied by work on the porosity and strength of cast iron in relation to the total-carbon and phosphorus contents. He was pleased to note that so far as porosity was concerned the Committee had come to the conclusion that composition was of importance and that a greater range of silicon and carbon was permissible, when using low phosphorus. He was particularly interested in irons for Diesel-engine work and at one time considered that, if the phosphorus content did not exceed 0.7 per cent. such irons were satisfactory. As the result of experience, however, he now favoured irons which had a low-phosphorus content and seldom specified more than 0.3 per cent. in irons containing 3.30 per cent. total carbon and 0.85 to 1.3 per cent. silicon.

With regard to the influence of phosphorus on the strength, he was glad the Sub-Committee had emphasised the necessity of considering the total carbon, when discussing the existence of a dangerous range and the phosphorus content. This was a point which was of importance and was sometimes inclined to be overlooked.

The Sub-Committee had referred to the B.S.I. Specification 321/28. He approved of the Specification in general and had no difficulty in the breaking of round bars. He agreed, however, that the "L" tensile bar was unsuitable. Regarding the grades, he could never understand why these were labelled "A" and "C," and certainly thought that specifications of higher strength should be adopted, more in line with the present Admiralty Specification. He considered that the present grades were perhaps one of the reasons why the specification was not more generally adopted. As regards expressing the transverse strength as transverse rupture stress, he was in full agreement, but realised that considerable difficulties exist in persuading designers and users to adopt such a term.

Condition of Phosphorus Content

In the report, two M bars with high phosphorus give very high transverse figures, and there is sometimes a dangerous range with 0.5 to 0.7 per cent. phosphorus. These facts bring out very clearly that phosphorus is like graphite. The form is all-important (or almost so) and the amount of secondary importance.

Phosphide can occur as two eutectics—as network either fine and continuous or coarse and irregular, or even liquated and "balled up." Silicon has a great influence on the *form* of the phosphide. It is not until careful micrographic comparison of the forms of phosphide are taken into account that these results will be clarified. It is already done for graphite—why not phosphide?

SUB-COMMITTEE'S WRITTEN REPLY

The Sub-Committee of the Institute of British Foundrymen on Cast Iron has now had an opportunity of considering the discussion on its report and replies as follows:—

The appreciative way in which this Report has been received is greatly valued by the Sub-Committee and is an incentive to it to proceed with its work. The Convener's reply to the discussion is endorsed, but this requires amplification and to be extended to cover the written discussion.

With regard to the effect of total carbon and phosphorus on porosity and the physical properties of cast iron, the Sub-Committee is pleased to note that its conclusions are endorsed by several of the speakers, but would emphasise its opinion that, for the average founder, the obtaining of soundness by a reduction of phosphorus to below 0.3 per cent. is simpler than by a reduction of carbon below 3.0 per cent. The point raised by Messrs. Pearce and Cook with regard to the eutectic has been very closely watched and all the evidence obtained in the experimental work pointed to the existence of some factor around 0.3 per cent. P, which is distinct from the normal effect of variations in the carbon eutectic point. As pointed out by Messrs. Cook and Tucker, this may be due to the form of the phosphide eutectic, but after discussion the Sub-Committee decided that in the present state of knowledge of this subject it could not offer an opinion on the theoretical aspects. With regard to Mr. Campion's point that the short freezing range of low-carbon irons is the main source of difficulty in handling these materials, the Sub-Committee agree that this is one part of the difficulty, but maintain that the high freezing point is also an essential factor. This is a point that requires further investigation.

The remainder of the discussion largely centred round the B.S.I. Specification and the Sub-Committee notes that the " L " bar is considered unsatisfactory by most of the speakers. There should be no difficulty in arranging for an alternative breaking centre for a longer "L" transverse bar, but as Mr. Shaw pointed out, this would be rather cumbersome. The Sub-Committee feels that with the support received in this discussion it can now go ahead with the preparation of suggestions to lay before the appropriate B.S.I. Committee. The Sub-Committee cannot agree with Mr. Shaw that the "S.M." and "L" bars should never be cast together, as it feels that this is the most effective way of investigating the effect of varying section on the physical properties on any composition of iron that is under investigation. On the question of the use of transverse rupture stress the Sub-Committee is definitely of the opinion that these data are much more valuable than the mere expression of breaking stress on a bar, particularly in view of the variety of test-bars now in use. It also considers that a similar expression for deflection in transverse, which takes into account variations in span and depth of test-piece and reduces them to a common level, should be evolved.

The points raised in connection with carbon pick-up will be borne in mind by the Sub-Committee in its future deliberations on the subject. The Sub-Committee thank Mr. Hudson for the data contained in Table A, which are very interesting from many points of view.

P. A. Russell,
Convener.

CONTRIBUTION TO THE STUDY OF GRAPHITE FORMATION AND STRUCTURE IN CAST IRON AND ITS INFLUENCE UPON THE PROPERTIES OF THE CAST METAL

By Heinrich Nipper, Dr. Ing.

(*Communication from the Giesserei-Institut of the Aachen Technical High School*)

[GERMAN EXCHANGE PAPER]

The crystallisation of a melt is determined, according to the work carried out by Tammann,[1] by the factors "nuclei number, KZ," and "the velocity of crystallisation, KG." The mode of undercooling of a melt depends upon the values of KZ and KG, and their proportion to each other. Above all, undercooling is dependent upon the value of the preceding melting temperature, the duration of this, the presence of solid, liquid or gaseous constituents liable to cause inoculation, the rate at which cooling takes place, potential inoculation due to the furnace or container walls, the jolting of the melt, and so forth.

With reference to the influence which these factors have upon the rate of freezing of grey cast-iron melts of varying composition, the following general remarks may be put forward:—

The first effect of high superheating is to decrease viscosity. Impurities in the melts, consisting of coarse or of more or less dispersed oxides, silicates, etc., coagulate and are separated out. Even in the case of hyper-eutectic melts, all particles of graphite are entirely dissolved. The high degree of purity thus arrived at allows of an extensive undercooling of the melt. It has not so far been possible to ascertain experimentally to what extent molecular changes in the melt, due to the high superheating, may favour or may cause the marked tendency for undercooling. In this connection,

Fig. 1.—Shows how the Crucible Walls influence Graphite Size. × 100.

Fig. 2. — Two Graphite Flakes (Kish) $\frac{1}{16}$ in. long, with Fine Eutectic Graphite. × 100.

the very complete researches by Piwowarsky,[2] by v. Keil, Mitsche, Legat and Trenkler,[3] and A. Reinhardt,[4] may be referred to.

Low Temperatures

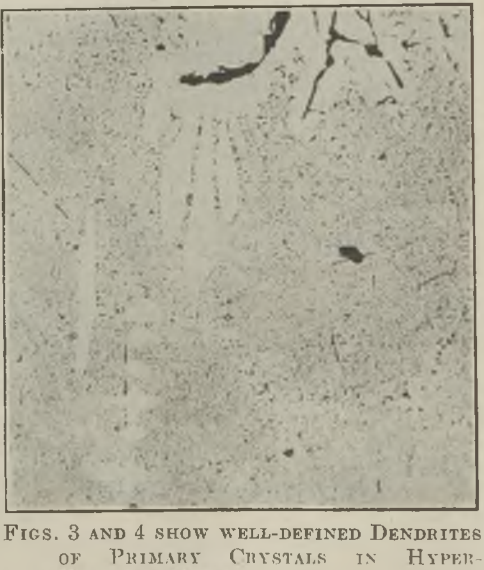
Heating over a long period at comparatively lower temperatures has also, in the first place, a purifying effect, making for a coalescence of impurities and, apparently, for the critical particle size favourable to nuclear formation. The capacity for undercooling thus increases. The explanation given by Hanemann,[5] where he refers to the break-up of the graphite nucleus, is very improbable for normal working temperatures, according to the later researches by Piwowarsky.[6] Piwowarsky has been able to show that in soaking tests a few seconds are fully sufficient to break-up even coarse graphite flakes at melting temperature.

Solid and liquid impurities present in an iron melt, according to their kind and the size of the particles, can largely lower the undercooling capacity on freezing. It is sufficient at this point to refer to new researches in this connection, namely, those of Reinhardt and v. Keil above mentioned. The after-siliconising effect and its gradual fading away by long standing may also come into play. (In regard to this, the researches by E. Piwowarsky[7] should be referred to.) A treatment of the melt with a suitable slag or direct refining have for effect largely to increase the undercooling capacity.

Gases in particular, when present in large quantities, and given out by the liquid melt and also in the freezing range, can greatly hinder undercooling. (With reference to this, the work by Piwowarsky[8] and by Bardenheuer and Zeyen[9] can be consulted, as also that by **Wagner.**[10]) The effect of melting in vacuo is dealt with further on, when personal researches are detailed.

By greatly increasing the rate of the cooling, the iron can be obtained white; it is brought down to freezing point subsequently to the

FIG. 3. × 100.



FIGS. 3 AND 4 SHOW WELL-DEFINED DENDRITES OF PRIMARY CRYSTALS IN HYPER-EUTECTIC MELTS.

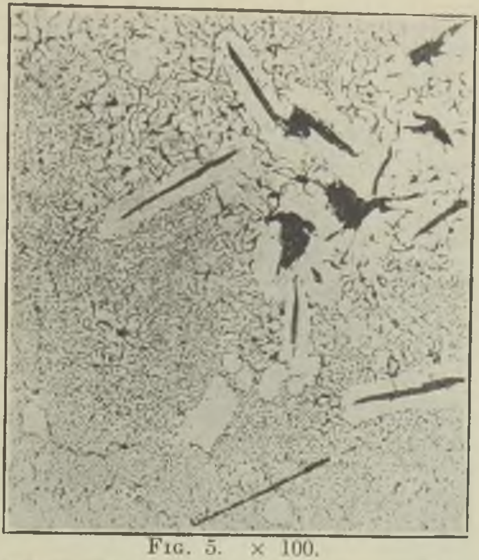


Fig. 5. × 100.

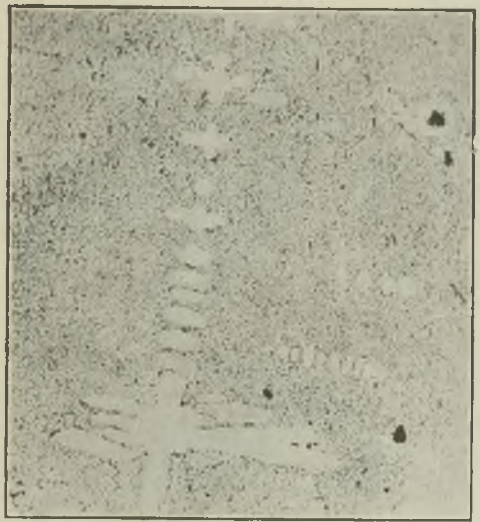


Fig. 6. × 100.

Figs. 5 and 6 show well-defined Dendrites of Primary Crystals in Hyper-Eutectic Melts metastable range, and is therefore completely undercooled.

The very marked effect which furnace walls have upon the graphite formation may again be referred to. Fig. 1 shows, under a magnification of 100 diameters, the long graphite lamellæ which proceed from the walls of a graphite crucible. The shaking of the melt materially hinders undercooling.

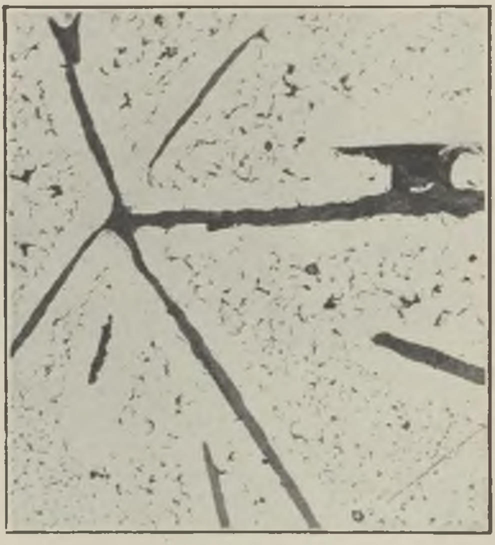


Fig. 7.—Shows Coarse Graphite radiating from a Nucleus. × 100.

Having stated in the above in a general way the most important factors which favour or hinder undercooling, it is now proposed to deal with the question as to how freezing without and with undercooling operates upon the graphite formation in cast iron. The question is divided under three main headings, namely, hypo-eutectic, eutectic, and hyper-eutectic alloys.

Fig. 8. × 100.

Fig. 9. × 100.

Figs. 8 and 9 show Graphite Flakes fractured in the Melt during Freezing.

Hypo-eutectic Alloys

(1) When a hypo-eutectic iron alloy freezes without marked undercooling then, in the first place, a primary solid solution will separate out in conformity with the lines of the equilibrium diagram. When the residual melt has reached the eutectic composition then more or less large graphite lamellæ will be formed, besides further solid solution, according to the quantity of residual heat and the freezing time this requires. In such instances, the structure hardly reveals a primary dendritic formation, and this all the less the nearer the composition of the melt approaches to the eutectic.

(2) When a hypo-eutectic alloy freezes with marked undercooling, then also will a primary solid solution separate out in the first place, in conformity with the lines of the equilibrium diagram. This separation continues also when the eutectic composition of the residual melt is reached, since the separation of the graphite sets in with a higher undercooling. The residual heat becomes first hyper-eutectic, and with a greater number of nuclei freezes suddenly to an extremely fine mixture of fine graphite and solid solution. Thus, in isolated portions of the melt at which undercooling has first been arrested, there may grow in the melt graphite crystals in the form of radiating stars. The dendritic structure increases markedly with a decrease in total carbon percentage. The fine grain graphite is arranged and interleaved in a decided reticular structure. The mechanical properties of these alloys correspond to the higher carbon percentages, the feature in this instance being a lamellar irregular embedded graphite eutectic, which characterises alloys of this composition frozen without any marked undercooling.

Eutectic Cast Iron

(3) Eutectic cast-iron alloys which freeze without any marked undercooling show, in accordance with the longer period of growth, more or less coarse graphite lamellæ irregularly arranged.

Fig. 10. ×100.

Fig. 11. × 100.

Figs. 10 and 11 show Thin Graphite Flakes broken and afterwards semi-coalesced.

(4) The eutectic graphite can become fine and extremely fine by a heavy undercooling. When there is a large number of nuclei, crystallisation which commences suddenly and ends rapidly does not allow a growth of the graphite nuclei. This condition is illustrated further on, when showing the structures of the hyper-eutectic melts experimentally made.

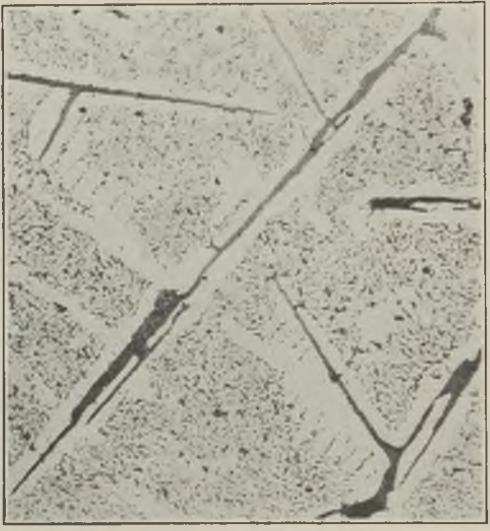
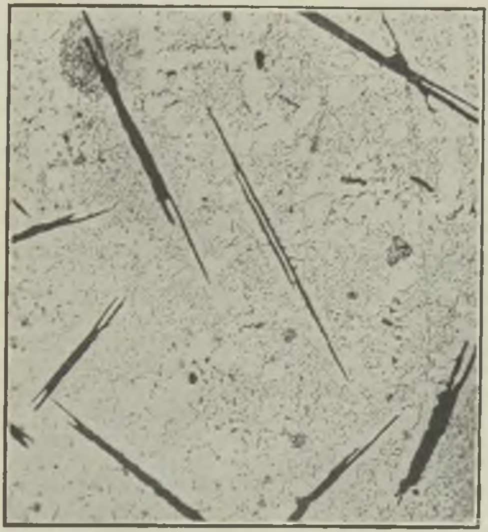


Fig. 12.—Showing Graphite with Lateral Aggregations conforming to Crystallographic Directions. × 100.

(5) Hyper-eutectic melts which freeze without marked undercooling first separate out coarse graphite (it is proposed to deal solely with freezing in regard to the stable system). When the residual heat attains the eutectic composition, then the case is one for normal and more or less coarse graphite formation—together with saturated solid solution—determined by the duration of growth. The graphite flakes are quite irregularly arranged.

Fig. 13. × 100.



Graphite Formation.
Figs. 13 and 14 show Novel Type of
Fig. 14. × 100

Undercooled Hyper-eutectic Action

(6) When the crystallisation of hyper-eutectic melts takes place with heavy undercooling, the primary graphite lamellæ can grow very markedly. The eutectic composition of the residual heat is made to fall and there may even occur the formation of primary solid-solution dendrites. These, in many cases, start from the primary graphite flakes. The residue then freezes very rapidly to exceedingly fine graphite and saturated solid solution.

FIG. 15.—GRAPHITE LAMINA.
× 30.

Micro-Structure of Graphite

The microphotographs reproduced here apply to a series of cast-iron melts produced at a temperature of about 1,640 deg. C. in a high vacuum (below 0.0001 mm. pressure) in carbon crucibles (melting time 20 min. and over, cooling time about $2\frac{1}{2}$ hrs.). The melts were superheated and very clean, were specially free from gas, and hence inclined to heavy undercooling.

The illustrations have a magnification of 100 diameters, and Fig. 2 shows parts of two large graphite lamellæ (Kish). Some of the lamellæ reach a length of 8 mm. ($\frac{5}{16}$ in.). The eutectic graphite separation is extraordinarily fine and granular, corresponding to the high undercooling. The haloes surrounding the graphite lamellæ are lamellar pearlite.

Figs. 3 to 6 show well-defined dendrites of primary crystals in hyper-eutectic melts, which, in part, clearly take their start from the Kish graphite flakes.

Fig. 7 shows course graphite (Kish) which has grown radiating from a nucleus in the melt.

Figs. 8 and 9 illustrate Kish graphite lamellæ with peculiar fracture phenomena. These fractures have been caused by bending and pressure stresses occurring in the melt when liquid and when freezing. The graphite flakes here seen have a length of 6 to 8 mm. ($\frac{3}{16}$ in. to $\frac{5}{16}$ in.).

FIG. 16.—GRAPHITE LAMINA. × 30.

Figs. 10 and 11 show thin coarse graphite lamellæ (Kish) which have been broken up by working the melt, and have been thrust aside and collected together again like drift-wood.

Fig. 12 shows coarse graphite lamellæ with lateral aggregations which correspond to crystallographic axes and enclose definite angles.

Figs. 13 and 14 are most interesting from the crystallographic standpoint. The longitudinally-sectioned small graphite flakes have somewhat the shape of double tuning forks. Owing to the impoverishing of the mother-liquor in carbon and to insufficient diffusion, the graphite flakes have quickly grown superficially at the ends, whilst the nucleus has not moved. This formation of a border apparently cleaved all round is of frequent occurrence in the case of minerals having a similar crystallisation, together with a rapidity of growth largely prevailing in one direction. This phenomenon had not been observed so far in regard to graphite in cast iron.

Fig. 17.—Coarse Graphite shown in Figs. 10 and 11 viewed under Polarised Light.

Examination of Graphite *per se*

With reference to the structure of the graphite lamellæ in cast iron, this also will be dealt with in a general way only. Graphite is a wholly opaque, hexagonal mineral having a good reflecting power. According to the work by

FIG. 18.—COARSE GRAPHITE FLAKES CORRESPONDING TO FIG. 7, VIEWED BETWEEN CROSSED NICOLS.

P. Ramdohr,[11] the examination of graphite can easily be carried out in polarised light. With finely-granular graphite, there is no difficulty in making the polished section. It is sufficient to give the specimen a preliminary polish by hand, wet, on a stationary glass disc, and to finish polishing by rubbing round gently on a cloth-covered block. Coarse graphite, also in the case of polished sections of cast iron, have repeatedly to be treated hot with kollolith or another similar scaling-wax preparation. Slipping on the hexagonal basis (0001) occurs so very easily that the grinding of a basal section of cast iron is almost impossible and produces exfoliation. The small and mostly peculiar-shaped graphite plates and graphite flakes in cast iron, when examined with a polarising system,, show a decided reflex pleochroism. When in the case of the graphite lamellæ the run of the basis is in the longitudinal direction of the strip-shaped section parallel to the plane of vibration of the nicols, their luminosity is as great as with basal sections. Luminosity is lowest perpendicular to the plane of vibration of the nicols. On turning the section between crossed nicols, a fourfold extinction is observed.

Fig. 15 shows a coarse graphite lamina under a magnification of about 30 diameters. The hexagonal shape is shown to have been well maintained. Reflectivity, as already mentioned, is good, and with reference to orientation is independent of the revolution of the specimen.

Another graphite lamina is illustrated in Fig. 16; this is of larger proportions, but is in poorer condition. The outline of the upper surface and of the edges is very distinct.

The radiographic researches made by Wever show that the crystal size of the graphite lamina in cast iron is of about 100 Angstrom units, corresponding to about half that of temper carbon. When viewing the strip-shaped sections through the graphite laminæ with crossed nicols, small graphite lines became uniformly extinguished. The coarse graphite fragments reproduced in Fig. 17, which correspond to those of Figs. 10 and 11, but taken in polarised light, also show—apart from faulty polished parts—approximately the same behaviour. The circumstance may be due to the fact that individual lamellæ are built-up of parallel, microscopically small particles giving the impression of uniformity.

Fig. 18 shows coarse graphite between the crossed nicols, corresponding to Fig. 7.

Figs. 19 and 20 illustrate between the crossed nicols the fragments on coarse graphite flakes, already referred to, also the peculiar-shaped end

Fig. 19.—Shows Fractured Graphite Flake viewed between Crossed Nicols.

of a graphite lamella. The pressure and bending stresses in the graphite generated during the cooling of the cast iron (there arising a substantially small shrinkage) cause an upsetting and crumpling of the individual graphite

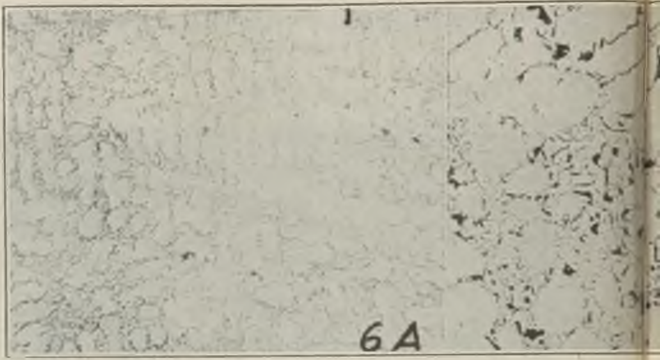
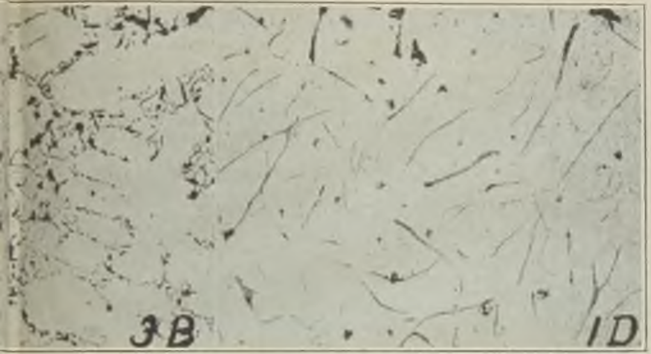


Fig. 26.—Characteristic Structures of Three C
Corrosion Resistance Experiments. The le

Table I.—*Summary of Chemical Composition, Mechanical Properties,*

Melt No.	Composition.[1]			Properties of dry cast bars of 33 mm. diam.			
	C	Si	Ni	Tensile strength. kg./mm.²	Trans-verse strength kg./mm.²	Brinell hardness.	Specifi Gravit
(*a*) ..	3,08	0,94	—	25,9	42,7	212	7,3976
(*b*) ..	3,03	1,74	—	24,2	37,8	196	—
(*c*) ..	3,07	2,52	—	19,8	33,5	199	7,3312
(*d*) ..	2,90	1,77	0,90	25,1	37,2	199	7,4037
(*e*) ..	2,92	1,25	1,85	27,1	—	—	7,4423
(*f*) ..	3,10	0,73	3,70	27,0	42,7	222	7,4380
(*g*) ..	3,09	0,32	5,63	27,9	43,2	225	7,4724
(*h*) ..	3,06	0,38	3,95	29,6	42,5	237	7,4848

[1] Average Mn 0.03 ; P 0.02 and S 0.015 per cent. [2] Bars as Series
for 1 hr. at 1,050 deg. C., and several times between 600 and 800 deg. C.
denote the diameter of the cast bars in mm.



Iron Tests by Nipper and Piwowarsky for their
rs indicate corresponding samples in Fig. 27.

d Structure of various Cast Irons studied by Bornhofen and Piwowarsky.

Series I. Pearlite with fine lamellar graphite 0.002 to 0.2 mm.		Series II. Pearlite with coarser graphite 0.03 to 0.2 mm.		Series III. Ferrite with coarse graphite.[2]		Series IV. Graphite like temper carbon[3].	
Bar.[4]	Carbide content.	Bar.	Carbide content.	Bar.	Carbide content.	Bar.	Carbide content.
T 33	1,52	T 50	1,50	T 50	0,04	K 33	0,04
N 33	1,29	T 50	1,20	T 50	0,04	K 33	0,04
N 20	1,22	N 50	1,18	N 50	0,00	K 20 K 33	0,02
N 20	1,23	N 50	1,26	N 50	0.03	K 20 K 33	0.04
T 20	1,32	N 50	1,29	N 50	0,04	K 20 K 33	0,06
N 33	1,24	N 50	1,20	N 50	0,03	K 33	0,06
N 33	1,26	N 50	1,28	N 50	0,06	K 33	0,34
N 33	1,46	T 50	1,42	T 50	0,02	K 20	0,08

nnealed between 650 and 800 deg. C. [3] Bars annealed in coal-sand mixture
= Dry sand casting ; N = Green sand casting ; K = Chill casting. The figures

lamellæ; hence their wavy character. While lamellar graphite in cast iron always consists of small basal plates, the microscopic examination of temper carbon showed that here was a revelation of a conglomeration of fine graphite layers, round fibrous aggregates, in which the basis of the small laminæ is oriented perpendicular to the radius of the sphere. This is dealt with in detail later.

Influence of Graphite on the Properties of Cast Iron

With reference to the influence which the amount, form and arrangement of the graphite have upon the properties of cast iron, the following general observations may be made:—

The difficulties in the casting technique and in machining increase markedly with a lowering of the carbon and graphite percentages. As far as possible, therefore, the carbon content of cast iron must not go below a determined value. Graphite in globular formation is the most favourable. The " notch " effect is of the least importance in such cases, and the superficial area corresponds to a minimum. A small number of large spheres would weaken the material at isolated parts to such an extent that fractures would easily occur. An exceedingly large number of the smallest spheres, hence a highly-dispersed distribution, would mean a much too great superficial lack of continuity in the material. The best solution lies between the two extremes. The superficial area of the graphite has to be in the most favourable proportion to the quantity present in the mass. Short, thick lamellæ, not connected too closely to one another, and not too numerous, are the most favourable form (the globular form of carbon deposition can only be arrived at in the case of malleable cast iron). An unfavourable graphite formation, of fine, connected shapes. the superficial area being large, even when occurring in the wide meshes of a network, as, for instance, in highly undercooled, highly hypoeutectic melts, is of a nature fully to determine the mechanical properties. Fracture proceeds along the meshes and goes from one graphite flake to another.

Reference may now be made to a few, mostly recent, researches dealing with the influence which the form and amount of graphite have upon the properties of grey cast iron, researches which for the most part have been carried out in Aachen.*

FIG. 20.—NOVEL FORMATION OF GRAPHITE VIEWED BETWEEN CROSSED NICOLS.

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* Opportunity is here taken to state that when in the course of this paper reference is made to a few research results mostly proceeding from Aachen, the author in no wise loses sight of the importance of the exceedingly numerous other researches in the same field, carried out both in foreign countries and in Germany. The present short paper can only cover a part of the subject; the references made are simply those which concern this same part.

A. Koch and E. Piwowarsky[12] carried out a very complete investigation on the influence of the carbon content upon the structure and strength properties of grey cast iron, with reference to varying silicon contents, temperatures and wall thicknesses.

They were able, generally, to confirm former results. The graphite content rose, and its formation was coarser with an increasing wall thickness; the transverse and tensile strengths also fell in somewhat the same proportions. For the same superheat, alloys the poorer in carbon could, naturally, be less undercooled; in the eutectic graphite crystallisation, the formation of a reticular, exceedingly fine granular graphite structure having a too-large superficial area did not occur, but, owing to the lesser undercooling, there ensued the formation of more or less irregularly divided, highly-grown fine graphite lamellæ. The impact strength, in particular, of several alloys was found to have increased eight to ten times.

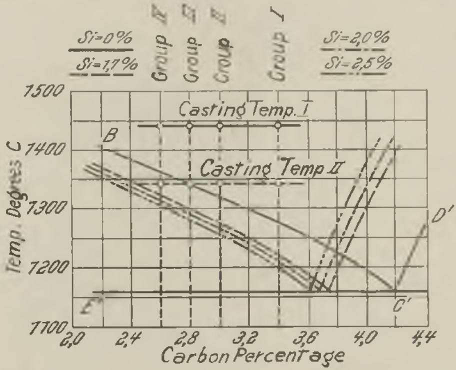

Fig. 21.—Position of Casting Temperatures in Experiments by Koch and Piwowarsky with respect to Liquid as Lines of various Fe-C-Si Alloys (constructed on C′ *D′* Lines determined by Piwowarsky and Schichtel for different Si contents).

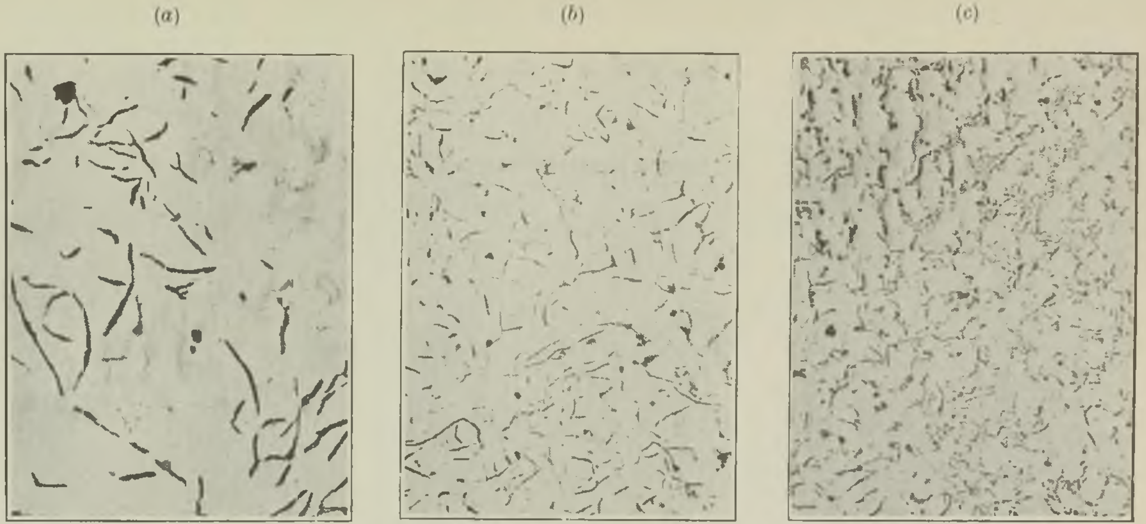

FIG. 22.—STRUCTURES OF THREE DIFFERENT CAST IRONS WITH WIDELY DIVERGENT GRAPHITE FORMATION OBTAINED IN WEAR TESTS ON C.I. FOR AUTOMOBILE CYLINDERS BY WALLICHS AND GREGOR. (*a*) SAMPLE NO. 22; (*b*) SAMPLE NO. 32, AND (*c*) SAMPLE NO. 41. ALL THE MICROS ARE UNETCHED. × 75.

Fig. 21 shows the casting temperature worked to by Koch and Piwowarsky, along the lines established by Piwowarsky and Schichtel[13] in the iron-carbon-silicon diagram.

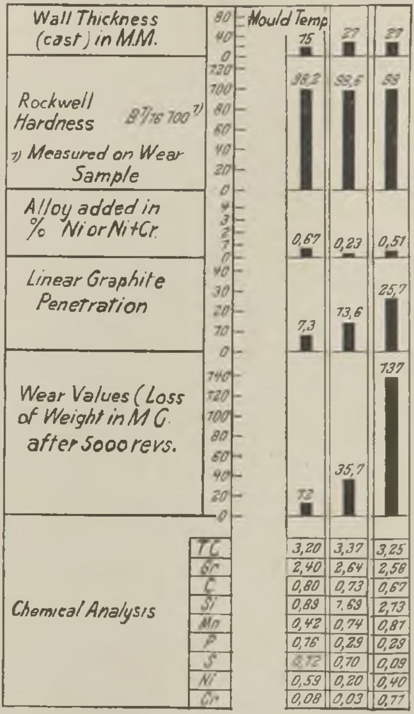

FIG. 23.—WEAR VALUES OF THREE AUTOMOBILE CYLINDER IRONS OBTAINED BY WALLICHS AND GREGOR WITH A WEAR-TESTING MACHINE.

Wear Tests

The reports by Heimes and Piwowarsky[14] on researches on cast iron, using a new type of wear-testing machine, clearly show that with graphite of increasing fineness, the structural composition being generally the same, wear largely increases in all classes of wear tests, namely, rolling and sliding friction, friction by rotation in an emery bush, and friction by cutting-in with a mild-steel disc. The structure becomes gradually more broken up, and in rolling friction especially frictional oxidation (Fink)[15] is greatly increased. In the case of dry sliding friction the graphite acts as a lubricant; in this instance, there occurs a most favourable graphite content and a most favourable graphite formation. When the graphite content is too high and also too fine, the structure breaks up. Of all the graphite arrangements, well-formed and relatively coarse temper carbon showed the lowest wear values. A ferritic structure, together with a relatively largely increased graphite segregation wears away much more than a purely pearlitic one. The influence of other alloy elements, apart from that which they have upon the carbon content and the structure, was not clearly ascertained.

Like Heimes and Piwowarsky, Wallichs and Gregor,[16] in their wear tests of various classes of cast iron for motor-car cylinders, using wear-testing machines and heavy traction engines, found that wear directly increases with increasing linear graphite dissemination. Following extensive ascertainments by Wallichs and his co-workers, hardness influences the resistance to wear of the test specimens, and can remain constant.

Fig. 22 shows the structure of three pearlitic brands of cast iron; it is unetched. Fig. 23 illustrates the results of wear for the same class of material. The work in this connection shows that a metal exhibiting definitely good lamellar pearlite with, in itself, a low carbon content, and a moderate linear graphite dissemination, gives the lowest wear valves and is easy to machine. The required structure can be arrived at by hot pouring in pre-heated moulds, the percentages of carbon and silicon being low.

In the course of their work, Bornhofen and Piwowarsky[17] have carried out researches to ascertain the influence of nickel and silicon, also of the graphite content and formation upon the growth of cast iron. Heating-up for 60 hrs. to 650 deg. C., therefore, under the A point showed very clearly that annealed chill-cast bars, having well-developed temper carbon, behaved the best. The main structure was ferritic. Pearlitic specimens, especially those showing a coarse graphite formation, exhibited by far the greatest growth (see Table I and Figs. 24 and 25). Silicon influences growth by the manner in which the graphite formation takes place. According to Bardenheuer,[18] following his researches with silicon steels, silicon has a greatly retarding action upon growth. It has quite the same effect in the case of chill castings, whilst in that of a pearlitic structure and, to a smaller extent, in that of a ferritic-graphitic structure, it favours growth. The formation of SiO_2, promoted by more or less deep penetration of gases along the coarse graphite plates, can here be taken into account and made responsible for the extensive growth. Figs. 26 and 27 show from the work by Nipper and Piwowarsky[19] the characteristic structure of three cast-iron brands (unetched). Both in a semi-normal hydrochloric-acid solution and in damp earth a high linear graphite dissemination, in contrast to temper carbon, and also to short and thick graphite flakes, brings about corrosion. In damp earth, the difference is somewhat less marked.

In conclusion, the results of quite recent researches made by E. Söhnchen in the Giesserei-Institut, which are destined to show the influence of the graphite formation upon some physical properties, are shortly dealt with.

Fig. 28 gives the structure and analysis of a test specimen cast in sand and of one chill cast. The material is ferritic annealed. Table II gives the magnetic properties, figures for heat and electricity conductivity, also a few corrosion results. The following may be added, briefly, in this connection.

The coercivity, which is comparatively high owing to the Cu content of the melt, is still

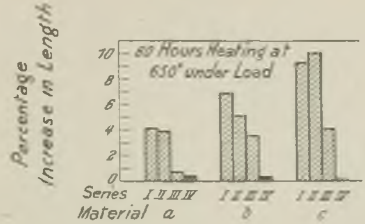

FIG. 24.—EFFECT OF VARIOUS TYPES OF GRAPHITE FROM BORNHOFEN AND PIWOWARSKY.

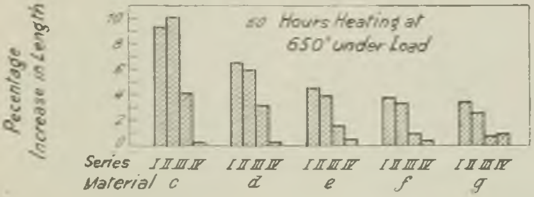

FIG. 25.—FORMATION DETERMINED BY COMPOSITION OF THE MELTS ON THE GROWTH OF VARIOUS CAST IRONS.

FROM BORNHOFEN AND PIWOWARSKY.

TABLE II.—*Effect of Graphite Formation in two Cast Irons of a similar Composition on various Properties, according to Söhnchen.*

Properties.	Sand Casting. Reheated.	Chill Casting. Reheated.
Graphite formation :	Coarse	Fine
Coercivity (Oersted)	5,6	7,2
Remanence (Gauss)	6,360	8,400
Saturation (Gauss)	18,900	18,700
Thermal conductivity (Ni=1) ..	0,94	0,69
Electrical conductivity .. .. (Ω^{-1}. cm^{-1})	$1{,}39 . 10^{-4}$	$1{,}71 . 10^{-4}$
Percentage loss in weight :		
N/5 HNO_3 (10 days)	11,0	12,4
N/5 acetic acid (10 days) ..	9,5	10,2
Air (50 days)	0,62	0,81

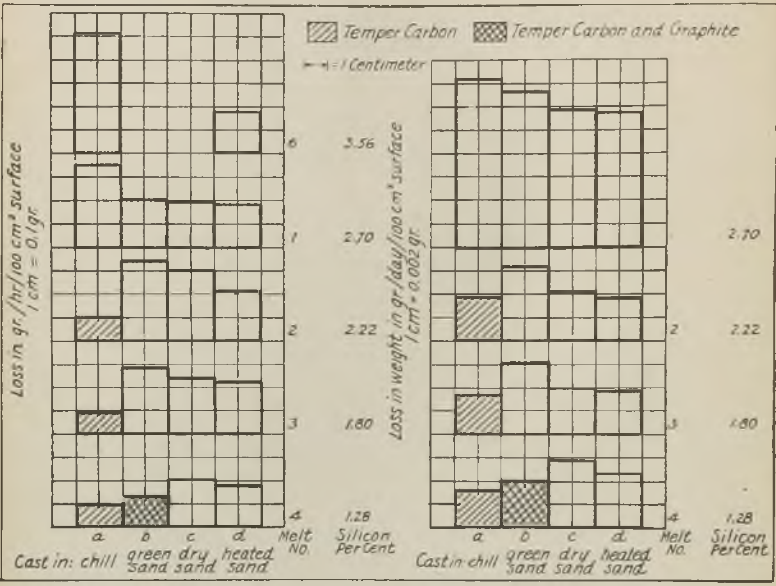

Fig. 27.—Corrosion Attack by Normal Hydrochloric Acid and Wet Soil related to Graphite Condition of Various Types of Cast Irons of the following Compositions:—

Melt No.	T.C.	Gr.	Si.	Mn.	S.	P.
6	2.8	2.80	3.56	0.41	0.025	0.059
1	3.05	3.03	2.70	0.40	0.024	0.053
2	3.04	3.02	2.22	0.40	0.024	0.058
3	3.02	3.00	1.80	0.40	0.024	0.058
4	3.03	3.02	1.28	0.41	0.024	0.054

further increased by the very fine heterogeneous components which are precipitated (graphite in chill casting), which conforms completely with observations made with various magnet steels. The remanence is also much higher with fine graphitic formations, while the saturation is not affected, which agrees with the observed effect of various carbide formations in steels. The thermal conductivity, which is affected to a much

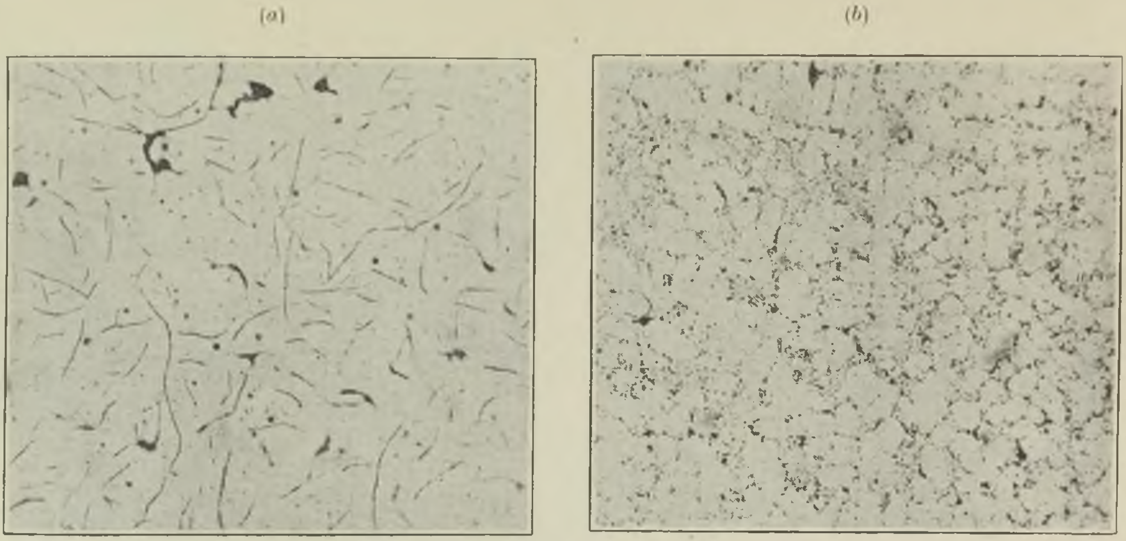

Fig. 28.—Graphite Structure of Two Cast Irons of Similar Composition (C 3.04, Si 2.28, and Cu 1.92) examined by Söhnchen for their Physical Properties. (*a*) Sand Cast, Heat Treated, Unetched. × 100. (*b*) Chill Cast, Heat Treated, Unetched. × 100.

greater degree by the particle size than the electrical conductivity, on the other hand, decreases, which is evidently mainly due to the finer nature of the ferrite grains, the electrical conductivity increases with the fineness of the precipitated components, in line with common observation.

Corrosion tests carried out on laminæ 20 mm. dia. and 5 mm. thick confirm the results of Nipper and Piwowarsky. Corrosion increases with an increase in the fineness modulus of the graphites.

REFERENCES.

[1] Tammann: Kristallisieren and Schmelzen, Leipzig, Joh. Ambrosius Barth, 1903, p. 131.

[2] Piwowarsky: Bericht Werkstoffausschuss V.D.E. No. 63, 1925. St. u. Eis, 1925, pp. 1455/61. Giesserei. 1925, pp. 836/37.

[3] v. Keil, Mitsche, Legat, Trenkler: Arch. f.d. Eisenhüttenwes, 1933/34, vol. 10, pp. 579/584.

[4] A. Reinhardt, Dissertation Aachen, 1933.

[5] H. Hanemann, Monatsblätter des Bezirksvereins Deutscher Ingenieure, 1926, pp. 31/36.

[6] E. Piwowarsky: Arch. f.d. Eisenhüttenwes, 1933/34, vol. 7. pp. 431/32.

[7] E. Piwowarsky: St. u. E., 1934, pp. 82/84.

[8] E. Piwowarsky: Giess. Ztg., 1926, pp. 379/85, 414/21. Hochwertiger Grauguss, Jul. Springer, Berlin. 1929, pp. 134 and 276. Giess. 14 (1927), pp. 253/57, 273/76, 290/95. St. u. E, 47 (1927), pp. 308/10.

[9] P. Bardenheuer and K. L. Zeyen: Giess., 1928, pp. 354/65, 385/97, 411/20. St. u. E.. 48 (1928), p. 515.

[10] A. Wagner: St. u. E., 1927, pp. 1081/82. Giess., 1928, p.921. St. u. E. (1930), pp. 655/68.

[11] P. Ramdohr: Arch. f.d. Eisenhüttenwes. 1, 1927/28, pp. 669/72.

[12] A. Koch and E. Piwowarsky: Die Giesserei, 1933, vols. 1 and 2, 3 and 4, pp. 1–13.

[13] K. Schichtel and E. Piwowarsky: Arch. f.d. Eisenhüttenwes. 3, 1929/30, vol. 2, pp. 139/147.

[14] F. Heimes and E. Piwowarsky: Arch. f.d. Eisenhüttenwes. 6, 1932/33, vol. 11, pp. 501/5.

[15] M. Fink: Org. Fortsch. Eisenbahnwes. 84 (1929), pp. 405/12. Arch. Eisenhüttenwes. 6 (1932/33), pp. 161/64.

[16] A. Wallichs and J. Gregor: Die Giesserei, 1933, No. 47/48 and 49/50, pp. 517/523 and 548/555.

[17] O. Bornhofen and E. Piwowarsky: Arch. f.d. Eisenhüttenwes. 7 (1933/34), vol. 4, pp. 269/74.

[18] P. Bardenheuer: St. u. Eis. 50 (1930), p. 74.

[19] H. Nipper and E. Piwowarsky: The Foundry, Dec., 1932.

A very warm welcome was extended to Dr. Nipper by the President (Mr. Roy Stubbs) and sincere thanks were expressed to him for having travelled from Germany to present the Paper in person. Dr. Nipper extended the greetings of German foundrymen and their good wishes for the success of the conference. He was asked to convey a reciprocal message to the German Ironfounders' Association.

DISCUSSION

Mr. A. Harley (Past-President), who welcomed the Paper as a brilliant contribution to current knowledge of graphite formation in cast iron, and expressed gratitude to Dr. Nipper, said that one of the micrographs seemed to prove that the fine graphite flakes were less resistant to corrosion than were the larger ones. That was very significant, because in automobile work one was very largely concerned with wear, and the subject of wear in cylinder barrels was closely related to corrosion. One could make sound castings with various compositions, but if there were wear in a barrel it was a bad casting—or should be. A special research by the Automobile Association had shown that wear in cylinder barrels was almost entirely a matter of corrosion. Therefore, the industry had to find an iron which not only would give a sound casting, but which would resist corrosion. Small graphite flakes were not necessarily good in cylinder iron if they were more liable than larger flakes to oxidation and corrosion during the working of the engine; so that he emphasised the point, which was a new one, and which should claim special attention. Mr. Harley also asked if Dr. Nipper had information as to the effect of small percentages of copper in cast iron, in relation to its resistance to corrosion.

Factors Influencing Wear Resistance

Dr. Nipper replied that he had not yet carried out experiments on the influence of copper in cast iron by testing samples with and without copper from the point of view of corrosion, but had merely considered it from the point of view of the amount of graphite.

Discussing the influence of the size of graphite flakes upon resistance to wear and corrosion, he pointed out that a certain amount of graphite must be present in all cast irons in order to facilitate pouring and machining. If the total carbon were all brought to one point only there would be a very big ball of carbon, and the iron would break at that point. The other extreme was to distribute the carbon as finely as possible by having a completely undercooled material; but that also was not a good thing. Between these two extremes there must be the optimum condition. The chief consideration was that the surface area of the graphite must be very small as compared with the total quantity of graphite present, and under those circumstances the wearing properties of the material were very good. There were different kinds of wear; for instance, depending on whether the material was rubbed or rolled, the wear was different. In most cases surface oxidation caused the trouble. The best wearing material was one containing not too much graphite and not too much silicon, but having a very well-developed pearlite and short but fairly strong graphite flakes in this pearlite. One could not produce temper carbon initially, but only by annealing afterwards. If one started from the fluid state the best one could do was to produce short but fairly heavy graphite flakes, so that the surface area of the graphite was very small as compared with the total quantity present.

Importance of Melting Conditions

Mr. J. G. Pearce (Director, British Cast Iron Research Association) contributed, not merely because of his own personal friendship with Dr. Nipper, but also because the author represented one of the leading metallurgical schools on the Continent; undoubtedly the leading school on the Continent in respect of research into foundry work.

The Paper might seem to be very highly technical, but it was valuable. Founders were vitally interested in the strength and mechanical properties of cast iron, and the strength was very largely governed by the structure. At one time it was thought that the strength was governed mainly by the composition; but the composition was only one of several factors affecting this matter. In this connection he recalled a Paper presented some years ago by Dr. Norbury, in which was demonstrated very clearly the effect of melting conditions; by changing those conditions, Dr. Norbury had produced, from the same composition, irons of totally different structures, and he had produced micrographs not dissimilar from some of those shown by Dr. Nipper. The fine-graphite structures then produced were referred to by Dr. Norbury as supercooled-graphite structures, being the result of a supercooling action in the melt itself. Invariably there was a temperature (or range of temperature) over which a melt normally solidified, and it was well known that, if the conditions permitted, a melt would fall below that temperature or that range before it solidified, the extent of the drop being the extent of what was called "supercooling." The structure altered with the extent of the supercooling, so that the mechanical properties and the strength altered correspondingly, and that was why the conditions described by Dr. Nipper concerned the foundry so much.

Factors Governing Supercooling

The law due to Tammann, and referred to at the beginning of the Paper, was that the number of centres of crystallisation which formed in unit volume in unit time measured the tendency to spontaneous crystallisation, and it was called the "nuclei number," represented by the letters "KZ," from the German "kernzahl." The linear crystallisation velocity was a measure of the speed of formation of these nuclei, and it was known in German as "KG"—"kristallisation geschwindigkeit." It was on the magnitude of these two and their ratio to each other that the extent of supercooling depended. An ordinary iron which did not need to be melted to a very high temperature before it was poured—an ingot-mould iron, for example, going into a thick section did not need to be melted to very high temperature—supercooled very little; but if an iron had to be superheated, then the tendency to supercooling, *i.e.*, for the solidification temperature to fall below the normal solidifying temperature, increased, because superheating tended to rid the melt of inclusions of graphite and particles of slaggy matter which in the ordinary way would promote crystallisation. If this supercooling action were pushed to its limit, and if the metal were quiet and free from ebullition (particularly obtained under the condition of Dr. Nipper's vacuum melts), one obtained the fine sooty structure which had been called supercooled graphite.

Utility of Supercooled Graphite

It had been shown, from the point of view of corrosion and wear, that this structure was not very desirable. It was curious that it should be bad to have either an extremely coarse graphite or an extremely fine graphite. That fine graphite was useful for some purposes, but not for most of the purposes for which cast iron was used, and it was to overcome the tendency towards supercooled graphite that the idea of inoculation was developed. It was illustrated in such irons as Nitensyl, which was nickel inoculated, and Meehanite, which was calcium-silicide inoculated, giving tensile strengths from 25 to 30 tons per sq. in.

The Inoculation Process

The essential feature was the inoculation of the white or mottled iron while still molten, and inoculation, which the Germans called "after-siliconisation," was of great theoretical interest. In this country there had been a tendency to regard after-siliconisation, or inoculation, as destroying the effects of supercooling; in other words, we had regarded superheating as promoting supercooling, which tended to produce this undesirably fine graphite, and inoculation was a commercial and practicable remedy against its effects. On the other hand, the Germans regarded after-siliconisation, or inoculation, as promoting supercooling. It was quite possible that both the Germans and ourselves were right, *i.e.*, that in the irons with which we had been working the inoculation destroyed the supercooling effect, whereas in the case of the irons with which they were working, in the conditions in which he was working, and with his plant and resources, the reverse was the case. Possibly we were converging on the truth, and should be able later completely to explain this extremely complicated problem. In this country we had stated all along that the inoculation theory did not quite explain everything that happened in these irons. Fundamental work of this very important kind, however remote it might appear to be from everyday practice, would result in a fuller and truer understanding of an extremely complex and very remarkable material, and a debt of gratitude was due to Dr. Nipper, not only for having prepared the Paper, but also for having come to this country to present it in person.

The Nature of "Kish"

Dr. A. B. Everest, after an expression of appreciation of the Paper, said there were one or two points which he found a little puzzling, and in connection with which he would like further information. In the first place, referring to the coarse-graphite flakes which Dr. Nipper had called "Kish," he gathered that these were flakes of hyper-eutectic graphite of a peculiarly-coarse form, and which must therefore have formed in the iron prior to solidification. As shown in the photomicrographs, these flakes were all straight and well developed, and Dr. Everest asked, therefore, why the graphite in ordinary cast iron, some of which was generally considered to be hyper-eutectic, was always curly and distorted and showed no evidence of a crystalline form such as indicated by the flakes shown by Dr. Nipper, even after they had been broken up.

Dealing further with the form of the graphite flakes, Dr. Everest expressed particular interest in the photographs taken by polarised light. He had understood that the ordinary graphite flakes in cast iron, although ultimately crystalline, were of such fine structure that they could be considered as amorphous. He recalled the experiments carried out some time ago by Moissan in which, by forcing crystallisation to take place under great pressure, the carbon separated as small diamonds, and he gathered that these diamonds were of a different atomic structure from ordinary graphite. One would expect a diamond to respond to polarised light and to show crystallographic effects such as illustrated in the Paper. One would not expect, however, that the ordinary graphite flakes in iron would show this effect, and he would therefore like to ask Dr. Nipper whether the "Kish" graphite shown could be considered as structurally similar to the ordinary graphite flakes since, if so, then there was definite evidence here of the graphite in cast iron being more definitely crystalline than is normally supposed.

Commenting upon the white bands around the graphite flakes, shown particularly in Fig. 2, Dr. Everest said that usually, when examining ordinary commercial iron under the microscope, one found bands of ferrite and not pearlite around the graphite flakes. One could see, however, in the particular instance shown in Fig. 2, that the pearlite had been formed there in preference to ferrite; but a point which Dr. Nipper had not referred to, to any great extent, was the fact that, by supercooling, one very often obtained ferritic structures, rather than pearlitic. In some experimental work Dr. Everest had found that, with an iron which would give an all-pearlitic structure in a ½-in. section, one obtained, in a ⅛-in. section, nests of graphite-ferrite structures, and in some centrifugal castings and other chill castings, one obtained the same structure where normally one would expect to get the more ordinary chilled structure. Prof. Hanson had suggested the theory that ferrite started life as Delta iron in the top left-hand corner of the iron-carbon diagram. Dr. Everest mentioned that Dr. Nipper had not apparently referred to this effect on supercooling, and he asked whether this phenomenon had come under Dr. Nipper's experience and, if so, what were the conditions and in what way they had differed from those involved in the present experiments. In this connection he referred to some experiments he had carried out with iron developed by Schutz, in which a hyper-eutectic composition was cast into a chill mould. By casting what would normally be a very soft iron in this manner, one could get a very dense iron showing the ferrite-graphite structure such as that in Fig. 6.

Structural Strains and Strength

He had been looking for a high-strength result, hoping to get an iron of something like 25 tons, but he had found that the strength was only about 13 or 14 tons, which was disappointing. It had been stated both by Mr. Pearce and Dr. Nipper that these ferrite-graphite structures were not desirable, that they had no good corrosion resistance, that they were weak, and so on; Dr. Everest asked whether the reason was that the structure was atomically strained. He believed his own results had shown that one obtained a hardness of about 200 Brinell with that structure, whereas, judging from the constitution, the figure should be much less. Similarly, if the structure had been somewhat akin to malleable iron and there was fine graphite, one would expect much higher strengths. Therefore, he suggested that the change was due to the strain in the structure resulting from supercooling, and he asked if experiments had been made on the effect of annealing in order to find out whether, by removing the strain, one obtained better properties in the iron.

Mr. J. S. G. Primrose, referring to the importance of the examination of structures by polarised light, which was comparatively new in this country, said he had had to use that method in distinguishing between basic and acid steels; and he emphasised that one was not using the usual form, transmitted polarised light, but reflected polarised light, which was very different; and yet it had been capable of giving indications of strain in a material. When the material was unstrained one obtained a uniformly-reflected polarised-light image, but when the material was strained it gave an irregularly-shaded image, which was very important as showing that the graphite in the kish was crystalline. He had had the idea that the very fine nodular graphite which was called "sooty" graphite, as it resembled soot or dust in size, would be non-crystalline, but, of course, the polarised light would be able to reveal the truth. He gathered that undercooling really meant the same as supercooling, and he asked whether the graphite which came out under those conditions was truly crystalline. The point was that Dr. Nipper had been able to secure a very fine precipitation by means of melting in vacuum. This "sooty" graphite could be brought about by other means; for instance, the presence of titanium in the pig-iron had occasionally given irons in the pig form which were completely malleable. One did not associate that with ordinary primary or secondary graphite, and usually when one obtained a malleable pig and examined it one found the "sooty" graphite He asked if Dr. Nipper could confirm that all forms of graphite—the primary (kish), the secondary (either straight or curly graphite flakes) or the tertiary form (supercooled)—were crystalline.

Dr. A. L. Norbury (British Cast Iron Research Association), who welcomed the photomicrographs in the Paper as being among the most instructive and interesting ever published in connection with grey cast iron, discussed some work which had been carried out by the Cast Iron Research Association in Birmingham during the past 18 months. The endeavour was to find out what caused the difference, not revealed by chemical analysis, between two pig-irons from two different furnaces. This fact had long been recognised by foundrymen—and incidentally they were not always believed. Makers of chilled rolls had insisted that iron from hot-blast as against cold-blast furnaces gave different chills and different quality to the rolls, even though the chemical analysis was apparently identical. Similarly, Mr. F. J. Cook, in a Paper presented to the Institute several years ago, had shown that two pigs from different furnaces gave considerably different strengths in engineering castings, although the analyses were again apparently identical. It had now been accepted that such differences exist, and the work by Dr. Nipper and Prof. Piwowarsky at Aachen, together with that of other investigators elsewhere, had shown that the superheating of the melt could produce such differences and could produce the very fine graphite flakes shown in Dr. Nipper's Paper. The work at Birmingham, however, had shown that the same fine graphite flakes could be produced in other ways without superheating. The investigators produced at will these very fine graphite flakes on quite heavy sections without superheating or chilling, and could also change the structure back into very coarse graphite flakes without altering the ordinary chemical analysis. They now knew the reasons for the difference between irons of the same ordinary chemical analysis. Dr. Norbury regretted that he could not give a detailed account of the results yet, but he hoped that that might be possible in the near future.

Dr. Nipper's Paper contained mostly facts, and it was difficult to find anything in it with which one could disagree; but he took the opportunity to express his great appreciation of it.

Process and Structure

Mr. A. Campion, who recalled that Dr. Nipper had attended the Institute's Conference in Sheffield in 1927 with Prof. Piwowarsky, and commented upon the pleasure of seeing him again, said the Paper was of extreme interest, and he was not sure that it was quite so purely scientific as some speakers were apt to think; it had certain practical applications. Some references he had made on the previous day to viewing cast iron from a different angle under different melting conditions were borne out by Dr. Nipper's Paper. The effect which had been referred to as supercooling or undercooling was not quite correctly called supercooling or even undercooling.

In the course of his practical experience with rotary furnaces it had led to some very curious results; and he believed he had seen there a confirmation of what Mr. Pearce had said about siliconisation, that it was acting in both ways, and that sometimes the sooty kind of graphite produced undesirable results, whereas in other cases this particularly fine graphite gave remarkably good results from the point of view of strength.

AUTHOR'S REPLY

Dr. Nipper replied to the discussion. After expressing his appreciation of the manner in which his Paper had been received, he dealt with the question as to why the graphite in pig-iron or in grey cast iron was not crystallised very well. The kish was produced crystallised in the fluid material, so that the kish graphite would have considerable crystal size; but the graphite that was produced in the more or less liquid state in the small solidifying temperature range had to find a place between the austenite crystals and acquired the shapes of those spaces.

Dr. Everest said some of the graphite which formed in ordinary cast iron was very often hypoeutectic, as was the kish graphite, and he was asking why the former did not come out in the straight form, because it formed when the material was solidified or was partly molten. He might be wrong as to the way in which the graphite separated.

Factors Influencing Crystal Shapes

Dr. Nipper said he believed the shape of the graphite crystals depended on the time in which it was produced, the time in which the metal remained fluid. He had not carried out experimental work to discover whether or not the very fine graphite was really crystalline, though in his own mind he felt sure that it was. In the case of coke, one found the same thing. Prof. Ramdohr, at Aachen, had carried out experiments to find the difference in cokes of different reactivity, and he had found that it was just a question of the size of the graphite crystals in them. One found very small and very large graphite crystals in coke, depending on the temperature and the time of coking, and that might be responsible, in the first place, for the different reactivities of the cokes. He felt certain that there would be a similar experience in connection with iron; that the kish and the very sooty graphite were both crystalline. The expression " sooty " was a very good one; in Germany the expression " Russartig " was used, and it meant resembling soot. When the material was broken the fracture was absolutely black. The experimental work would have to be continued, though the polishing and examination of the very small graphite was not very easy. The temper carbon was built up somewhat differently. There was a point in the middle where the first temper carbon came out, and the other temper carbon was brought there from the side. The structure of the graphite parts was perpendicular to the radius of the temper carbon ball, and one had to determine whether the graphite was formed when in the fluid state or when in the solid state.

Conditions Appertaining to " Sooty " Graphite

In most cases, if there were a very sooty graphite, the matrix was ferritic, and he believed the reason was that there were large nuclei for the break up of the pearlite, and the carbon could very easily get to the graphite, which, by reason of its small size, exposed greater surface area. He had not carried out much experimental work on this matter, but he believed much depended on the amount of silicon present, and on the rate of cooling. At first he was astonished, but he had found that the whole matrix of most of his samples was definitely pearlitic.

With regard to the qualities of the material, he believed an explanation had been given that the primary dendrites grew first and continued growing when the remaining solution was already eutectic; then the material became hypo-eutectic and was brought to a small network, and afterwards the whole material had the quality of the spaces between the austenitic dendrites, where the material was in reality hypo-eutectic and the quality was very poor. So that one had not the whole of the material of the quality which one would expect according to the composition, but had the quality only of the small networks where it was hypo-eutectic.

He had not been able to carry out experimental work as to stresses in the small samples dealt with, which weighed only a few hundred grammes, and which were made in a small carbon crucible. They were not made purposely for the investigation of strength and hardness or stresses, but for determination of gases, such as hydrogen, nitrogen and oxygen. Incidentally, he had cut them open and polished them in order to see the internal structure.

OVEN-DRYING OF CORES AND MOULDS

By E. G. Fiegehen, M.I.Mech.E. (Longueil, P.Q., Canada)

Cores and moulds, as moulded ready for baking, contain sand, water and binders. Of these, the water is essential for mixing with the bonding material, such as clay, corn binders, starch, etc., into a plastic condition, so that, when milled with the proper amount of sand, a mixture is produced that is sufficiently plastic to be used for moulding and sufficiently strong, before baking (green bond), to retain its shape and to withstand handling on its way to the oven. The process of blending sand with binders and water is called " tempering " the sand, and the proper percentage of components and intimate mixing, in an efficient mill, is essential to success.

The object sought in milling and tempering sand is to cover each individual grain of sand with a thin coating of the binder. The binders have a tendency, in baking, to concentrate at the points of contact of adjacent sand grains, cementing these together and leaving air spaces between the grains, giving the desired porosity to the finished core to permit of the escape of steam and gases formed during the pouring of the mould.

If too much binder be used, or a binder unsuited to the purpose, it will wholly or partially fill up these necessary voids between the grains, and thus reduce the porosity of the core; if the sand be insufficiently milled the distribution of the binder will not be uniform and some portions will have low porosity, due to concentration of binder, whilst other portions will be insufficiently bonded; in any case defective castings will be produced.

Water as Aid to Baking

The tempering water also serves a further useful function as a conductor of heat to the interior of a core or mould, in the baking process, for when heat is applied to the outside of the core by the hot gases in the oven, it passes through the water in the core twice as easily as it does through the sand grains owing to its superior heat-conductivity. In G.G.S. units the average conductivity of still water is 0.0014 whilst the conductivity of sand is 0.0006, giving a ratio of conductivity in favour of water of 2.33 to 1.

The presence of the binder will probably modify the conductivity of the sand but, to illustrate this point, it may be said that the conductivity of water in a core is at least twice that of the sand. The presence of core-rods or core-arbors in a sand core provides an excellent medium for the rapid transmission of heat into the interior, for the conductivity of steel is very much greater than water. It is therefore desirable to retain the water in the core during the preliminary stages of drying so that the temperature at the centre of the core may rise to the boiling point of water.

Types of Binders Used

The binders used are gummy or adhesive substances such as clay, a mixture of corn-starch, flour, molasses, etc., or various core-oils, depending upon the application of the core. The binders are intended to cement the grains of sand together at their points of contact; baking greatly increases this cementing effect and produces strong cores that may be easily handled and fitted in place and which will resist the stresses imposed upon them in casting as well as the scour of the molten metal, whilst being of such a nature that, after casting, they may be broken up and readily removed in the cleaning operation, leaving a smooth surface on the casting.

It will be obvious that upon the proper selection of sand and binders for cores and moulds much of the success of the foundry operations will depend. Pitch has been used as a binder, but it does not give a "green bond," neither does it mix with water, and consequently it does not become a real binder until melted by the heat of the oven.

How Linseed Oil Acts

Raw linseed oil is an excellent binder and is extensively used. If linseed oil be kept in a closed bottle it will not dry up or "set," but if it is spread out, thinly, and exposed to the air, particularly hot air, it will dry up slowly by oxidation, whilst if hot air is blown upon it, it will dry up more rapidly.

According to the American Foundrymen's Association—oxidation of linseed oil is slow up to 350 deg. Fah. (176 deg. C.) but very much faster from 350 to 450 deg. Fah. (176 to 232 deg. C.). At 500 deg. Fah. (260 deg. C.) the qualities of the oil are destroyed. For oil cores (baking temperature 350 to 450 deg. Fah. (176 to 232 deg. C.) it has been found that a minimum of 1,000 cub. in. of air is necessary to oxidise the oil and produce maximum strength in cores weighing 1 lb. and containing 2 per cent. by volume of linseed oil. A baking time of 90 min., at 425 deg. Fah. (218 deg. C.), produces maximum strength of core 1 in. thick.

Hot air is used for drying moulds and cores, since it has a great capacity for absorbing water; at atmospheric pressure and 200 deg. Fah. (93 deg. C.) 1 lb. of bone-dry air will absorb about 2.3 lbs. of water vapour before reaching its saturation point. The temperature of the air must be regulated to prevent over-heating and the destruction of the binders used and no direct flame or intense radiant heat should come in contact with the cores in the oven. When the cores have been heated by the hot air, to the boiling point of water of atmospheric pressure (212 deg. Fah. or 100 deg. C.), the moisture in the cores is converted into steam which escapes through the pores of the sand core to the surface and out of the oven through the vents.

Hot air is especially useful in the drying of cores since, owing to its capacity for absorbing water, a current of hot air acts like a sponge passing over the wet surface of the mould or core, carrying the water away with it, to be followed by the passage of fresh dry air to continue the process. Thick cores take longer to dry than thin ones, for the reason that the heat has further to penetrate to the centre and the evaporated water takes longer to reach the surface; an increased temperature cannot be used to hurry the operation, otherwise the binders will be burnt and the core will be useless.

Mould and Core-Drying Compared

Nearly the whole surface of a sand core, if properly loaded in the oven so as to ensure efficient circulation, is exposed to the oven gases, whereas a mould being partly enclosed in a flask generally exposes, freely, only one face. Consequently, it takes appreciably longer to dry a mould than a core of the same weight and thickness of sand, for again the heating cannot be hurried for fear of damaging the mould.

Until the binders have "set," cementing the grains of sand together firmly, a core has very little mechanical strength, and will readily crack on the sudden application of heat, owing to unequal expansion of the hot surface and cold interior or, possibly, owing to the expansion of water or steam trapped between the sand grains of a dense core, forcing them apart; both these evils may be caused by too rapid heating.

To dry cores and moulds successfully, without surface cracking, a moderate oven temperature, determined by experience and carefully controlled, is essential, and it is now recognised that three distinctive stages of drying have to be arranged, as set out below.

Period I.—Constant Rate Drying

During this first period of drying, the surface of the core is wet and the effect of heating from the outside is to cause some of the water in the interior of the core to travel to the surface, where the surface tension has been lowered by heating. The heat of the oven gases causes this surface water to evaporate, but so long as any water remains on the surface, the temperature of the wet surface cannot rise above the boiling point of water (212 deg. Fah.—100 deg. C.), however hot the oven gases may be.

This may be difficult to realise, but it is most important and can be proved by an experiment of placing a paper bag containing water over a gas flame. So long as any water remains in the bag the paper will not be burnt, but when all the water has been evaporated, the bag burns immediately. In the same way the wet surface of a core acts as a heat shield to it, preventing the temperature rising above 212 deg. Fah. (100 deg. C.), at which temperature cracking is not to be feared. At this stage it is desired to get heat into the body of the core but to make no attempt to dry it.

The water in the core is a much better conductor of heat than either sand or air, and consequently the proper method is to make use of this property of water by retaining it in the core until it is heated throughout. To this end, it is best not to allow the moisture-laden air in the oven to escape, at this stage, but retain it and circulate it, from top to bottom of the oven, to ensure a uniform temperature of all cores in the oven and to preserve a damp atmosphere, which will retard evaporation of the surface-water on the cores.

If there were no circulation, the hot air would rise and remain at the top of the oven, as it does in a heated room, leaving the cores on the lower shelves comparatively cold, and if the moist air in the oven be allowed to escape, the water-shield on the surface of the cores would disappear. When the cores are heated evenly to the centre, which can be ascertained by a trial of dummy cores, there is no further need for the internal water in the cores and the process is ready for the second stage.

Period II.—Saturated Surface Drying

In the first period no attempt was made to dry the cores, but suitable conditions were arranged for heating them, throughout, rapidly and safely by the aid of their contained water and whilst they were shielded from overheating by their wet surfaces. In this second period the real drying is to be effected. The flues are opened now to allow the moisture-laden air to escape, and the circulating fan draws in fresh air, to be heated and to absorb moisture from the surface of the cores and pass out through the pipe with this moisture.

The evaporation of water, in contact with moving air at a given temperature, varies almost directly as the velocity of the air, and it is found that an air-current striking a surface at right angles is about twice as efficient, in evaporating water, as a current passing longitudinally over the surface. The protecting film of moisture will gradually disappear and the temperature of the oven must consequently be reduced, during this period, for fear of burning the binders and causing cracks in the now unprotected cores.

It is found that the circulation of a large volume of air at a moderate temperature is more effective and safer than the use of a small quantity of very hot air. As the moisture is evaporated from the surface of the cores, fresh moisture from their interior travels to the surface, is evaporated, and passes out of the oven.

Eventually the surface dries up and then, the water-film insulation effect being removed, the whole core rises in temperature nearly to that of the hot gases. This rise in temperature, together with the presence of fresh hot air—containing oxygen—which can now penetrate the pores of the dry core, causes the binder to dry and oxidise and cement the grains of sand firmly together, giving the necessary dry strength to the core.

There will still remain a small proportion of moisture in the interior of the core, and to evaporate and remove this there is a third stage.

Period III.—Sub-surface Drying

The whole body of the cores are now well above the temperature corresponding to the boiling-point of water, so that, in this period, the heat in the cores themselves is sufficient to evaporate the small amount of moisture remaining in the interior, which passes out of the core through the pores in the sand. Consequently only sufficient air circulation is now required to carry off this reduced flow of steam, and only a small amount of heat need be supplied, by the furnace, to maintain the temperature of the oven; the flues must still be open sufficiently to allow the steam to escape. Recirculation may be stopped in this period, for all the cores are now uniformly heated, and the binders are " set " by the oxygen in the air supplied in the previous period.

Summary of Operations

Period I.—Rapid heating—Vigorous recirculation with fan—Air-inlet flues closed—Continued until the interior of all cores reaches approximately 212 deg. Fah. (100 deg. C.).

Period II.—Reduced heating—Moderate recirculation — Air-inlet flues open — Continued until the surface of cores is thoroughly dry and binders are set.

Period III.—Minimum heating—No recirculation—Air-inlet flues partly open.

Core Ovens

The earlier examples of core ovens were constructed of building-brick, and generally coal-fired, with primitive flue arrangements and control, and no provision for recirculation to speed the drying and equalise the temperature in all parts of the oven. Comparatively high temperatures were used, and the top of the oven was much hotter than the bottom. The loss from cracking and burning was naturally high, and to complete the baking the lower cores had to be transferred to the upper shelves.

In all modern (Canadian) steel foundries newer types of ovens, embodying the principles outlined above, are being installed with most satisfactory results. The shell of such ovens generally consists of steel plating, in panel construction, between which insulating mattresses of rock-wool, or insulating bricks, are inserted to minimise loss of heat from the external surfaces. The economical thickness of insulation can be determined by comparing its cost, spread over its useful life, with the fuel saving effected by its use over the same period.

In average practice, a thickness of 4 in. of insulation is found satisfactory. Such ovens are most frequently fired by oil or gas as being more easily controlled and involving less labour than coal firing; the combustion chambers of firebrick are preferably located below the oven, thus saving valuable floor space.

The flues from the combustion chamber to the interior of the oven are located and dimensioned so as to ensure a uniform distribution of the combustion gases. To each oven an exhausting fan is fitted, driven by a motor and arranged to draw, through ducts, the hot air and gases from the top of the oven and discharge them at the bottom of the oven, equalising the temperature in the chamber effectively. By this means a circulation of from ten to twenty times the net volume of the oven is secured according to requirements. Owing to the high temperature of the gases passing through the fan, water-cooled bearings are necessary.

As an alternative to a fan, a series of air-blowers of the ejector type have been tried, and have given satisfactory results when operated by compressed air from the shop mains. As against the somewhat greater cost of power with this method may be set the low capital cost and reduced maintenance. A simple type of single-cone blower used for this purpose was found, on test, to induce about 10 cub. ft of oven gases for each cubic foot of free air, compressed to 60 lbs. per sq. in. Better results may be expected from a multi-cone design of blower.

Loading Considerations

Most of the core and mould-ovens installed in Canadian steel foundries are of the car-type, the core plates being placed on core racks, which, in turn, are loaded on wheeled cars and run into the oven. By the use of two cars per oven, one can be loaded whilst the other is in the oven, in the case of large-mould ovens the car-type is extremely desirable to permit loading by a crane, although, in some instances, a removable oven-roof permits this to be done and saves the space occupied by car tracks. The car-type design has the disadvantage that the car itself occupies an appreciable volume of oven space and absorbs a quantity of heat, unprofitably. Sometimes core racks are loaded into the oven by electric—or petrol—lift trucks, and then the utilisation of oven space is much better, and crane-handling of racks is eliminated.

Core Plates

Modern core plates are of welded steel, ribbed and perforated construction, and are equally as strong as the old-fashioned thick cast-iron plates, but weigh much less and consequently absorb less heat. For certain cores, aluminium holders, carriers or " driers " are provided, in which the core is moulded and in which they remain whilst baking; this makes it unnecessary to consider the " green strength " of such cores, the binders in which can be chosen with more particular regard to final strength and porosity.

Substantial savings may be effected by a careful consideration of the handling and loading of cores; with regard to the latter it is quite obvious that the arrangement of the oven-car, core-plates and cores in an oven has an important effect upon the movement of the gases therein, all being obstructions in the flow of the circulating gases.

Control Experiments

A survey of temperatures, at various points in actual operation, may indicate obstructed circulation and suggest some re-location of duct openings or rearrangement of the cores on the trays. Useful information regarding the flow of the gases may be obtained by illuminating the interior of the oven with electric lamps arranged to project their light through openings and then observing, through other openings, the movement of smoke, introduced into the combustion chamber for the purpose.

In this matter of uniformity of temperature, it is important that oven doors should be close-fitting, for, owing to their large perimeter, a small opening will admit a large quantity of cold air.

Doors should be fairly flexible, laterally, to reduce the tendency to warp, due to the difference in internal and external temperature; the forces set up by unequal expansion are large, but they cause little distortion of a door deliberately made weak in the bending plane.

The provision of numerous hinges, properly aligned, and well-designed latching gear which will force the flexible door to its seat, is essential, and the sealing of the bottom of the doors should not be overlooked. It is useless to try to control the flow of gases and temperature-equalisation in the oven if the leakage past the door varies in quantity and location with each batch of cores baked.

Temperature Control

All core ovens should be provided with indicating and recording thermometers; the records properly numbered and dated, are most useful in indicating the efficiency of the operator and in tracing subsequent trouble to its source. It is desirable to have several thermometers, located at various points in the oven, even if, as usual, one only, at a selected spot, is relied upon for normal records and perhaps control. The comparison of the temperatures at various points will indicate the efficiency of the circulation in the oven. Where automatic temperature control is fitted to an oven, means must be provided to give the temperature appropriate to each period of drying, as previously indicated above.

Continuous Core Ovens

Continuous core ovens have been found very satisfactory and uniform in performance for the drying of large quantities of small- and medium-size cores, all requiring the same period of baking. The cores are placed upon trays suspended from a slowly-moving chain conveyor, arranged horizontally or vertically and are baked whilst passing through a heated chamber to the unloading station.

The time of baking is regulated by the speed of the chain, which is adjustable; re-circulation and the necessary variation in temperature and venting, as required, can be arranged and the addition of a good conveyor service, for loading and unloading, makes a very efficient installation, and, in the case of the vertical type, very little floor space is occupied.

Heat Supply

The amount of heat to be supplied to a given oven will depend upon the weight of the cores, core plates, car, etc., that have to be heated, the moisture content of the cores, binders used, and a number of other factors. In providing heating apparatus on the installation of the oven, a loading will have to be assumed that will call for the maximum demand for heat and air circulation. The variables entering into this problem are numerous, and it is hardly to be expected that the result of calculation will be exact, but if care is taken to obtain accurate information regarding the loading of the oven and judgment is exercised in the selection of coefficients and the application of a factor to cover the effect of leakage, variable room temperature and air humidity, the result should be reasonably close to the actual performance.

In calculating the heat required to bake a given charge of cores or moulds, we may summarise the following major items:—

Assume that the cores, as moulded contain by weight:—

	Per Cent.
Sand and binder	87
Water	8
Core rods	5

Oven Temperatures.

Period I.—450 deg. Fah. (232 deg. C.).
Period II.—300 deg. Fah. (149 deg. C.).
Period III.—450 deg. Fah. (232 deg. C.).
Room temperature, 60 deg. Fah. (15 deg. C.).

Item 1.—Heat required for sand.

Temperature rise, 450-60 = 390 deg. Fah. (217 deg. C.).

Approximate weight of dry sand, as rammed, 125 lbs. per cub. ft.

Approximate specific heat, 0.195.

B.T.U. = Weight of cores (lbs.) × 0.87 × 390 deg. × 0.195.

Item 2.—Heat required to evaporate moisture in sand.

B.T.U. = Weight of cores × 0.08 × 1122.

Item 3.—Heat required for core rods.

Temperature rise 450 − 60 = 390 deg. Fah.

Specific heat of steel = 0.165.

B.T.U. = Weight of cores × 0.05 × 390 deg. × 0.165.

Item 4.—Heat required for core plates and racks, oven truck and rails, internal ducts, etc.

Temperature rise 450 − 60 = 390.

B.T.U. = Total weight of steel and iron × 390 deg. × 0.165.

Item 5.—Heat required for oven structure (steel plating with enclosed insulation). Mean temperature at equilibrium will depend upon construction and can be found from tables of external temperature and surface loss.

B.T.U. = [Wt. of steelwork × (mean temperature − 60) × 0.165] + [Wt. of insulation × (mean temperature − 60) × 0.20].

Item 6.—Heat required for brickwork of combustion chamber and ducts to oven.

This is a really difficult item, owing to the great weight and high capacity for heat of the brickwork.

This is further complicated by a variation of both its specific heat and conductivity with temperature.

Owing to absorption of heat, it may be 4 or 5 hrs. before the heat from the combustion chamber penetrates to the outside of its firebrick wall.

The consequence is that there is a greater demand for heat in the first heating of the oven than for succeeding heatings. As against this, there is less loss from the external surfaces of the brickwork on the first heating than in subsequent heatings.

However, some approximation must be made, and it will be assumed that the mean temperature of the brickwork, during the first heating, is $\frac{1}{3}$ (450 − 60) = 130, giving a temperature rise of 130 − 60 = 70 deg. Fah. Then B.T.U. (approx.) = weight of brickwork (lbs.) × 70 deg. Fah. × 0.20 (average). For those desiring a closer approximation of the heat absorbed by a brick structure, there exists a fairly simple graphical method of plotting time-temperature curves and hence the heat demand on a time basis.*

The relative magnitude of the above rough approximation to the total heat demand of the oven will indicate whether this refinement of calculation is justified, bearing in mind that, for its first oven heats, considerable latitude, in oil supply and time of baking, can generally be obtained.

Item 7.—Heat required to replace radiation and convection losses from external surfaces of oven and ducts.

The external loss coefficient in B.T.U. per sq. ft. per hr. can be found approximately from tables when the wall construction and the internal and external temperatures are known.

The heat loss from horizontal surfaces, such as the roof, facing upwards, is generally taken as 10 per cent. greater than for the vertical faces. If a current of air be blowing on the surfaces, the loss will be increased.

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* W. Trinks—Industrial Furnaces. J. Wiley & Sons.

Item 8.—Heat to replace losses from exterior of combustion chamber walls. As noted above, this loss for the first 4 or 5 hrs. will be nil. After that time, an allowance of one-half the loss per sq. ft. per hr. of the oven walls will be ample.

Item 9.—Heat to raise the temperature of the circulating air. Temperature rise, 300 to 60 = 240 deg. Fah. Changes of oven volume per hr. = 20. Specific heat of air, at constant pressure = 0.24 (approximately).

$$\text{B.T.U.} = \frac{20 \times \text{net volume of oven (cub. ft.)} \times \text{hours recirculation in operation} \times 240\text{ deg.} \times 0.24}{19.6\text{ (cub. ft. per lb. at 300 deg. Fah.)}}$$

Item 10.—Heat required for heating the air for combustion at the burners (which leaves the oven at approximately 450 deg. Fah.).

This is a comparatively small item, since only about 22 lbs. of air are required for the combustion of 1 lb. of fuel oil.

In the case of oil-fired oven, where the products of combustion pass direct into the oven, give up a large proportion of their heat there and pass out at the vents at, say, 450 deg. Fah., the " stack loss " is much smaller than in the case of, say, annealing furnaces where, owing to the conditions, the gases have to leave the furnace chamber perhaps at 1,850 deg. Fah. (1,010 deg. C.); consequently, the efficiency of combustion in oil-fired ovens is higher than in annealers, the oven acting, in fact, as a heat recuperator for the combustion gases.

Referring again to Item 9, it may be remarked that the heat required for raising the temperature of the circulating air in Period II, together with the heating of a certain amount of cold air leaking into the oven in Period I, may often equal the heat actually required for heating the cores and driving off their moisture. It is important, therefore, to ascertain, by trial, what volume of circulation is actually needed for satisfactory results, in baking and hardening the cores that the oven is designed to handle.

Any excess of circulation would certainly do no harm, but it obviously represents a wasteful expenditure of heat and power to drive the fan. Only comparatively small cores need to be baked bone-dry throughout. In cores of appreciable thickness (say, over 2 in. thick), only 2 or 3 in. below the surface need be bone-dry, for the general run of work; at 6 in. deep there may be, perhaps, 1 per cent moisture and at 10 in. deep, say, 3 per cent. moisture without detriment.

Such cores, however, should be used shortly after leaving the oven, for, if they are stored there is the obvious risk of the contained moisture travelling outwards to the surface, by capillarity. Any cores kept in stock will be baked practically dry and must be stored in a dry, heated space, generally above the core ovens, to prevent absorbtion of moisture that is always present in the air.

Electric Core Ovens

When electricity can be obtained at a very low rate, core ovens may be heated by resistors placed, generally, on the sides of the oven itself. The heat from these resistors must, however, be transmitted to the cores by air circulated by a fan, since abundant air is required, any way, as an absorbent of moisture, and direct-radiant heating is inadmissible, owing to the toasting effect, which causes cracks and destruction of the binders.

The quality of the cores used is one of the major factors in the production of good castings, free from blow-holes, scabs and other defects, easy to clean, true to size and of a good finish. With high-class materials, good equipment, technique and supervision good cores are not difficult to produce.

The cost of cores, related to the total production cost per ton of finished castings, is not excessive. It is clear, then, that careful attention to all aspects of this problem, the installation of up-to-date ovens, attention to loading, testing, temperature control and handling will be well repaid in the reduction of rejected castings and the production of a better grade of product.

DISCUSSION

Humidity Driers

The discussion was opened by Dr. J. G. A. Skerl (B.C.I.R.A.), who, after commenting on the dearth of Papers on the equipment necessary for the efficient drying of cores and moulds and that knowledge of the processes entailed was mainly empirical, said the ovens described in the Paper were known as humidity driers. These driers had been developed mainly for the elimination of moisture, in ceramic ware, such as porcelain, and also for fireclay and other refractory goods where the closeness of the material and the high percentage of water rendered it imperative that drying should proceed evenly and slowly throughout the whole mass of the article if crazing and cracking were to be avoided on the surface. Whether these humidity types of driers and stoves would be as advantageous for moulding-sand practice was a matter upon which more information would be desirable. In a core or mould openness was almost essential in order to get rid of gases formed during casting, and there was also a certain amount of elasticity or give in the sand due to the fact that it was never in practice rammed to the fullest extent, so that there was every opportunity for the water vapour to leave the core without straining it to give cracking troubles. When a mould or core does crack the fault can readily be traced and cured by reference to the amount of bonding material present, the moisture content of the damp sand and the general composition of the mixture without consideration of the stoves or detriment to the castings produced. It would appear that from the cracking standpoint the humidity drier would only be of advantage for moulds and cores in which there were rapid changes of section where the drying strains would be greater than usually encountered.

Synthetic Sand Practice

The sand conditions described in the Paper were almost entirely American and Canadian, in the mixtures of silica sand, clay and the farinaceous or oil type of binder, a mixture which he (Dr. Skerl) had not heard of being used in this country. It would have been of greater interest to British foundrymen if the Paper had been partly sub-divided to deal in one section with the natural sand or even silica sand and clay type of core and mould, and in the other section with oil-sand core practice. In the case of an oil-sand mould or core mixture in which no natural sand was used the necessity of attaining a temperature at which the water could be driven off without cracking the core or mould was not so evident, although it must be remembered that many core compounds contain water.

The Paper would have been enhanced if a time schedule of a humidity drier working on a stated load of moulds or cores had been given, so that a comparison could readily be made with what might be considered normal stove practice in this country. Fireclay and other ceramic ware was dried much more efficiently and quickly in humidity driers, particularly if they are of the tunnel type, than under ordinary stove conditions where the temperature and the circulation of the air is controlled without reference to the humidity. Time, temperature and humidity curves of a humidity drier at work on foundry moulds and cores would be of great interest.

In conclusion, Dr. Skerl stated that the Paper abounded in suggestions as to methods of adequately studying core-oven practice, methods which could be applied to the normal stove practice as carried out in this country.

Two Distinct Problems

Mr. W. H. Smith supported Dr. Skerl's suggestion that it would have been useful to have had a clear dividing line drawn between water-bonded cores and oil-sand cores, for the reason that water-bonded cores would commence to dry at a temperature slightly above 200 deg. Fah. (93 deg. C.), a temperature which had practically no influence on oil-sand cores; a temperature of approximately 350 deg. Fah. (175 deg. C.)

must be attained before oil-sand cores began to dry.

One of the essentials, which the author had not made clear, was the type of fuel used. Apparently he was using gas or oil, but the Paper seemed to suggest that gas was predominant. A certain amount of core drying was done by the use of gas in this country, but in the interests of economy most of the core and mould drying was done by coke fuel, which was a much more economical proposition. When using gas, there was not the slightest difficulty in maintaining an even temperature, even without re-circulation; he knew of gas stoves which had been built, not for core drying, but for the second heat-treatment of aluminium alloys, where the temperature did not vary more than one degree in any part of the stoves over the period of 24 hrs. That result was obtained by using a special mixing chamber, forced circulation and a thermostat, and the temperatures were recorded at various parts of the stoves throughout the day.

The Burnt Core Troubles

It appeared that the author had had considerable trouble in connection with the burning of cores and moulds. Having conducted experiments on stoves and having had something to do with the building of them, Mr. Smith was of opinion that the trouble was due more to the construction of the stoves than to anything else. One did not need limits anything like so fine as one degree of variation, up or down, for core or mould drying, but one did need a reasonably even temperature and a certain amount of pressure. He had proved beyond question by many experiments that, if one imposed a strong induced draft on a stove, the temperature would be uneven. If there were a strong pull on the chimney, or if there were a fan on the outlet, the hot gases would follow a more or less straight line from the inlet to the outlet of the stove, and in that line there would be burning, whereas in other parts of the stove there would be ineffective drying. Another advantage of the pressure system was that the resistance set up in the stove caused a distribution of the heat entering the stove; there was also to some extent a mixing of the hot gases entering with those already in the stove, and that prevented the temperature rising sufficiently to burn the contents. Again, there was a penetrating effect on the cores or moulds, which was absent if a partial vacuum was created by an induced draft. With regard to the possibilities of burning moulds or cores, there were stoves working in Manchester which had dried three batches of medium-size moulds at a temperature approaching 600 deg. Fah. (316 deg. C.) in 8 hrs.

Pressure System of Drying

Dealing with oil-sand cores, he said that, with a proper pressure system and reasonably good alignment of inlet and outlet, it was possible to dry cores of sizes varying over a very wide range without damaging the smaller cores, whilst at the same time drying the larger ones perfectly. Evidently the type of continuous stove used in this country was different from that referred to by the author. Not only had we no re-circulation, but we actually divided the drying period took away the saturated air, and took the cores into a second chamber, and reintroduced fresh air, so that we obtained a result absolutely opposite to that of re-circulation. Theoretically, it would appear that, by re-circulation, one was taking the air back to do what it had omitted to do in the first place; it seemed better to make the air do its work the first time, however, and to finish the work with a fresh supply of air if necessary. In the continuous stove we could go still further than in the stationary stove in regard to variation of sizes of core, and it had been demonstrated that a core weighing ¾ oz. or less and a core weighing ¾ cwt. could be dried satisfactorily on the same shelf, in a continuous stove; he did not think that was possible in a stationary stove.

Clay, Water and Oil-Sand Cores

Dr. H. Nipper (Technical High School, Aachen, Germany) referred to some experimental work he had carried out to ascertain whether or not the addition of a certain amount of clay and of water to oil-sand cores would be useful, because sometimes clay and water were added to oil-sand cores in the foundry, with the idea, he believed, of making the cores stronger. He had found that in the dry state the strength was very much reduced, to nearly half as much as without clay and water; it did not decrease so very much in strength with water alone as with water and clay. This, he believed, was easy to explain, because when one dried a core, one drove out the water and afterwards oxidised the oil, and the oil bound the grains together. When the water was driven out, however, at a time when the outside of the core had already been oxidised and the core possessed a certain strength, the steam coming out would break up the connection between the little grains, and so the strength was reduced again. It might be that in some cases where it was not necessary to have a very strong core in the dry state, but where certain strengths were necessary in the green state, it might be advisable to add a certain amount of clay, for it was found that in a green state the oil cores mixed with water or especially when mixed with water and clay were much stronger than pure oil-sand cores.

Optimum Strength related to Water Content

Mr. A. Tipper, commenting on Dr. Nipper's remarks as to the effect of water, and possibly clay, on oil-sand cores after baking, suggested that the fine clay material absorbed the oil, and for this reason one did not get anything like the same amount of oil available for bonding the sand grains together as when using a clean silica sand. This has been proved experimentally in various Papers on the subject, and would mask the true effect of water additions.

The speaker had carried out a number of tests, using an oil-bonded, clean silica sand, with increasing water additions. The baked strength increased to a maximum and then decreased again with further water additions. That, of course, was not "green bond" but dry strength.

The essential factors in drying appear to be:—(1) Temperature control; (2) circulation of hot air, and (3) an adequate supply of oxygen in the core stove.

The author had not dealt with the fact that different materials require different percentages of oxygen during baking, in order to obtain the best results; variation in degree of oxidation required was a matter which must be considered. The author's remarks concerning the effect of water during baking were most interesting, but needed consideration with discretion, and probably there would be further developments of the theory that the drying or baking of moulds and cores occurred in three stages.

Size-of-Mould Factor

Mr. W. J. Molineux suggested that the points with regard to the relative conductivity of water and sand, and also iron reinforcement, had not been fully appreciated by foundrymen. Perhaps, however, in actual practice one did not reap such advantages as one would imagine from a glance at the Paper. It was rather unfortunate that some comparative results obtained from the type of stove outlined in the Paper, and from the standard type of hot-air drier, were not given. Although the principle might apply to moulds of thick section, in which the moisture was encouraged to migrate to the surface of the mould and to become evaporated, one could not quite imagine that that occurred in the oil-sand core, and the author should have differentiated between the two types of material being treated. In many foundries moulds of very widely varying thicknesses of section had to be treated simultaneously, and one would imagine that it was pretty well impossible to economise in drying time where such large variations in thicknesses of section had to be dealt with at one time, though it might be possible on many occasions, or in some particular foundries where specialised work was dealt with, to effect some little economy in time.

It was mentioned in the Paper that continuous-drying ovens had achieved success. But one could not visualise a type of continuous oven in which the three-stage drying system could be applied without considerable complications.

Water and Oil-Sand Practice

Mr. J. H. Cooper, commenting on Dr. Nipper's remarks concerning water in core sand, said that wet sand was not used in Germany if it could be avoided, because there were so many compositions of core oil—dextrine, linseed oil and a hundred and one others—and the system was to dry all the sand if possible, using the large sand in order to minimise the amount of core oil to be used. If one used a bond to give green-sand bond, using loam or anything else, the amount of core oil necessary increased by leaps and bounds. He believed German foundrymen objected to water because it boiled on the edge, so that one did not get a smooth surface. They used dry silica sand, as little fine sand as possible, and secured very easy and quick cleaning; the finish was definitely good. When water was used, instead of getting a straight bond, one obtained an emulsion, which caused endless trouble.

Dr. Nipper said that water might help to give better distribution of the oil if there were a very small amount of oil, but that was about the only good it could do. He agreed that clay absorbed a certain amount of the oil and prevented very uniform distribution of oil.

Higher Drying Temperatures Advocated

Mr. W. West (Leyland Motors, Limited) asked what the author had meant to convey by his statement that at 500 deg. Fah. (260 deg. C.) the qualities of linseed oil were destroyed. In this connection Mr. West referred to some direct work carried out by Dr. J. Newton Friend and himself four years ago on linseed oil, in which it was found that at 500 deg. Fah. the linseed oil polymerised and the molecular weight was increased 12 times. Applying that in practice, a foundryman would find that drying was very greatly accelerated. So that the statement in the Paper with regard to the destruction of the qualities of linseed oil at 260 deg. C. might be somewhat misleading to foundrymen, inasmuch as it was, or should be, a fundamental principle among foundrymen that the greater the amount of volatile matter that came off in the core stove the less remained to come away in the mould. Foundrymen need not be so diffident about raising drying temperatures; if good linseed oil were used the cores would not disintegrate, but would be more permeable than cores dried at lower temperatures; furthermore, there would be less blowing of the metal in the moulds. He asked, therefore, for some explanation or amplification of the author's statement.

On the proposition of the President, a hearty vote of thanks was accorded to the author.

AUTHOR'S REPLY

In replying to the discussion upon this Paper, the author wishes to make it clear that his approach to this subject has been purely that of a mechanical engineer, with no special knowledge of foundry practice.

The necessity for improved core and mould drying methods became acute in connection with a contract for a quantity of cast steel runners, for Francis-type hydraulic turbines of 50,000 h.p. The mould for such runners is made by grouping a number of interlocking moulds or cores, on a base-plate in a casting-pit, the group being surrounded by a steel-plate supporting shell between which and the cores sand is rammed.

The cores or mould-segments must be true to dimensions and undistorted. Owing to the large dimensions of these cores, it became necessary to construct a special duplex drying-oven, consisting of two chambers, each approximately 15 ft. cube.

The construction consisted of steel plate shells enclosing 4 in. of rock-wool insulation. The roofs were removable, for crane service, and a combustion chamber for oil-firing was located below each oven.

One core, such as those shown in Fig. A. formed a charge for each chamber, and was built upon a special base-plate. These cores were moulded in a built-up core box, to which sections were added as the work proceeded in height.

The matrix was a special core-arbour, built up to the approximate contour and held rigid by a bracket, that can be seen in the photograph (Fig. A) bolted to the base-plate. Moulding was done with the aid of air-rammers, using sharp Ottawa sand. A characteristic sand mix is as under:—1,600 lbs. sharp Ottawa sand; 58½ lbs. fireclay; 9 lbs. "Rex" corn binder; 1 gall. of molasses; ¼ gall. of fuel oil. This was milled for 10 min. and had a moisture content of 4 to 6 per cent.

Particulars of a set of cores are as under:—

Core no.	Weight each.	Average thickness.	Drying time.	Weight of coke in centre.
	Lbs.	Ins.	Hrs.	Lbs.
1	46,000	30	70	1,500
2, 3 & 4	24,000	21	60	500
5	60,000	66	80	2,000

The cost of these cores, when ready for the oven, was very considerable, and a regular supply to the moulders was essential. They were to be baked without cracking and distortion, with a reasonable fuel cost and with full control of the process.

A search was made through technical literature, for guidance, and a description of the drying of wet whiting, by the three-stage "humidity-drying" method was found in the handbook of the American Society of Heating and Ventilating Engineers.

Fig. A.—Cores for Francis-type Hydraulic Turbine Wheels of 50,000 h.p.

The problem in hand differed, in many respects, from this, but the principle of re-circulation and the "water-shield" method of protecting cores and eliminating cracking seemed to be sound and much in advance of current practice. Cracking and distortion were the chief risks to be overcome.

Each drying chamber was therefore provided with a motor-driven fan, connected to the interior by sheet-metal ducts, arranged to draw the air from the top of the oven and re-introduce it at the bottom. Each fan was of sufficient capacity to ensure about 20 changes of air per hr., and the ducts were designed for a low velocity and shaped to ensure an even distribution of air; vents and dampers were also provided.

There was some anxiety over the fate of the first two cores, for time did not permit of preliminary experiments, but, fortunately, the results throughout were very satisfactory.

The oven temperatures, as recorded, were substantially the same as those described in the Paper, for each stage of drying. Based upon this experience, the old-style ovens in the plant are being equipped for re-circulation; all use oil-fuel, which is cheap in Canada and needs little attention. This plant produces steel castings only, has a complete sand-conditioning and handling equipment, and most of the cores are moulded on jolt machines.

Referring to Dr. Skerl's remarks, it will be evident that, the sand grains being impermeable, all the water content of the green core must be located entirely in the voids of the core, and thus the permeability of a hard-rammed core, for steel casting, when in the green state, must be very low, and the reduced heating in the third period may lessen the risk of cracking, by preventing the accumulation of steam pressure.

In the first period, the automatic limitation of the surface temperature to 212 deg. F. keeps the temperature gradient in the core moderate (as compared with "toasting" methods), and thus tends to prevent cracking, due to differential expansion, especially at rapid change of section.

Inquiries were circulated for a humidity indicator and recorder, suitable for core-oven use, but none was offered for a higher temperature than 212 deg. F., except by the indirect method of extracting a measured sample of the air, cooling it, measuring the humidity at the reduced temperature, and calculating, from this, the humidity in the oven; this could not be attempted under foundry conditions.

Large cores, such as those described. are not dried throughout, and it was desired to have a means of measuring the percentage moisture content at different depths. An electric moisture detector was secured, designed for lumber grading, and its needle-point contacts were replaced by contacts, at the end of an insulated probe, which was thrust into the core.

The results were not sufficiently encouraging to place any reliance upon them, but it was thought that by re-arranging the detector circuits for the small range of humidity required and by devising some means of protecting the electrodes from moisture, until the desired depth was reached, and especially of ensuring uniform contact conditions, such an instrument could become of great value.

Mr. Smith will understand that the author is only qualified to discuss the mechanical aspects of the points he has raised, but he is able to agree with him that, to secure uniform temperature distribution in ovens and furnaces, careful attention to the circulation of the heated gases is essential.

The actual flow of the gases, past the obstruction of the contents of an oven or furnace, is by no means easy to predict. In the case of the special core-ovens described, we were able to secure useful information and guidance, on this point, by injecting smoke, through the burner port, into the combustion chamber, and observing its movement, in the oven, through sight-holes provided in the wall, the interior of the oven being illuminated, for the purpose, by electric lamps.

Mr. Smith is correct in stating that considerable core loss was involved in the days when cores were baked, in a hurry, at temperatures of 315 deg. C. or more without circulation; it is true that foundrymen developed mixtures that would stand up, fairly, to such harsh treatment, but the true remedy is controlled circulation.

All our ovens had an oil-fired combustion-chamber below the floor, and the escape of the hot gases, upwards to the oven chamber, was made uniform by arranging the line of flue openings, along each side wall, of increasing area, from the burner to the last opening, the intention being to make the total friction up to each outlet, and consequently the flow of gas, constant at all openings.

Pressures in these ovens were always slightly above atmospheric to prevent inflow of cold air. This pressure is due to the injector action of the oil-burners; the circulating flow is practically balanced.

The penetration of hot air into cores, due to pressure, to which Mr. Smith refers, can only take place for a moment, until the external pressure is balanced, when it ceases.

The best method of heating the centre of cores is by conduction through the contained water, as arranged in the first period described in the Paper.

The function of re-circulation, in the first period, is solely to equalise the temperature in the oven, the dampers are closed so that the same air is used over and over again; it does not matter how saturated it is with moisture—we want it so to protect the surface of the cores whilst heat is penetrating, conducted by the internal moisture.

It would appear to be very uneconomical to dry large and small cores in the same batch, undoubtedly it can be done.

To Mr. Tipper's three essential factors in drying, the author would add a fourth—moisture control.

His third item appears to have been incorrectly reported; the oxygen in the core stove is needed for combustion of the fuel, whilst in the oven it is available for oxidising the binders.

With an air supply corresponding to 20 changes of oven capacity per hr., ample oxygen should be available, and it is partly for this purpose that the air-dampers are opened, in the second period.

Replying to Mr. Molineux, it would appear that the successful drying of over 60 very large cores, without detrimental cracking or distortion, was evidence that there must be some merit in the wet-surface theory, applied to the first period of drying.

Obviously, the drying of a water-bearing core depends upon evaporation, whilst the drying of an oil-sand core is mainly a matter of oxidation —both demand re-circulation of air, but only in the former is the water-shield idea applicable.

Continuous ovens are restricted, chiefly by considerations of length, to the drying of small and medium cores, requiring a moderate time for baking.

The combustion chamber is usually located between the conveyor passes and the core-tray carriers pass through constrictions or "throats," rather longer than the pitch of the carriers; the sealing effect of the throats, owing to small clearances, is fairly good.

Part of the path of the conveyor is sometimes devoted to a cooling area, and the heated air, from this, is used as combustion air to the burners, thus improving the thermal efficiency somewhat.

American makers now offer re-circulation in these ovens and, having regard to the possibility of dividing the path of the conveyor into sealed compartments and to the extreme slowness of movement, it would appear mechanically possible to provide for all three heating periods in sequence. Continuous ovens show to best advantage, of course, in mass-production foundry programmes.

Mr. West's remarks, regarding linseed oil, are very interesting, possibly the observations published by the American Foundrymen's Association, stating that oxidation is very much faster between 175 and 230 deg. C. than at lower temperatures, is an indication of polymerisation in the samples under test, and it is known that linseed oil samples vary greatly.

Further, one would assume that the statement, "at 260 deg. C. the qualities of the oil are destroyed," refers to its bonding properties, which may reasonably have some relation to its volatile constituents, which with increasing temperature are driven off.

RECENT DEVELOPMENTS IN BRITISH SYNTHETIC MOULDING SAND PRACTICE

By J. J. Sheehan, A.R.C.Sc.I., A.I.C. (Member)

The title of this Paper is based on experience gained mainly in converting the sand systems of a mechanised foundry from natural moulding sands to the use of synthetic-moulding sand. The foundry operates a fully-mechanised grey-iron system making automobile cylinders and heads, a partially-mechanised steel system making automobile parts and a jobbing floor. The subject-matter of the Paper may be conveniently dealt with by considering it the solution of the problem of this " change over " and the adaptation of the change to the three systems. The problem, stated more specifically, was to develop a moulding sand that would operate successfully as a grey iron, a steel and a jobbing floor sand, and further to make the basis of this sand, burnt sand which has already functioned in oil-sand cores.

Apart from the economy suggested by this scheme, the trouble experienced in the use of natural moulding sands demanded thorough investigation and rectification, and was an additional incentive to change.

The conditions existing prior to the change may be summarised briefly in Table I.

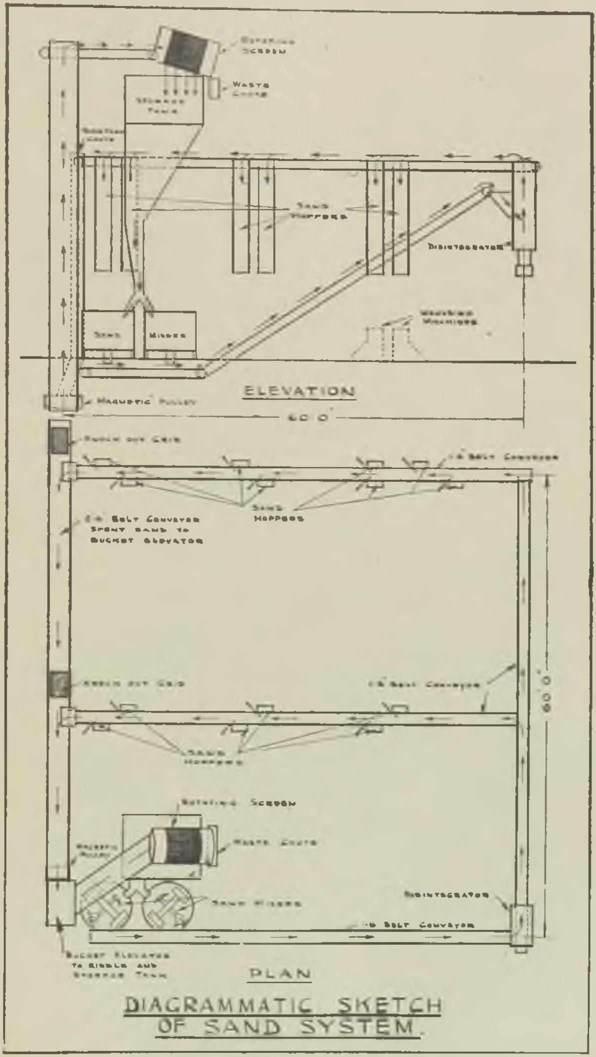
Attention was of necessity centred on the grey-iron system and investigations begun into the sand system as such and into the sands used, keeping in view the needs of the other systems and possible economies.

As previously stated, the grey-iron system is fully mechanised. The sand preparation and distribution " lay-out " is detailed diagrammatically in Fig. 1.

The sand-preparation plant consists of two raised roller mixers, a distintegrator and a magnetic pulley. The distribution is by rubber-belt

TABLE I

Location.	Sands in Use.	Method of Preparation.	Existing Sand Conditions.
Jobbing floor	Red sand, from the Bunter deposits	Panless mixer	Satisfactory
Grey iron system	Red sand and Belgian yellow sand	Raised-roller mixer	Very unsatisfactory.
Steel system	Belgian yellow sand	Raised-roller mixer	Satisfactory, but capable of improvement.



DIAGRAMMATIC SKETCH OF SAND SYSTEM.

FIG. 1.

conveyors and the storage by overhead hoppers, one large hopper for spent sand over the mixers and a series of smaller hoppers over the moulding machines for the prepared sand. This system is simple and looks effective, but failed absolutely to prepare and deliver natural moulding sands in a condition suitable for good moulding, more particularly for good machine-moulding.

The scrap, due to sand defects at this particular period, was excessive and certainly diversified—dirty castings, broken moulds, dropped moulds, leaking castings, due to sand inclusions on thin sections, scabbed castings, swollen castings—and an exhaustive examination of the sand as delivered by this system revealed the cause and led ultimately to the cure.

The statement " the sand as delivered by this system " is deliberate, and is used to avoid at this stage apportioning the responsibility for the defective condition of the moulding sand, as between the system and the chemical and physical composition of the sand as received.

It is more convenient first to tabulate the defects and the conditions causing them (Table II).

General Remarks on Table II

There are many more types of defective castings associated with sand condition, such as pulled tops, rat-tails, ripples, but as these are more nearly related to coal-dust content and quality rather than to basic sand condition, a discussion of them is not included.

As the tabulated possible conditions giving rise to the defects mentioned could not exist at one and the same time in the sand, those that actually obtained at the time of the investigation are italicised, and to simplify the reference the physical constants of the moulding sand then in use are given below.

Strength, 13 to 15 lbs. per sq. in.
Permeability, 30 to 32.
Moisture, 4 to 5 per cent.

The outstanding deficiencies of this sand are low permeability and high strength, the low permeability affecting the sand condition directly and the strength indirectly in that the high clay content giving this strength compacted the sand so thoroughly that it caked at the bottom of the mill and the rollers rode over the compacted mass. Inefficient mixing was the result. Inefficient or irregular aeration also resulted as the disintegrator was unable to break up this caked mass.

The sand was composed of 18 parts red sand and 14 parts of Belgian, 22 parts of old sand; this mixture is obviously wrong, and, briefly, for the following reasons:—(*a*) Excessive amounts of new sand, and (*b*) the smaller grains of the red sand fitting between the grains of the Belgian and giving an almost impermeable mass. It would be unfair to the sand-preparation system to consider it inefficient when unable to prepare satisfactorily such a mixture.

However, operating the system on a single naturally-bonded moulding sand was also unsatisfactory, though not to the same extent. The mixers were incapable of breaking up the coarser clay pellets in the short time demanded by the mechanised moulding equipment. This is illustrated by Fig. 7, showing the condition of unbroken clay pellets fused in the sand mass.

Actually 50 tons of backing sand per 8-hour day are required by the moulding section, and the mixers are capable of holding 644 lbs. per batch, allowing only 2½ minutes for mixing each batch.

The inability of the raised-roller type faster-working mixers to handle a heavily-bonded natural moulding sand is also demonstrated by the figures in Table III and gives a comparison also with the older type heavy-roller mixer used on floor moulding.

The increase in strength after 4 minutes' milling in the old-type heavy-roller mill was 53 per cent. against an increase of 43 per cent. for the newer mixer. Evidence of incomplete mixing is also strikingly shown, the strength figures for the average from the mill being considerably less than that portion of sand compacted under the rollers.

TABLE II.—*Sand Condition causing these Defects and Expressed in Physical Constants as measured on the A.F.A. Standard Sand-Testing Equipment.*

Condition.	Illustration No.	Test figures.
(*a*) Too dry	FIG. 2. Dirty castings (cylinder head)	(*a*) Less than 4 per cent. moisture for actual moulding sand.
(*b*) Too weak, *i.e.*, low green strength or low dry strength.		(*b*) Less than 4 lbs. per sq. in.
(*c*) *Badly mixed sand weak or dry in patches.*		(*c*) *Sand so strong (above 10 lbs. per sq. in. green strength) that good mixing is not easily obtained.*
(*a*) Too weak	FIG. 3. Broken moulds and dropped moulds	(*a*) Less than 4 lbs. per sq. in.
(*b*) *Too strong*		(*b*) *More than 10 lbs. per sq. in.*
(*c*) Too dry		(*c*) Less than 4 per cent. moisture.
(*d*) *Low "flowability"*		(*d*) *Too strong to be aerated by the disintegrator (above 10 lbs. per sq. in.)*
(*e*) High "flowability"		(*e*) So aerated or weak that the mould is completely rammed by fewer jolts than necessary with sand of normal flowability, additional jolts crack the mould.

	Fig. 4.	
(*a*) Too weak	Leaking castings due to sand inclusions (portion of bore)	(*a*) Less than 4 lbs. per sq. in.
(*b*) *Permeability low*		(*b*) *Less than* 40.
(*c*) Too dry		(*c*) Less than 4 per cent.
	Fig. 5.	
(*a*) *Permeability low*	Scabbed castings. (Cylinder head—Combustion spaces)	(*a*) *Below* 40.
(*b*) Too wet		(*b*) More than 6 per cent. for natural sands.
(*c*) Badly mixed		(*c*) *Too strong (above* 10 *lbs. per sq. in.) to allow of efficient mixing.*
(*a*) *Too strong giving low permeability*	Swollen castings not illustrated ..	(*a*) *More than* 10 *lbs. per sq. in. normal number of jolts does not compact the mould.*
(*b*) *And/or badly mixed*		(*b*) *More than* 10 *lbs. per sq. in. Too strong to allow of efficient mixing.*
	Fig. 6.	
(*a*) *Low permeability*	Blown castings (cylinder block) ..	(*a*) *Below* 40.
(*b*) Too wet		(*b*) More than 6 per cent.

TABLE III.—*Old Type Mill.*

Sample.	Mois-ture.	Perme-ability.	Strength.	Clay.	Sand.	In pan.	Fine-ness No.	Clay.	In pan.	Perme-ability.	Strength.
				Per cent.	Per cent.	Per cent.		Per cent.	Per cent.	Per cent.	Per cent.
Untreated ..	—	—	—	4.6	95.4	2.0	87.7	—	—	—	—
Lab. treated ..	—	—	—	6.9	93.1	3.2	100.2	—	—	—	—
Milled 4 min. ..	—	—	—	12.1	87.9	4.3	105.6	+ 75	+ 34	− 25	+ 53
				Raised	*Roller*	*Mixer.*					
Untreated ..	—	—	—	4.7	95.3	4.7	104.8	—	—	—	—
Lab. treated ..	4.6	35	7.0	8.1	91.9	4.3	104.8	—	—	—	—
Aver. from mill	4.6	32	10.0	11.9	88.1	4.3	104.5	+ 47	Nil	− 8.6	+ 43
From under rollers ..	4.7	28	11.0	13.6	86.4	4.9	106.3	+ 68	+ 14	− 20	+ 57

The rectification of these two major defects, the sand condition and the inability of the mixers to function rapidly was made possible by a simple adjustment to the sand mixture, using one to two parts Belgian sand and one part Southport sand; this gave the following physical constants:—

Facing Sand.		*Backing Sand.*	
Permeability ..	46.0	Permeability ..	57.0
Strength	8.6	Strength	5.7
Moisture	5.0	Moisture	4.0

This alteration raised the permeability, lowered the strength and thus allowed the mixers to function without compacting the mass; in fact, the rubbing of the grains of Southport through the Belgian sand efficiently broke up the whitish clay pellets naturally occurring in the latter sand; the disintegrator also functioned excellently, no choking-up occurring. The raised-roller mixers now worked most efficiently and rapidly. In fact, they were ideally suited for the high-speed quantity-production sand system.

This semi-synthetic sand functioned in the system excellently, and the improvement in the scrap from sand defects was most marked, as is shown in Table IV. This concluded the first stage of development, and while maintaining these good conditions with this semi-synthetic sand, investigations were continued, to determine the attributes necessary to good moulding sands for steel, grey iron and jobbing-floor work.

No effort was made further to utilise the red sand in the systems. A thorough analysis of this sand revealed its unsuitability, but undoubtedly also yielded much interesting information which may be ultimately utilised in synthetic-sand practice.

The red sand under discussion is Bromsgrove red, and is typical of the sands of the Bunter

TABLE IV.—*Cylinder Crankcase. Details*

Week ending, 1933.	Jan. 6.	Jan. 13.	Jan. 20.	Jan. 27.	Feb. 1.	Feb. 8.	Feb. 15.	Feb. 22.	Mar. 1.	Mar. 8.	Mar. 15.	Mar. 22.	Mar. 29.
Cause of scrap and number scrapped	*	*	*	*	*	*	*	*	*	*	*	*	*
Dirt	17	12	12	4	4	7	6	8	6	4	2	2	5
Broken moulds	5	3	4	2	4	—	1	11	1	4	—	3	6
Leaking ..	23	15	23	4	2	3	4	6	24	7	10	9	10
Scabbed ..	16	6	6	8	3	13	15	19	1	—	9	10	12
Swollen ..	3	1	1	3	2	2	5	—	12	—	—	—	—
Total scrap sand defects	64	37	46	21	15	25	31	44	44	15	21	24	33

Week ending, 1933 & 1934.	Aug. 2.	Aug. 9.	Aug. 16.	Aug. 23.	Aug. 30.	Sept. 6.	Sept. 13.	Sept. 20.	Sept. 27.	Oct. 4.	Oct. 11.	Oct. 18.	Oct. 25.
Cause of scrap and number scrapped	†	†	†	†	†	†	†	†	†	†	†	†	†
Dirt	—	—	—	—	—	—	—	—	—	1	3	—	—
Broken moulds	4	—	1	1	8	8	2	7	1	1	5	1	2
Leaking ..	1	—	1	1	—	2	—	—	—	3	—	2	1
Scabbed ..	1	—	—	—	—	—	—	1	—	—	1	—	—
Swollen ..	—	—	—	—	—	—	—	—	—	—	—	—	—
Total scrap sand defects	6	—	2	2	8	10	2	8	1	5	9	3	3

* Red Sand Mixture was in operation up to week ending April 5.
ending December 13. ‡ Synthetic Sand in oper

deposits. The chemical analysis of this sand is as follows:—

Ignition loss	1.00 per cent.
Silica (SiO_2)	86.70 ,,
Iron oxide (Fe_2O_3)	1.60 ,,
Alumina (Al_2O_3)	6.3 ,,
Titania (TiO_2)	0.2 ,,
Lime (CaO)	0.3 ,,
Magnesia (MgO)	0.3 ,,
Alkalies (Na_2O K_2O)	3.4 ,,

of Scrap Caused by Sand Defects.

Apr. 5.	Apr. 12.	Apr. 19.	Apr. 26.	May 3.	May 10.	May 17.	May 24.	May 31.	June 7.	June 14.	June 21.	June 28.	July 5.	July 12.	July 19.	July 26.
*	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†	†
—	1	1	4	2	—	1	1	4	—	1	5	3	2	2	1	2
6	5	8	5	2	8	11	19	3	—	1	2	1	5	—	1	6
6	13	7	8	2	2	3	10	1	1	5	2	1	2	2	2	4
17	8	6	12	5	8	2	1	3	—	3	1	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29	27	22	29	11	18	17	31	11	1	10	10	5	9	4	4	12

Nov. 1.	Nov. 8.	Nov. 15.	Nov. 22.	Nov. 29.	Dec. 6.	Dec. 13.	Dec. 20.	Dec. 27.	Jan. 3.	Jan. 10.	Jan. 17.	Jan. 24.	Jan. 31.	Feb. 7.	Feb. 14.	Feb. 21.
†	†	†	†	†	†	†	‡	‡	‡	‡	‡	‡	‡	‡	‡	‡
—	1	2	1	1	1	6	3	—	1	4	2	4	—	2	2	1
11	1	8	8	7	6	—	—	—	1	—	—	—	—	—	—	—
1	3	—	1	1	1	—	1	1	—	—	—	—	—	—	—	—
1	—	—	—	—	1	—	1	1	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13	5	10	10	9	9	6	5	2	2	4	2	4	—	2	2	1

† Semi-Synthetic Sand Mixture was in operation up to week
ation *from* week ending December 20, 1933.

and the mechanical analysis (Tylor screen):—

+ 35 mesh	0.2 per cent.
+ 48 ,, ...	1.2 ,,
+ 65 ,, ...	8.6 ,,
+ 100 ,, ...	34.0 ,,
+ 150 ,, ...	26.2 ,,
+ 200 ,, ...	14.9 ,,
+ 250 ,, ...	5.2 ,,
— 270 ,, ...	3.2 ,,
Clay	6.5 ,,

FIG. 2.—DIRTY CASTING—CYLINDER HEAD.

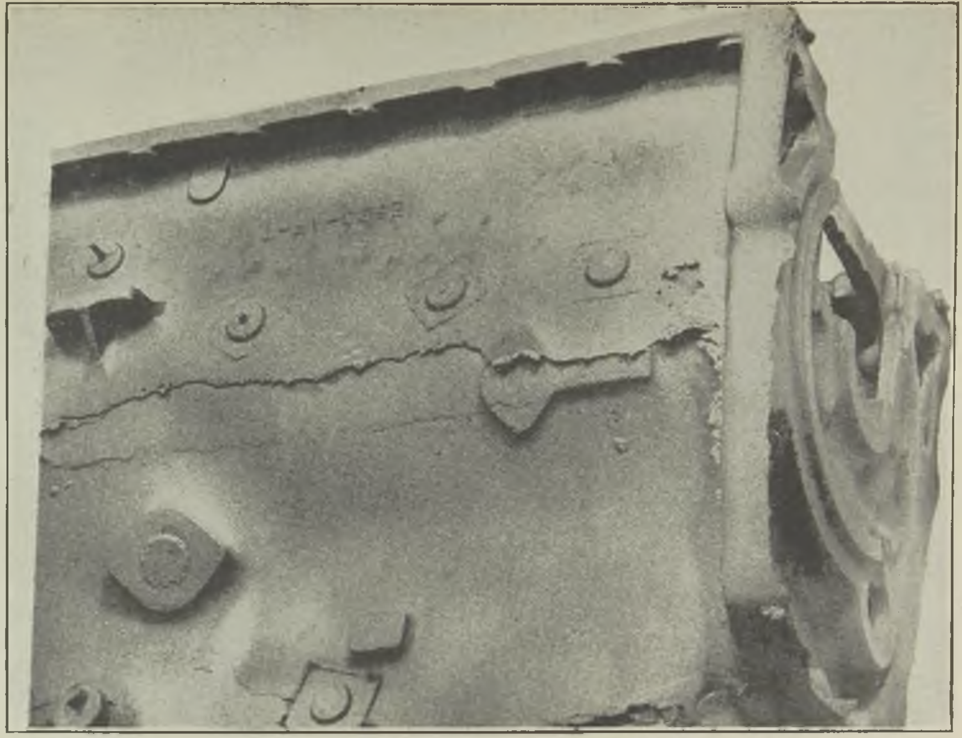


Fig. 3.—Broken Mould or Dropped Mould.

The chemical analysis of similar sands from the same Bunter deposit (Table V) is included to illustrate the type (figures taken from Table III of a Memoir on "British Resources on Refractory Sands," by P. G. H. Boswell, O.B.E., D.Sc.).

The value of these sands lies in their regular occurrence. For high-temperature work, such as automobile cast irons and steels, their disadvantages are numerous, because (1) they contain between 2 and 3 per cent. of potash, thus rendering them easily fusible at elevated temperatures, forming silicates of the alkalies and alkaline earths. In the best moulding sands the potash and soda contents combined do not exceed 0.7 per cent.; (2) the Bunter sands are peculiar among moulding sands, in that the potash and soda persists even in the coarser grades of the sand, and exist as potash and soda-felspars. While the little potash occurring in the better steel moulding sands exists in the finer grades only, and then mainly as the less fusible micas (this peculiarity is a consequence of the mode of formation of the Bunter deposits, and they were formed under desert conditions where decomposition of the relatively soluble potash minerals was inhibited for want of water); and (3) an examination of the figures in the mechanical analysis reveals the cause of the low permeability figures obtained using these sands.

The most permeable sands are those with the greatest proportion of their bulk of the same grain size, and with the greatest proportion of rounded grains. It will be seen that this red sand has its bulk distributed over many sizes. The microscope reveals also that, while the coarser grains are almost perfect spheres, the finger grains are sub-angular and pack on ramming between the larger grains. This condition is illustrated by Fig. 3, wherein (*a*) represents the coarser grains, (*b*) the finer rounded grains, and (*c*) the sub-angular grains, packed by ramming.

The microscope, however, also revealed an interesting advantage possessed by these deposits.

The surface of the medium and fine-sand grains is covered with a coating of ferric hydroxide; this ferruginous bond holds most tenaciously even after repeated washings with water.

There is some evidence that this ferruginous bond is burnt on to the sand grain. Ferric hydroxide mixed with similar sand grains is readily washed out, while ferric hydroxide precipitated on the sand grains and burnt on resists repeated washings.

This coating gives a grip to the clay bond and assists it in making the sand that much stronger. But what is much more interesting and important, particularly in jobbing floor work, is that this coating grips the drier bond at the mould surface, while on smooth, rounded, uncoated grains the clay bond dries, cracks and readily falls off, thus allowing the sand to frit away and expose another layer of sand to the same action (this effect is enhanced when using highly-permeable sands, which allow freer air passage and consequently more rapid drying).

FIG. 4.—LEAKING CASTING DUE TO SAND INCLUSION. PORTION OF BORE.

It is difficult to over-stress the importance of this phenomenon. It has been the main cause of the opposition to synthetic sand by the hand moulders. The synthetic sands built up from rounded, smooth-grained sands using a water-washed deposit and a clay bond, crumbled away

FIG. 5. SCABBED CASTINGS. CYLINDER-HEAD COMBUSTION SPACES.

at the surface of the mould, particularly when the mould is open for some time, and were incapable of being patched or "sleeked."

This assumption is confirmed by the following experiments:—(*a*) The bond was taken from the red sand and transferred to a round, grained, smooth sand surface. The new sand was lower in strength than the original red sand; (*b*) a clay bond was milled with the sand grains from a washed red sand and a smooth-grained silica sand of approximately the same grain size (the red sand was again stronger; and (*c*) the bond from red sand was transferred to the sand grains of Belgian moulding sand, and the bond of Belgian was transferred to the grains of red sand (in each case the strength of the red sand was 20 per cent. higher).

Experiments (*c*) are represented by the following:—

Bond kept constant	Belgian grain	+ Red bond	= Strength x
	Red grain	+ Red bond	$= x + \frac{x}{5}$ strength
Bond kept constant	Belgian grain	+ Belgian bond	= strength y
	Red grain	+ Belgian bond	= strength $y + \frac{y}{5}$

The base grains of Belgian sand are not coated with ferric hydroxide.

At this stage the experiments narrowed the investigation of this advantage of red sand to a consideration of the surface tension between (*a*) smooth quartz and water, including smooth quartz and water-carrying clay bond; (*b*) rough quartz and water, and water-carrying clay bond; and (*c*) quartz on which ferric hydroxide has been precipitated and burnt on as ferric oxide and water and water-carrying clay bond.

It was not found possible with the equipment available to measure these surface tensions directly and express them numerically, but it was found possible to demonstrate the difference in surface tensions between the water-carrying clay bond and sand grains representing the quartz conditions mentioned.

In an effort to demonstrate the difference between (*a*) and (*b*), silica sands from Leighton

TABLE V.—*Chemical Analyses*

Percentage

Page.		SiO_2.	Al_2O_3.	Fe_2O_3.	FeO.	MgO.	CaO.	Na_2O
167	Aughton Park, Ormskirk	92.30	3.94	0.34	0.15	0.16	0.12	0.03
169	Belfast, Knockvale ..	81.47	8.84	1.84		0.81	0.86	1.50
171	„ Lagan Vale ..	74.80	7.70	1.13	0.56	1.33	4.55	1.34
155	Birmingham, Hockley Cemetery, close ..	84·86	6.69	1.08	0.35	0.43	0.29	0.40
160	Compton, near Wolverhampton (bulk) ..	86.37	6.40	0.96	0.25	0.42	0.26	0.36
160	Compton, medium sand-grade (MS)	94.37	2.82	0.46		0.17	0.16	0.12
160	Compton, fine sand-grade (FS)	89.10	5.32	0.88		0.28	0.24	0.15
160	Compton, coarse silt-grade (cs)	85.31	6.95	1.23	0.22	0.37	0.41	0.49
160	Compton, fine silt-grade (fs)	69.05	14.15	2.70	0.53	1.05	1.27	0.56
160	Compton, clay-grade (c)	58.17	19.58	5.47	0.55	1.78	1.34	0.38
149	Heck, near Selby ..	87.14	5.89	1.00	0.29	0.41	0.25	0.14
164	Kidderminster, Station Pit	85.66	6.59	0.86	0.36	0.55	0.26	0.16
65	Mansfield, pig-bed sand	88.60	5.40	1.08	0.22	0.28	0.18	0.06
65	„ lower medium	82.51	4.96	0.97	0.30	1.56	2.39	0.10

Buzzard and Erith silica sand of selected grain sizes were similarly bonded and milled, but no differences in bond strength were evident.

It was decided then artificially to roughen the silica grains, and this was most conveniently done by exposing some sand to the vapours of hydrofluoric acid. The acid-treated grains gave the higher strength figures illustrated by the following:—

	Before Treatment.	*After Treatment.*
Strength ..	12.1 lbs. per sq. in.	13.6 lbs. per sq. in.

Larger samples of sand were later treated with a dilute solution of hydrofluoric acid and etched by the vapour during evaporation.

of Bunter Moulding-Sands.

weights.

K_2O.	$_2O$ +	H_2O −	CO_2.	TiO_2.	ZrO_2.	P_2O_5.	SO_3.	Cl.	MnO.	BaO.	Total, etc.
2.14	0.56	0.34	n.d.	0.19	none	trace	n.d.	trace	trace	0.02	100.29
2.78	Ign. 2.24			0.35	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100.69
2.65	1.18	0.50	3.52	0.30	n.d.	0.04	0.02	trace	0.04	0.04	99.70
3.41	1.21	0.55	none	0.40	trace	0.09	none	trace	0.01	0.04	99.81
3.25	1.00	0.57	none	0.35	trace	0.06	none	trace	0.01	0.04	100.30
1.57	Ign. 0.48			0.06	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100.21
3.13	0.71			0.21	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100.02
3.31	1.43			0.43	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100.15
5.45	4.28			0.97	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	100.01
5.37	6.34			0.73	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	99.71
2.95	1.00	0.55	none	0.18	0.02	0.08	0.03	trace	0.02	0.03	99.98
3.41	1.22	0.74	none	0.40	trace	0.10	none	trace	0.01	0.03	100.35
2.49	1.06	0.28	none	0.19	n.d.	none	none	trace	0.02	0.01	99.87
2.20	1.29	0.47	2.92	0.17	n.d.	0.07	none	trace	0.02	trace	99.93

Using the same sand but less clay bond, the increased strength was confirmed :—

Before Treatment.	*After Treatment.*
5.8 lbs. per sq. in.	6.4 lbs. per sq. in.

An increase of 10.3 per cent in strength.

These figures are the average of six determinations taken over a period of 2 hrs.

Sand on which ferric hydroxide was precipitated and burnt on as ferric oxide was compared with the same sand untreated. Erith silica sand was used. A solution of ferric chloride was added to the sand sufficient to add about 1 per cent. of Fe_2O_3 to the sand mass, a solution of ammonium hydroxide was added to precipitate the ferric hydroxide and the sand mass was then

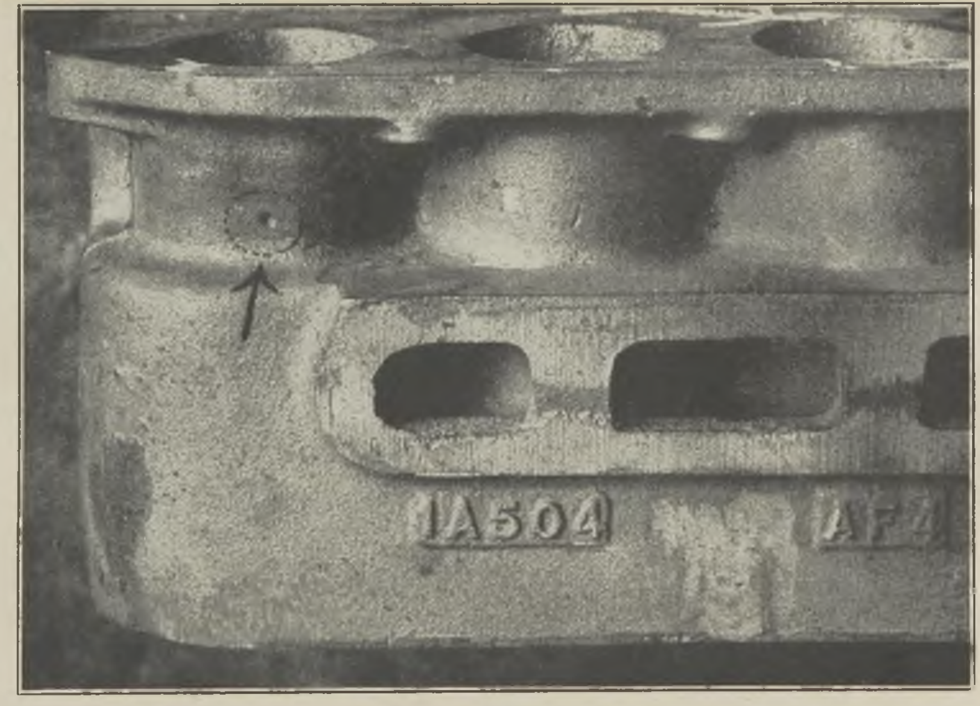


Fig. 6.—Blown Casting. Cylinder Block.

dried and heated to drive off the ammonium chloride formed and to burn on the ferric oxide.

Equal amounts of clay-bond and water were added to the treated and untreated sands, and the samples were milled for the same time. Strength and permeability figures were obtained and are as follow:—

	Untreated sand.	Treated sand (Fe_2O_3 burnt on).
Permeability ..	125	135*
Bond strength ..	5.4 and 5.7	6.0 and 6.2
35 min. later ..	5.3 ,, 5.4	6.4 ,, 6.5
60 ,, ,, ..	5.3 ,, 5.3	6.5 ,, 6.5
110 ,, ,, ..	5.5 ,, 5.5	6.7 ,, 6.7
19 hrs. later ..	7.4	8.0
Average of 8 determinations ..	5.4	6.4

An increase of 18.5 per cent. in strength.

* The difference in permeability is due to this sand being stronger and not as easily compacted by ramming as the untreated sand, possibly also to the fact that the bond on the treated sand was in the state of thin pellicles continuously enveloping each of the oxide-covered sand grains, while the bond on the untreated sand due to the lower surface energy was not as evenly distributed.

The strength increases are marked and are obviously a function of the surface tensions between the water-carrying clay bond and the quartz conditions represented by the conditions of the sand grains used.

Apart from the strength increases enumerated, other interesting manifestations of increased surface tension were evident during the experiments. On the nickel-plated wheels of the laboratory mixer used, the sands with the lower surface tension between bond and grains adhered to the polished surface. The sands with the higher surface tension did not adhere to the wheels. This adds another advantage of this type of sand when working with metal patterns.

When the surface tension between bond and sand grains is higher than between bond and metal surface, moulding sand sticking to the pattern should be a rare occurrence. These conditions are diagrammatically represented in **Fig.** 9.

FIG. 7.—SHOWS CONDITION OF UNBROKEN CLAY PELLETS FUSED IN THE SAND MASS.

Previously, and particularly in American synthetic moulding-sand practice, increased surface tension effects between bond and grain were obtained by solution in the water of the green bond of such substances as soluble alkalies; glycerine; solution of sodium lactate; molasses; sugar solutions (corn or cane), and wood extracts, but as these additions also increase the surface tension between the metal pattern and the bond, there is danger in their addition, and the previously-mentioned method of preparing or selecting the sand grain is preferable.

This subject of the physical condition of the base sand grain in moulding sands is interesting and important, and the above experiments do not by any means exhaust the possibilities of such an investigation, either from the purely scientific view point or from the point of view of practical application in the foundry. It is possible easily to burn on ferric hydroxide or other compound on the sand; later a method of doing so will be described.

The experiments certainly point to a choice of a particular type of silica sand grain as the basis of synthetic moulding sand, and such choice has been incorporated with satisfaction in the synthetic moulding sand used by the author.

Solely as an experiment of laboratory interest, a red sand of the Bunter type was synthesised by using a rough-grained silica sand, on which ferric oxide was burnt on, and a clay bond. This sand had all the appearance of the sands from the Bunter deposits—colour, feel, surface tension phenomena, and the added advantages of freedom from deleterious alkalies.

Continuing the second stage of the investigations and maintaining the semi-synthetic sand consisting of a mixture of Belgian sand and Southport sand, which still gave excellent results, a thorough examination of the Belgian sand was undertaken. It was felt that if an examination of the red sand revealed some characteristics to be avoided in a synthesis, the examination of the Belgian yellow would reveal some attributes to be desired.

While a very thorough investigation of this sand was undertaken in the Austin Laboratories, much valuable help was obtained on this sand, and indeed all through the investigation, from a " Memoir " by P. G. H. Boswell, O.B.E., D.Sc., namely, " British Resources of Refractory Sands," published in 1918, and it is proposed to quote extensively from this " Memoir."

Chemical Composition

The following are figures from the " bulk analysis " of this sand:—

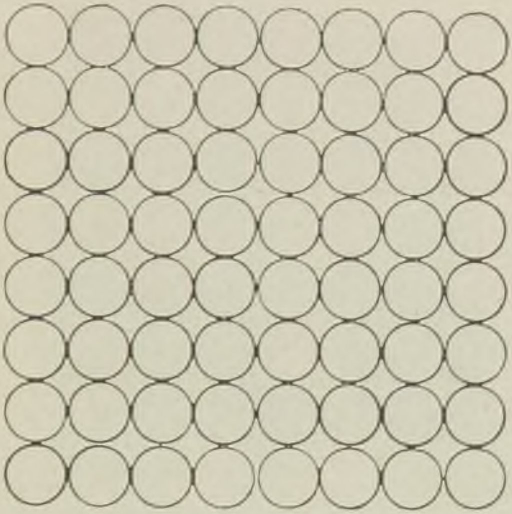
Boswell.			*Austin Laboratories.*	
	Per cent.		Per cent.	Per cent.
SiO_2	86.47	SiO_2	93.3	92.75
Al_2O_3	4.96	Al_2O_3	2.23*	3.6
Fe_2O_3	2.58	Fe_2O_3	1.40	1.00*
FeO	0.29			
MgO	0.37	MgO	0.30	0.30
CaO	0.26	CaO	0.30	0.30
Na_2O	0.12	Na_2O }	0.61	0.50
K_2O	0.47	K_2O }		
$H_2O +$	2.44			
$H_2O -$	1.54	$H_2O -$	1.37	1.45
CO_2	None			
TiO_2	0.40	TiO_2	0.20	0.20
ZrO_2	None	—	—	—
P_2O_5	0.09	—	—	—
SO_2	None	—	—	—
Cl	Trace	—	—	—
MnO	Trace	—	—	—
BaO	Trace	—	—	—

* Variation consisted only in the substitution of some alumina by some ferric hydroxide.

The Austin analyses are of samples that show variation in bulk consignments and were undertaken to ascertain what these variations consisted of and their possible effect in the moulding system. The interpretation of these analyses reveal the reasons for its suitability as a moulding sand.

The soluble and easily fusible alkalies are present in small amounts only; the same is true of the lime, magnesia and baryta contents.

(a)



b)

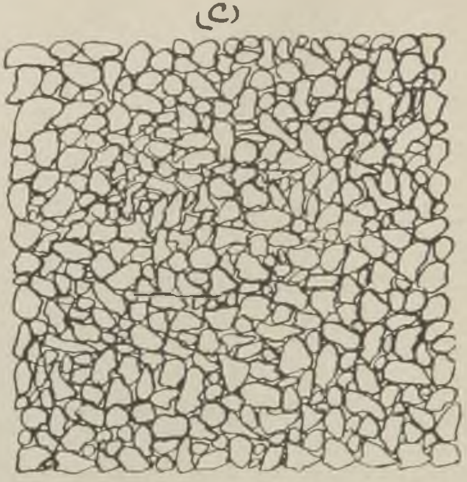


FIG. 8.

Therefore the sand would be expected to be refractory, and such is the case. The silica content is high, so also is the iron content. The percentage of combined water, not driven off at 110 deg. C. (H_2O+), is also high; therefore the sand would be expected to have " good life," and such is the case. By " good life " is meant the ability to retain its bond strength after repeated use.

The mechanical analysis, as given by Prof. Boswell, is set out in Table VI.

The outstanding points about the mechanical composition are the high proportion of medium-grade sand, the relatively large quantity of clay and the low percentage of fine-sand grade.

Examination of this medium sand grade shows it to be a good-quality high-silica sand.

TABLE VI.

Coarse sand. > 0.5 mm.	*Medium sand.* > 0.25 mm. < 0.5 mm.	*Fine sand.* > 0.1 mm. < 0.25 mm.	*Coarse silt.* > 0.05 mm. < 0.1 mm.	*Fine silt.* > 0.01 mm. < 0.5 mm.	*Clay.* < 0.01 mm.	*Total Sand grade.* > 0.1 mm.
7.5 per cent.	64.9 per cent.	12.0 per cent.	3.3 per cent.		12.3 per cent.	8.44 per cent.

Austin Laboratories (Tylor Screens).

Mesh.	*Mesh.*	*Mesh.*	*Mesh.*	*Mesh.*	*Mesh.*	*Mesh.*	*Mesh.*	
+ 35	+ 48	+ 65	+ 100	+ 150	+ 200	+ 270	− 270	
Mm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	*Mm.*	
> 0.417	> 0.295	> 0.208	> 0.147	> 0.104	> 0.074	> 0.053	< 0.053	
< 0.589	< 0.417	< 0.295	< 0.208	< 0.147	< 0.104	< 0.074		
								Clay.
0.1 per cent.	1.0 per cent.	8.4 per cent.	64.6 per cent.	7.7 per cent.	1.9 per cent.	0.7 per cent.	1.5 per cent.	14.1 per cent.

Chemical analysis of the sand grade:—

	Boswell. Per cent.		*Austin Laboratories.* + 65, + 100, + 150 fraction.
SiO_2	98.63	SiO_2	99.15
Al_2O_3	0.19	Al_2O_3	0.23
Fe_2O_3 FeO	0.22	Fe_2O_3 FeO	0.30
MgO	0.12	MgO	Trace
CaO	0.36	CaO	0.15
Na_2O	None	Na_2O K_2O	Trace
K_2O	0.08		
TiO_2	None	TiO_2	0.05

Loss on ignition 0.25. Loss on ignition 0.18.

Under the microscope this high purity is confirmed.

The fact, however, that the limonite pellicle around the grain is not burnt on and may easily be washed off by elutriation indicates a lower surface tension between the bond and the grain

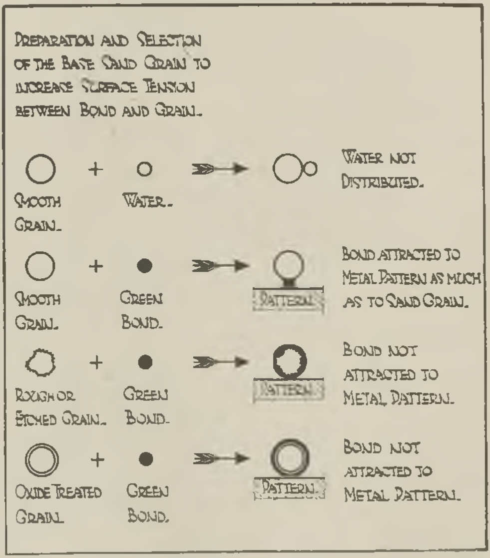


FIG. 9.—PREPARATION AND SELECTION OF THE BASE SAND GRAIN TO INCREASE SURFACE TENSION BETWEEN BOND AND GRAIN.

than that exhibited by the red Bunter sands. Experience on the moulding floor confirms this assumption, as the sand is difficult to patch.

This difference between the Bunter sands and the Belgian yellow may be accounted for by their geological formation. The grains of the red sands, formed under desert conditions, developed roughened surfaces from continued dry abrasion and the dry ferric oxide, readily adhered.

The presence of colloidal-iron hydroxide in the Belgian sand is probably the result of the decomposition of the colloidal mineral glauconite (silicate of potassium and iron and aluminium). The decomposition occurring under conditions the reverse of dry, demonstrated by the absence of the water-soluble potassium. Grains of undecomposed glauconite are sometimes found in this sand. By submitting the Belgian sand to " desert " conditions in the Austin laboratories, *i.e.*, by drying and heating and re-hydrating, it has been possible to reproduce a sand similar to the Bunter reds, in appearance and behaviour, without, of course, containing the harmful soluble alkalies.

The examination of these two sands has revealed the following characteristics, which are briefly tabulated as follow:—

The mechanical analysis of—

RED SAND.	BELGIAN YELLOW.
Reveals a great want of uniformity in grain size of the sand, resulting in a very low permeability.	Reveals a high percentage of the sand of uniform grain size, resulting in a very high permeability for sand of such fineness.

The chemical analysis of—

RED SAND.	BELGIAN YELLOW.
Shows excessive amounts of potassium oxide and sodium oxide in the various grain sizes and in the clay bond, indicating excessive amounts of easily fusible felspars and their decomposition products.	Shows a high silica content in the grain sizes and a low figure for the alkalies in the bond.

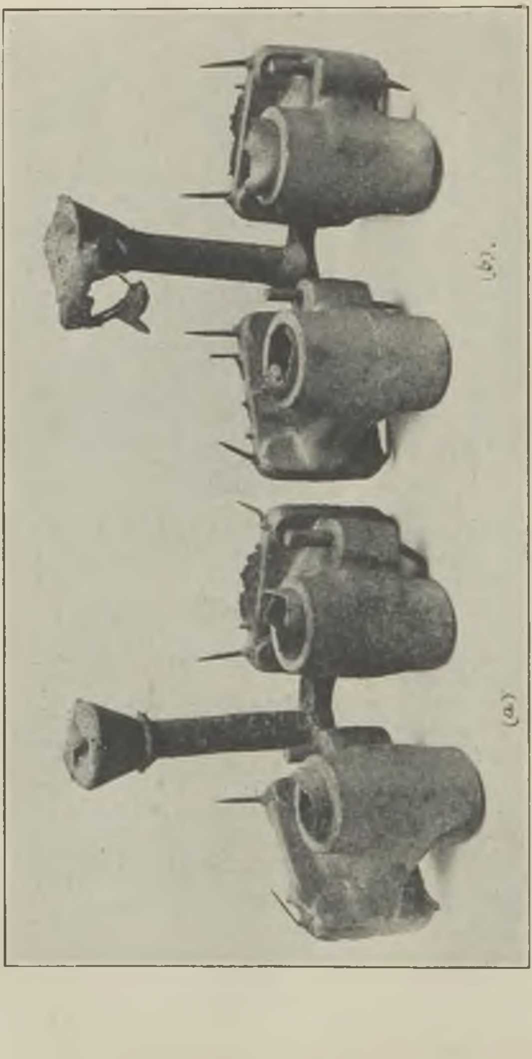


FIG. 10.—CASTINGS MADE IN (A) NATURAL MOULDING SAND, AND (B) SYNTHETIC MOULDING SAND.

The physical analysis of—

Red Sand.	Belgian Yellow.
Indicates a high surface energy between the bond and the sand grain due to burnt on pelicles of ferric hydroxide around the grain.	Indicates a low surface energy between the bond and the sand grain. The pelicles of limonite are loosely held and easily washed off.

Selecting the most desirable characteristics of both was the basis of the synthesis:—(*a*) Silica sands of high purity to be the base grains as in Belgian sand; (*b*) two major grain sizes in the sand so that permeability might be more readily controlled; (*c*) these sand grains to be coated with thin pellicles of ferric hydroxide to increase the surface tension between bond and grains, as in the red Bunter sands. (The silica-sand grains may be selected with the hydroxide envelope naturally occurring or artificially superimposed and burnt-on, which is more satisfactory); and (*d*) the bond to be refractory and to correspond in composition to that of the best steel sand bonds and fireclays, but, in addition, to have a high green bond and a high dry bond.

The selection of the bond was based on a consideration of the properties of two colloidal-clay binders readily available—Bentonite imported from America, and Colbond a domestic product. Colbond has a remarkably high green strength, though not so high as Bentonite. From a series of tests carried out at concentrations likely to be used in the systems, the green bond strength of Bentonite and Colbond were found to be in the ratio of

Bentonite	5
Colbond	3

However, keeping in mind the original purpose of the investigation—to develop a synthetic sand suitable for a mechanised grey-iron system, a mechanised-steel system and a jobbing floor—it was decided to operate with Colbond.

An examination of composition and properties of the two binders, shown in Table VII, reveals the reasons for the choice.

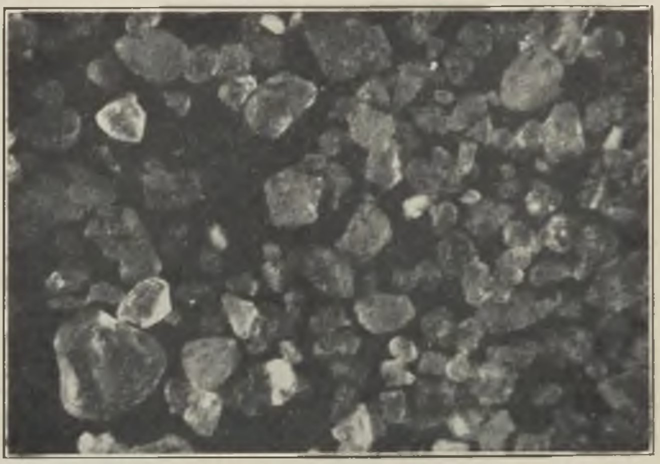


Fig. 11.—The Smaller Grain Size of Bromsgrove Red Sand Washed Repeatedly with Water, showing the Majority of the Grains with Ferric-Hydroxide still adhering.

Fig. 12.—The Larger Grain Size of Bromsgrove Red Sand Washed with Hcl.

TABLE VII.—*Chemical Analysis of Colloidal Clays.*

Bentonite	A.	Bentonite	B.	Colbond.	
Silica	62.57	Silica	57.98	Silica	61.57
Alumina	22.45	Alumina	22.46	Alumina	18.56
Iron oxide	3.89	Iron oxide	3.92	Iron oxide	3.08
Lime	0.75	Lime	1.92	Titanic oxide	0.96
Magnesia	2.46	Magnesia	3.24	Lime	1.07
Sulphur	0.30	Sulphur SO_3	0.75	Magnesia	0.62
Chlorides	0.20	Chlorides	—		—
Loss on ignition ..	6.18	Loss on ignition	7.93	Loss on ignition	13.41
Alkalies	0.80	Alkalies	1.35	Alkalies	0.65

Fusion Points.

Bentonite A.	Bentonite B.	Colbond.
1,340 deg. C.	1,275 deg. C.	1,500 deg. C. to 1,480 deg.C.

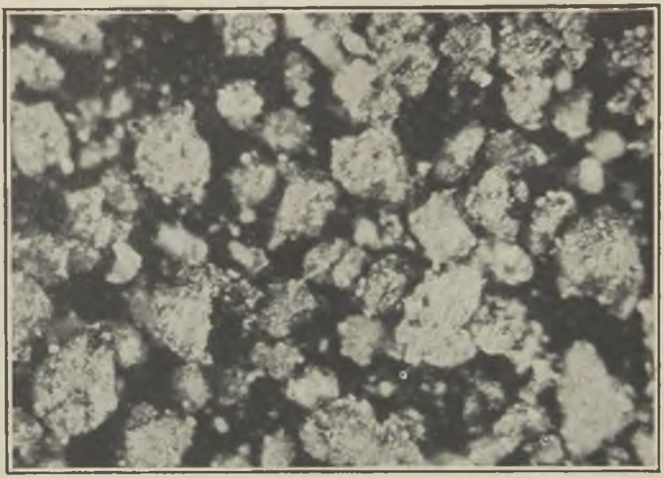


Fig. 13.—Bromsgrove Red Sand with Clay Bond adhering.

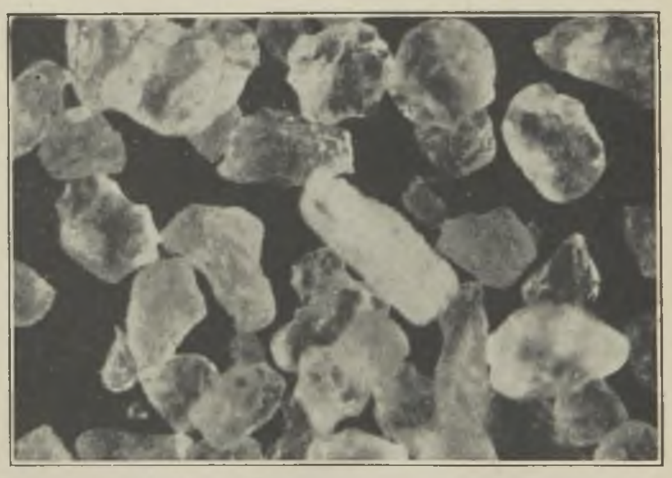


Fig. 14.—Erith Silica Sand as naturally occurring, showing Absence of Ferric-Hydroxide Pellicles.

The fusion point of Colbond is remarkably high, as indicated by Dr. Mellon's figures, given below, obtained from the constituent clays of this preparation.

	Yellow.	Red.	Black.	Mixture of equal parts of yellow red and black.
Cone ..	17	17	18	18
Centigrade	1,480	1,480	1,500	1,500

(The above determinations are the work of Dr. J. W. Mellor.)

As a comparison the fusion points of clay bonding material of naturally-bonded moulding sands are included; this table (Table VIII) is taken from a Paper on "Sands and Sand-Testing" by J. G. A. Skerl, D.Sc., F.G.S., given at the 28th Annual Convention of the Institute of British Foundrymen, June, 1931.

Having decided on the clay bond and type of sands to be used, the synthetic sand was put into production.

Several good silica sands were available, and an Erith silica sand of medium grain size and a Leighton Buzzard sand of fine grain size were selected. The following is the mechanical analysis of these sands.

Erith Silica.* I.M.M.		*Leighton Buzzard*.* I.M.M.	
+ 30 mesh	0.9 per cent.	+ 40 mesh	0.1 per cent.
+ 40 ,,	12.0 ,,	+ 50 ,,	0.8 ,,
+ 50 ,,	28.7 ,,	+ 70 ,,	11.4 ,,
+ 70 ,,	46.6 ,,	+ 100 ,,	45.4 ,,
+ 100 ,,	9.4 ,,	+ 150 ,,	36.6 ,,
+ 150 ,,	1.7 ,,	+ 200 ,,	3.0 ,,
+ 200 ,,	0.4 ,,	− 200 ,,	1.0 ,,
− 200 ,,	0.3 ,,	Clay	1.9 ,,

* I.M.M. Screens were used in these later determinations, to conform to the more general practice in this country.

Later a silica sand from the Bedford deposits was substituted for the Erith, when the investigation showed the advantage of the ferric

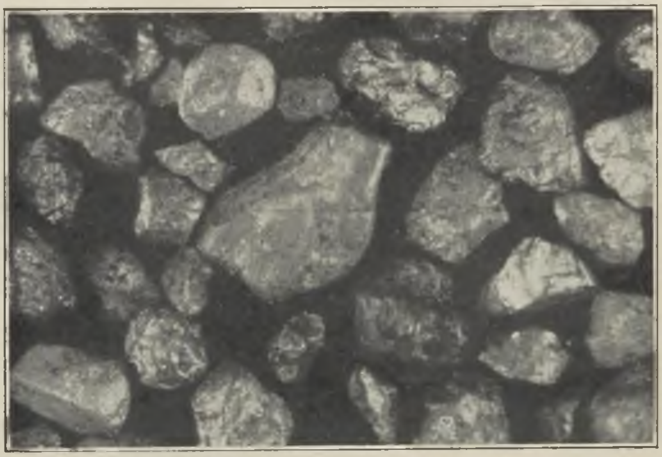


Fig. 15.—Erith Silica Sand with Precipitated Ferric-Hydroxide burnt on, showing one remarkably Smooth Grain to which the Precipitated Ferric-Hydroxide evidently did not adhere.

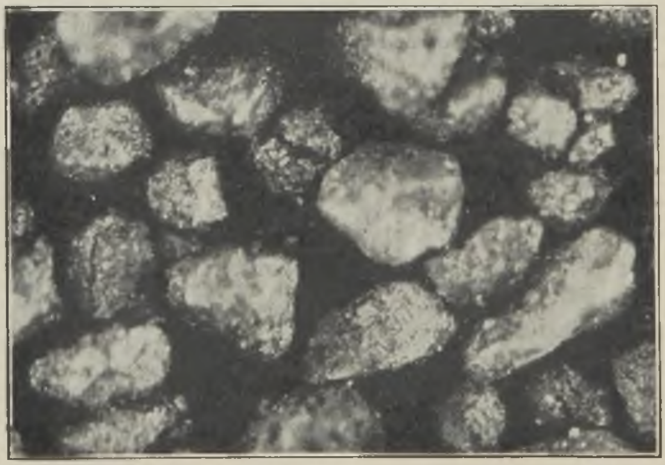


Fig. 16.— Erith Silica Sand with Ferric-Hydroxide and Clay Bond Additions.

TABLE VIII.—*Chemical Analyses and Refractoriness of the Clay-bonding Material in Sands.*

Sand.	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Alks.	Loss on ignition.	Fusion point in deg. C.
									Deg.
Southampton—Badenham	54.02	16.65	14.75	0.58	0.39	1.06	2.35	10.20	1,330
,, Westwood	53.90	20.08	10.40	0.85	0.44	1.88	2.15	10.30	1,380
Erith—Mild loam	57.23	11.12	8.51	0.54	0.45	1.17	1.13	19.85	1,320
,, Yellow loam ..	55.60	9.75	11.69	1.14	0.41	1.08	1.78	18.55	1,370
,, Medium loam ..	54.49	11.98	7.36	0.78	0.55	1.70	1.04	22.10	1,315
,, Strong loam ..	62.16	11.48	6.29	0.68	0.93	1.50	0.94	16.02	1,295
,, Extra strong loam	57.34	13.21	6.59	0.54	0.94	1.62	0.98	18.78	1,330
Pickering	72.59	13.04	4.40	0.22	0.62	0.81	2.74	5.58	1,270
Bromsgrove—Top bed ..	52.13	23.71	8.93	0.48	0.36	2.33	2.84	9.22	1,390
,, Middle bed	53.76	25.39	6.94	0.62	0.34	2.06	3.12	7.77	1,400
,, Bottom bed	55.63	24.64	6.82	0.70	0.44	1.90	2.43	7.44	1,415
Kingswinford—Top bed ..	56.95	23.24	8.00	0.60	0.52	2.08	1.56	7.05	1,320
,, Middle bed	55.46	23.37	8.70	0.85	0.37	1.97	1.98	7.30	1,360
,, Bottom bed	56.07	24.20	8.19	0.71	0.45	1.17	1.34	7.25	1,380
Scottish—Avenuehead ..	54.25	26.66	2.50	0.64	1.02	1.71	3.20	10.02	> 1,400
,, Greenfoot ..	52.89	31.41	2.40	0.33	0.36	0.10	3.97	8.54	> 1,400
,, Loudoun ..	54.26	27.51	4.09	0.32	0.20	0.15	1.29	12.18	> 1,400

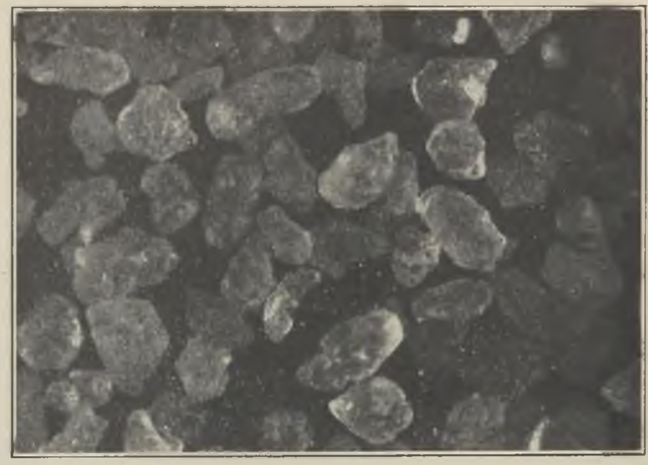


Fig. 17.—Leighton Buzzard Silica Sand, showing by Contrast with Fig. 14, Erith Silica Sand, a Thin Pellicle of Ferric Hydroxide, in this instance Colloidal Limonite.

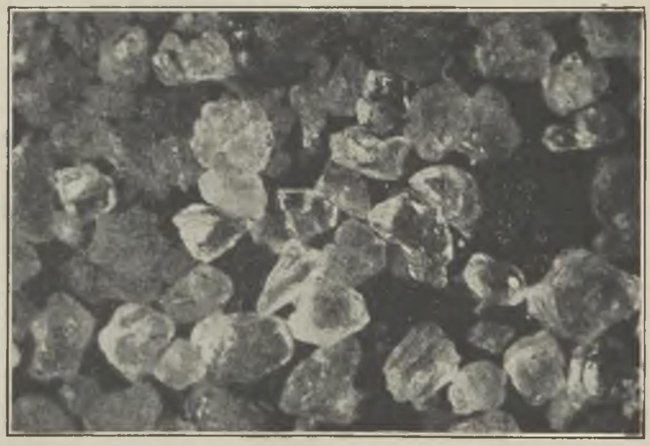


Fig. 18.—Water-washed Sand Grade of Belgian Yellow Moulding Sand.

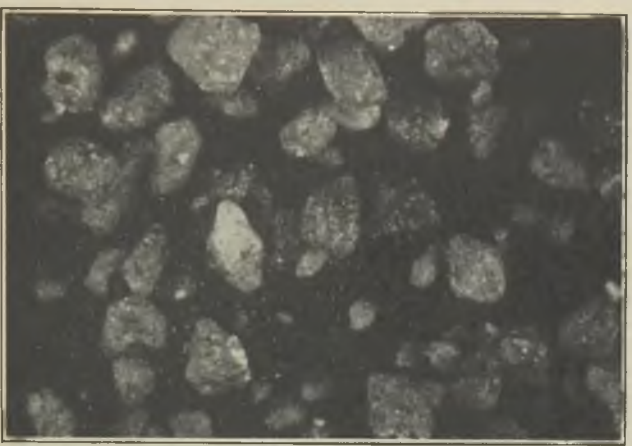


FIG. 19. — BELGIAN SAND GRADE WITH BOND ADHERING.

hydroxide which was found naturally occurring around each grain of this sand (equivalent in amount to 0.90 per cent. Fe_2O_3).

The following is a résumé of the resulting sand practice.

Facing Sand Preparation.

Using 14 parts	spent backing sand by volume.
4	,,	Leighton Buzzard Sand by volume.
¾	,,	Colbond by volume.
1¼	,,	coal dust by volume.

Mixing for 3 min. dry and 4 min. wet, gave the figures of :—

Strength	8 lbs. per sq. in.
Permeability	50 ,, ,, ,,
Moisture	5 per cent.

The Colbond additions were calculated from laboratory determinations, but as the strength figures steadily increased the amount was later reduced to 2/3 parts.

Backing Sand Preparation.

Using 14 parts of spent backing sand and
1 part of Erith silica sand (by vol.).

Mixing for one min. gave the following figures :—

Strength	6 lb. per sq. in.
Permeability	60
Moisture	4.5 per cent.

Later the Erith silica sand was substituted by spent core-sand (mixture of Erith and Leighton Buzzard sand), this being one of the intentions necessitating the investigation.

Again, it is intended to substitute the new sand additions to the facing sand by spent core-sand. This latter substitution is awaiting the installation of a sand recovery plant using Hummer screens—then the finer separation may be added to the facing sand and the coarser separation may be added to the backing sand.

That the present synthetic sand is giving satisfaction may be gathered from Table II, showing the reduction of scrap due to sand defects.

No spent sand is now being dumped; the new sand additions are, however, higher than the grey-iron system requires, and the extra sand is necessitated by shop requirements in moulding sand, mainly as " drier " sand for cores used in the jobbing grey iron and steel sections, and that the jobbing floor is now drawing from the grey-iron-sand system for sand for special work.

The suitability of this synthetic sand in the steel system is illustrated by photos of unfettled castings, Fig. 10 showing castings made in (*a*) natural moulding sand and (*b*) synthetic sand.

This investigation " to develop a moulding sand that would operate successfully as a grey iron, a steel and a jobbing-floor sand, and to make the basis of this sand, burnt sand which has already functioned in oil-sand cores " has resulted in considerable economy, apart from the reduction in scrap obtained.

It has also revealed very important surface energy effects between bond and sand grain, dependent mainly upon the physical condition of the sand grain. It is intended to pursue this subject further, as this synthetic system has already indicated further economies and some remarkable possibilities. An example will illustrate this.

It is possible to burn on the sand grain many more materials (preferably refractory materials) which will increase the surface tension between grain and bond and increase the green and dry-bond strengths of the sand; manganese compounds are an instance. These are:—

(1) *Manganese resinate* added to the linseed oil will decrease the drying time of the cores.

(2) *Manganese compounds* will be burnt on to the grains by the heat of the metal on the cores and subsequently by the heat of the metal on the moulding sand.

(3) In steel moulding, *manganese silicate* will be formed at the surface of the mould, and the stripping of the casting made to resemble or improve upon the easily-stripped moulds in manganese-steel castings.

The results of such additions are:—(1) An economy in the core shop, (2) an economy in clay bond, and (3) an economy in the fettling shop.

The burning-on of aluminium hydroxide to the sand grain suggests even other advantages apart from its desirability as a refractory and its suitability as an addition to siliceous clay binders, such as gelatinous compound, should have high surface-energy effects.

It is felt that, while this subject has many possibilities, it is most inadequately treated in this Paper, but time did not permit the confirmation of many interesting results, and only those repeatedly confirmed are mentioned. Further work is in progress. It is believed, however, that more rapid progress in the study of this subject could be made with the co-operation of interested members of the Institute of British Foundrymen. For this reason the preliminary findings are given here in the hope that such interest will be stimulated.

As an appendix, photographs of the sands used in the investigation have been included.

The author wishes to thank the Austin Motor Company for permission to publish this Paper, and very particularly to thank the staff of the

Austin foundry and laboratories for their indispensable co-operation in the work entailed in preparing this Paper.

DISCUSSION

Importance of Roughened Grain Surfaces

Mr. John J. Sheehan's Paper sounded a new note in foundry-sand practice and received, what it richly deserved, an excellent discussion.

Mr. F. Hudson, who opened the discussion, said the Paper was most interesting, particularly considering the original line of thought adopted by Mr. Sheehan and the numerous debatable points. It was not surprising that the original natural moulding-sand mixture gave serious trouble, both in preparation and service, and he doubted if any equipment could be obtained to effect efficient mixing of a sand of this nature. Perhaps Mr. Sheehan would confirm the statistics given in regard to sand requirements and time for mixing each batch, as a mixing time of 5½ minutes would give the required output instead of the allowed time of 2½ minutes. Furthermore, he did not think the test results, giving a comparison between the modern raised-roller type of mill and its elder brother were fair, as here, again, the test mixtures were inclined to be exceptional for green-sand moulding, which he presumed was the practice employed.

Alkalies and Refractories

He was also particularly interested to note that Mr. Sheehan discontinued the use of red sand as part of his sand mixture, a point in keeping with his own experience, for the improvement of permeability, but inclined to be overstressed so far as refractoriness was concerned. Candidly, the question of alkalies lowering the refractoriness of a sand was of little consequence in the presence of coal dust or other carbonaceous matter, particularly when light to medium castings were being produced. He thought it would also be admitted that the refractoriness of sand was effected by two factors: (1) the temperature of the metal in the mould and (2) the pressure of the metal on the mould surface.

Temperature of Metal in Moulds

These factors did not entirely depend on temperature of pouring, but were largely affected by the type of casting being produced. For example, in the case of cast iron the following points might be of interest:—Using an initial casting temperature of 1,340 deg. C., it has been found by actual test that the temperature of the metal in the mould immediately after pouring is completed is seriously reduced. (See Table A.)

Table A.—*Initial pouring temperature* 1,340 *deg. C.*

Casting section with normal size of gates.	Temperature of metal in mould immediately after pouring in deg. C.	
	Green sand.	Dry sand.
¾ inch	1,100	1,100
1 ,,	1,140	1,150
2 ,,	1,160	1,160
3 ,,	1,180	1,200
4 ,,	1,190	1,210

For example, in the case of a casting, ¾-in. section, the temperature of the metal in the mould has been reduced from 1,340 deg. C. down to 1,100 deg. C. This point should be fully taken into account when considering the refractoriness of moulding sands, as even the least refractory sand would stand up to 1,100 deg. C. and only the pouring basin and runner would be subject to the action of the metal temperature as poured.

Grain Surface and Strength

The effect of grain surface on the strength of the sand was particularly interesting, and personally Mr. Hudson said he would like to compliment Mr. Sheehan on the promotion of this new line of thought, and the clear manner of its exposition. At the same time, however, he would not be so dogmatic as to say that moulds made from synthetic sands were incapable of being patched or "sleeked." The average moulder in this country had become accustomed to the use of heavily-bonded natural sands containing excess clay bond. Moulds made from such sands could be easily sleeked and patched because when the moulder applied water to the mould with his swab, there was sufficient clay present to absorb this water without becoming unduly sticky. In the case of moulds made from synthetic sand the use of the swab was fatal, as the swab carried more water than the clay present was capable of absorbing, and the result, in the Scottish vernacular, was a "clarty mess." For the repair of moulds made in synthetic sand a swab should not be used, and water should be added to the mould surface by means of a fine spray such as one used for spraying roses. To his mind the effect of moisture was intimately associated with grain surface conditions, as regards the question of surface tension, and in this present Paper this had not received the attention it merited. In fact, one could not very well consider one without the other, and their combined effect could quite readily reverse some of the statements made by Mr. Sheehan. For example, the effect of adding such materials as molasses and wood extract, etc., did not necessarily increase the surface tension between pattern and the bond, and he certainly could not agree that there was danger in their addition.

Mr. Hudson said he noted that fusion points were given for Bentonite and Colbond. Perhaps Mr. Sheehan would indicate if these could be classed as authentic? Would it not have been preferable to determine the fusion point of the final sand mixture made from these products?

Is Facing Sand Necessary?

Finally, he asked Mr. Sheehan why he used facing sand at all, as from the physical properties given for his synthetic backing sand this should be capable of producing satisfactory moulds alone. In his own practice he was getting satisfaction when using over 99 per cent.

old sand, and the trouble was to keep down the green bond. The reason for this had been puzzling for some time, but after reading the excellent Paper he was of the opinion that the cause could be partially attributed to the roughening of the base sand grains through repeated use and the corresponding better adhesion between the sand grain and added bond. He closed with the suggestion that perhaps Mr. Sheehan would see his way to give a further Paper at some later date, when his researches were complete.

Grain Surface and Coal Dust

Mr. Ben Hird said the author had smoothed down another patch on the very rough road to a perfect moulding sand, and it was only by each smoothing down his little patch as well as possible that the industry would arrive at what it sought. He, like Mr. Hudson, had difficulty in understanding why Mr. Sheehan used facing sand at all, because he could use the backing sand quite satisfactorily for facing sand. Mr. Hird said his experience was similar to Mr. Hudson's, and the backing sand and facing sand on his mechanical plant was the same. Further —and this was the point of chief interest to him—he had found that the sand, without the addition of any red sand or bonding clay, only 2½ per cent. coal dust to each mix, gained in bond strength, and it was necessary to weaken it periodically. His own view was that surface tension was the crux of this rather peculiar gain in strength when there was no addition of new sand or clay, and he was particularly interested that Mr. Sheehan had arrived at that view. It was stated in the Paper that "There is some evidence that this ferruginous bond is burnt on to the sand grain. Ferric hydroxide mixed with similar sand grains is readily washed out, while ferric hydroxide precipitated on the sand grains and burnt on resists repeated washings. This coating gives a grip to the clay bond and assists it in making the sand that much stronger. But what is much more interesting and important, particularly in jobbing floor work, is that this coating grips the drier bond at the mould surface." That, continued Mr. Hird, was the point he had raised about coal dust. If one examined the black sand grains which was caused by coal additions one would find that the small specks of coal, after having been heated by the metal, became coke or a hard tarry substance, which adhered firmly to each sand grain, so that the grains became very rough. There were two deposits—a kind of sooty tar which affected the sand grain as though it were covered with fine emery, and in addition to that there were clinging to it, mostly on the grains which form the mould faces, the small specks of coal which had been burnt by the heat of the metal to a carbon or coke. These were almost like the small white limpets clinging to the rocks on the seashore, and they give a very rough surface to the sand grains. He suggested that if Mr. Sheehan would follow this line of thought, instead of roughening the grains with acid or striving to burn on the hybrids mentioned, he would find that the coal dust would give him just what he was looking for. Mr. Hird congratulated Mr. Sheehan on a most interesting Paper and hoped he would make further experiments with coal-dust additions to sands.

Facing Sands and Reclamation

Mr. J. J. McClelland complimented the author particularly on having presented a Paper which could be followed clearly by the practical man, and for having tackled a subject which it was hoped would eliminate eventually very many of the difficulties with which the practical man had to contend. In asking the author to expand his remarks on one or two of the points raised, Mr. McClelland referred to the *résumé* which the author had given of his resulting sand practice, where it was suggested, in regard to the facing-sand preparation, that there should be used 14 parts of spent backing sand by volume, 4 parts of Leighton Buzzard sand by volume, ¾ part of Colbond and 1¼ parts of coal dust. One did not notice any suggestion in the Paper as to whether the spent sand was to receive any treatment, but he raised the question because he had found that after sand had been used for a considerable time, and sometimes a shorter time, it gathered a certain amount of silt, which reduced the permeability. Did the author intend to treat the spent sand in order to eliminate any silt that might have accumulated? It was also stated in the Paper that it was intended to substitute the new sand additions to the facing sand by spent core sand. Mr. McClelland asked if it were to be assumed that the spent core sand had contained an artificial or natural bond before use, because in practice it was found that after use the bond was not entirely eliminated, so that by using that sand again one obtained the value of any bond remaining in it.

Another statement in the Paper to which he referred was that no spent sand is now being dumped, and that the new sand additions were higher than the grey-iron system required. If we were to get all that we expected or hoped for from this new synthetic sand method, commented Mr. McClelland, why should we need new sand? New sand was generally introduced for the purpose of renewing lost bond, but if the treatment referred to in the Paper was to be successful at all, one naturally presumed that it would eliminate the necessity for the introduction of new sand, except to the extent of the amount lost in the use of the sand.

American and British Practice

Dr. J. G. A. Skerl (B.C.I.R.A.), in congratulating Mr. Sheehan on the value of his Paper, stated that it had interested him greatly, since he was at one time in very close contact with the foundry wherein the experiments had been carried out. The moulding mixture containing the mixture of red Bromsgrove sand and yellow Belgian sand, upon which Mr. Hudson had adversely commented, was the result of the attempt to meet a certain specification for a green-sand moulding mixture as used in at least one of the large American automobile foundries, the specification being based and checked on American foundry-sand control equipment. Mr. Sheehan's results confirmed his own experience that specifications for moulding-sand mixtures for strength and permeability would not be of much value unless we possessed a knowledge of the fundamental characteristics of the sands used. The important consideration with a moulding sand was the properties, not at atmospheric conditions, but at temperatures at which the metal which was cast into it was molten. Two sands possessing similar strength and permeability constants at ordinary temperatures would behave quite differently at a temperature of 1,000 deg. C. or less, due to those fundamental factors, some of which, like the oxide film, Mr. Sheehan had been investigating.

Ferruginous Bonds

The work done on the ferruginous and other bonds by Mr. Sheehan reminded him of the Paper presented by Mr. C. W. H. Holmes to the Iron and Steel Institute,* and that presented by the same author as the I.B.F. Exchange Paper to the International Foundrymen's Congress, Paris.† These Papers had brought forward the idea of a "static" and a "mobile" bond in moulding sands, based on experimental evidence, which the present Paper confirmed.

It was interesting to note that in this country it was believed, following Prof. P. G. H. Boswell, F.R.S., whose valuable work had received recognition in Mr. Sheehan's Paper, and others, that iron oxide was beneficial in a moulding sand, especially for green-sand moulds. In America, on the other hand, the opposite view that it was detrimental, was more usually expressed. One could point out that over a period of years it had been shown that the increase in the iron-oxide content of the bonding material had definitely improved the practical results in the case of one commercial British semi-synthetic moulding sand.

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* Journal Iron and Steel Inst., Vol. CVI, pp. 61-87, 1922.

† F.T.J., Vol. 28, 1923, pp. 296-298, 308-311.

Belgian Sand

Mr Sheehan had quoted some figures from Prof. P. G. H. Boswell's "Memoir on Refractory Sand" regarding Belgian yellow sand. The chemical and mechanical analyses of Prof. Boswell's and Mr. Sheehan's samples of Belgian yellow sand differed considerably and indicated variation as to source. A refractoriness test, by Dr. J. W. Mellor, F.R.S., of Stoke, of 1,480 deg. C. was given for the Belgian yellow sand, but from the facts, which showed that large steel castings are made in Belgian yellow sand in many foundries in this country, he would suggest that the figure is low. The evidence would seem to point to the fact that the Belgian yellow sand as tested by Mr. Sheehan is not representative of this sand as generally used in this country.

The question of the refractoriness of the bonding material in a moulding sand had been raised in the Paper and in the discussion. It was generally true of natural moulding sands that the bonding material was less refractory than the bulk of the sand itself, but properly distributed bonding material in a sand mixture, particularly under those conditions where as little as possible is required, as when efficient mixing and milling is carried out it was found that the influence was not very great. If a bonding material of even comparatively low refractoriness is properly distributed throughout a sand the resulting material is fairly highly refractory. By attention to such points as good distribution of the bonding material, some firms are able to make steel castings in the red Bunter sands which Mr. Sheehan finds not refractory enough for his cast-iron cylinder blocks, even though most foundries making these castings use such sand.

Iron-Oxide Content

Mr. Sheehan has stressed the iron-oxide content as of great importance and carried out many of his experiments to this end. Nevertheless, in his present sand practice he is using a bonding material containing only 3.08 per cent. of iron oxide, as against 10 per cent. in Belgian yellow sand clay-bonding material (Prof. Boswell's figures) and about 7 per cent. in the Bromsgrove bonding material. He (Dr. Skerl) suggested that a bond containing a higher iron content would offer certain advantages.

In a footnote to the screening figures on Erith silica and Leighton Buzzard sands, it is stated that I.M.M. screens were used to conform to the more general practice in this country. It should be stated that the Institute of Mining and Metallurgy have dropped their series of sieves in favour of the British Standard Specification sieves, which have similar apertures to the Tyler screens.

Finally, in thanking the author again for his Paper, Dr. Skerl expressed his pleasure in hearing a Paper in which fundamentals were dealt with, and that he would continue the experiments.

Permeability and Bond

Mr. J. H. Cooper, who said the acquisition of the information contained in the Paper had entailed far more work than was realised, asked Mr. Sheehan what was the largest green-sand mould he had made in synthetic sand. He himself had seen castings weighing up to 4 tons made in Belgian green sand in this country; they were very well made, and had exceedingly good finish.

With regard to the reference made in the course of the discussion to the addition of new sand to add to bond, Mr. Cooper contended that in many cases new sand was added, not to increase the bond of the material, but to increase the permeability. It seemed that Mr. Sheehan agreed with that view, because in many cases he had used Leighton Buzzard sand to open the material. When sand was used in a mould under any conditions it was always split up by the heat of the metal in casting, and eventually became so fine that one could get almost any bond. But that was at the expense of permeability, and in all moulds, whether made with synthetic or other moulding sands, there must be permeability in addition to bond strength.

Grain Surface

Mr. F. K. Neath, discussing the function of iron oxide as a bond, said there was no doubt that the condition of the surface of the grains in synthetic sands was an important matter. He had carried out a large number of tests on synthetic sands, and there was no doubt whatever that when using a pure silica sand with a dead smooth surface there were difficulties in securing the maximum bond; it was much preferable to use a sand which had already roughened or had some small amount of bond firmly adhering to the grains, or even to use sand from the fettling shop, than to use grains which were smooth or had no bond burnt on. This led him to refer to the influence of coal dust. Recently some German investigators had confirmed Mr. Hird's theories as to the function of coal dust, stressing that that function was not merely to generate a gas film to protect the sand grains, but rather to form a tarry or pitchy coating which gave the grains refractoriness and improved their bonding value.

The Paper by Mr. Sheehan, together with that read by Mr. Hudson before two of the Institute's branches during the past session, indicated that the work being done in this country on moulding sands compared very favourably with that of any other country; everyone wished both Mr. Sheehan and Mr. Hudson every success in their experiments.

AUTHOR'S REPLY

Mr. Sheehan replied to some points raised in the discussion. After thanking the speakers for the kind manner in which the Paper had been received, he said he was quite conscious that there remained still a good deal with regard to the sand question that was open to discussion. With regard to Dr. Skerl's remark that he would have to retrace his steps in a good many cases, Mr. Sheehan said he considered that the Paper represented a step forward, and he would not like to retrace his steps, but would prefer to continue to go forward.

Necessity for Silt Inclusion

With regard to the point raised by Mr. Hudson concerning the patching of synthetic sand, he said he had found, contrary to what was generally accepted, that a certain amount of silt was necessary in a sand. Recently he had been very much relieved when he had received a communication from people in America who used a synthetic bond, to the effect that they were recommending the addition of 4 per cent. of silt, and they specified that the sand should contain 4 per cent. of material that would pass through 100 mesh. In the past we had all been afraid of silt, but its inclusion was necessary in synthetic sands if we had to induce the jobbing-floor moulder to take kindly to synthetic sands. In a mechanical moulding system one was not allowed to patch a mould, and if a mould was defective, a foreman would put his foot through it; but for a jobbing floor, where it might take two or three days to build up a mould, it was necessary to provide a sand that could be patched.

With regard to the fusion points for the synthetic bonding materials, Mr. Sheehan assured Mr. Hudson that the figures were absolutely authentic. The Colbond figures had been determined by Dr. Mellor and the Bentonite fusion points were taken from the published booklet.

Why Facing Sand is Desirable

As to the question why facing sand should be used, he said he was not particularly ambitious to use it, but it was a very easy way of making new additions. One could add fine sand to the facing sand to give a fine finish and one could add the coarser sand additions to backing sand, where a fine finish was not important, for it did not come into contact with the face of the mould. One could make coal-dust additions and bond additions to the facing sand where they were most effective. Whether or not one used a facing sand, it did not add anything to the cost of the sand, because one just made it in one mill and obtained the backing sand from another in a mechanical moulding system; one must have two mills in order to maintain a continuous supply of sand to the circuit. Perhaps there would be no necessity on the jobbing floor if one brought the backing sand to a quality condition equal to that of facing sand; but where one had to use two mills to maintain a continuous supply in a mechanical moulding system, he saw no objection to using one as a facing and the other as a backing sand mixer.

Coal Dust and Sand Grain Surface

Mr. Sheehan acknowledged that the work of Mr. Hird had been an inspiration to him on the sand question in very many ways, even before he had known Mr. Hird; before he had returned to this country he had read Mr. Hird's communications in the "Foundry Trade Journal." He agreed that the residue of carbonaceous material on the sand grain was a decided advantage; it was similar to that obtained by precipitating an oxide film on the sand grain. He was not very bigoted about the type of film that was put on to the sand grain, whether it be carbonaceous oxide or hydroxide, or whether it be iron oxide, or aluminium oxide, or manganese oxide, but he considered that some film was necessary on a smooth quartz grain. It certainly increased the bond 10 per cent., which represented a considerable saving in bonding material and in new sand. Perhaps as well as the carbonaceous bond or tarry material that was precipitated on the quartz-sand grain, there was also precipitated a certain amount of coke, and that would be very tenacious. He believed, too, that the finer the coal dust the finer the precipitation on the sand grain and the more tenacious it became.

Use of Reclaimed Sand

Mr. Sheehan expressed the belief that recovered sand was superior to new sand, and that a recovery plant would be necessary in every foundry eventually. He believed the recovered sand which founders had been throwing away was decidedly more valuable than the new sand they introduced. It was purely a matter of getting rid of excess of silt or dirt.

Speaking of the roughening of the grain, he did not intend to put that forward as a practical proposition, although it might be such. He had been looking for a rough-quartz grain, but could not get it conveniently, so that he had had to roughen by hydrofluoric acid, and had been astounded to find a 10 per cent. increase of strength as the result of that alone. There was no film precipitated on this particular grain, but just roughening it increased the surface extension between bond and grain—an increase of 10 per cent. in strength was attained.

Replying to Mr. McClelland, he said he was glad to have written a Paper which the practical man appreciated, because, certainly, he had appreciated the difficulties to be overcome in putting the synthetic-sand system into practice. The foundry referred to in the Paper was not the only one which he had changed over from the use of natural moulding sand to a synthetic sand, but it had offered particular problems, in that he had to operate a steel foundry, a grey-iron foundry and a jobbing floor. Every foundry had its own particular problems, and unless one understood the underlying requirements one would not be able to effect the change-over.

Standardised Sand and Permeability

With regard to the amplification of the formula given for the synthetic sand, he said he had used that particular formula merely to maintain a particular standard of permeability and bond. Any other formula that would have given that result would have been equally welcome and equally usable. There was no treatment of the backing sand as such; it just returned untreated into the system. With regard to the spent core sand, he said he had run for a month by using spent core sand as new-sand additions, and it was true there was some value in the bonding material which had not been burned out in the cores. He had been particularly anxious to take advantage of that; the practice previously was to throw away something which could now be used. It was not necessary to buy any moulding sand, but just to use the core sand as a core sand and then convert it into moulding sand by the addition of a bond.

There had been no difficulty in introducing the synthetic sand into the jobbing floor; he had found that the men there were beginning to use the sand from the grey-iron system on their own initiative. That was a justification for the use of the particular type of synthetic sand introduced, because the jobbing-floor moulder in a good many cases resented these innovations. When he had found the jobbing-floor moulders were using the sand he had been encouraged, and nowadays the sand made up for the grey-iron system had to provide a facing sand for the jobbing floor. He was introducing this type of sand also for the steel foundry—he did not use the coal-dust additions in steel moulding sands.

Control Considerations

Commenting on Mr. Cooper's remarks, he said the only new sand additions that he intended to make ultimately were those necessary to make up the losses on the castings as such, *i.e.*, the sand burnt into the runners or into the castings and carried away in castings. Of course, the new additions he had made were to introduce bond and to regulate the permeability; when one had the bond independent of the grains of sand, and the grains of sand were predetermined by the core requirements, one could very readily control both permeability and the bond.

He was completely in agreement with Mr. Neath that iron oxide as such was not important. He had tried iron oxide additions without burning them on, and had had a bond, although not so good as any of the synthetic bonds that were otherwise available. He was not insistent about the type of pellicle around the sand grain. He did not care whether it was ferruginous, or manganese or aluminium oxide, so long as one got it around the sand grain, by any method. Some of the methods mentioned, such as introducing manganese resinate into the core oil and burning that resinate to a manganese oxide, introduced a pellicle around the sand grain which was very valuable in steel work. He exhibited a sample of a sand with manganese oxide burned on, which was equally as valuable as one with iron oxide burned on, as regards bond strength, and he pointed out that Mr. Hird had found that a carbon bond burned on would be also valuable. He considered that the surface condition of the grain was more important than what was added as bonding material, provided the bonding material met one's requirements in giving sufficient green- and dry-sand strength.

Mixing Speeds and Composition

Dr. Skerl had said that his foundry was at one time in the grip of American practice. It was in the grip of an American practice applied wrongly to British conditions. Though he (Mr. Sheehan) had a good deal of American prejudices himself, he considered that British moulding-sand practice was superior in many ways to the American. But the Americans had to meet the difficulty that they were deficient in natural moulding sand resources and they had to turn out sufficient sand for a moulding system to meet the enormous productions in that country. With the additions of synthetic bonds one could mix within a minute, or 1½ min. or 2 min., but if using natural moulding sands one had very often to mill them for a period of from 7½ to 10 min. That would not be permissible in a mechanised moulding system such as those existing in America, producing 12,000 monoblocs in two shifts (16 hrs.).

Mr. Sheehan said he was rather keen on the factor of refractoriness. Both Mr. Hudson and Dr. Skerl had stated that refractoriness did not matter so much in a moulding sand; but he could not operate in the steel foundry with a red sand, because a portion of the sand became fusible actually, and although he had had excellent slag traps in the mould, slag was developed near the runner and washed into the mould. It might be possible to run a steelfoundry with red sand, but he did not see the necessity for so doing when one could obtain much more refractory sands quite easily and as cheaply.

Sieves

As to the statement that the I.M.M. sieve was no longer standard in this country, he said he was not bigoted even about sieves; he did not think it mattered very much whether one had an I.M.M. or B.S.I. sieve, or Tyler sieves from America, so long as one interpreted the figures from them, and when one got good results with sand that was retained on the 70 mesh of the I.M.M., one should maintain that condition. It was valuable from the point of view of exchanging ideas and information to keep to a particular standard sieve, however.

Dealing with some of the samples exhibited at the meeting, Mr. Sheehan said one was a Belgian sand made into a red sand by burning on some of the iron oxide existing in the Belgian sand. It could easily be washed. Another was a red sand washed with water, but he could not wash from it the ferruginous bond, which was very valuable in red sands. He could take it off by hydrochloric acid and leave a perfectly clear silica sand. On another sample he had superimposed or precipitated the ferruginous bond. On another was precipitated a pellicule of manganese oxide.

Vote of Thanks

Mr. J. W. Gardom, who said he was responsible for securing the Paper, proposed a hearty vote of thanks to Mr. Sheehan for it. Its value could be gauged largely by the fact that it had invoked so spontaneous a discussion. Perhaps the author might have made it more clear that he was using the sand referred to in a mechanical system, for it appeared that some of those who had discussed the Paper were probably thinking of its use in ordinary floor moulding. It had been pointed out that natural sand could not be prepared quickly enough in a mechanical foundry, and that statement covered the point made that the sand that was used in the foundry, before Mr. Sheehan had got to work there, was not suitable. Reference had also been made to permeability being too high, a statement which appeared to be a little exceptional. Finally, Mr. Gardom expressed the hope that the work which had been started on sand testing in this country, and which had been carried a stage further by Mr. Sheehan, would continue.

Mr. H. Winterton (Junior Vice-President) seconded the proposal. Discussing some of his own experiments, he said that with one artificial bond he had turned out three blends, one with the ordinary sand and two with artificial sand, and one could be excused for choosing the latter as having been made with the original sand. He looked forward to the time when we might be able to say that the same sand was being used in foundries year after year, and that there would be no more difficulties in deciding where to dump it. We should by that time have solved the problem of perpetual motion. Finally, Mr. Winterton said that he could promise Mr. Sheehan a very lengthy and exhaustive discussion by the Scottish Branch if he would present such a Paper there.

The vote of thanks was carried with acclamation.

Mr. Sheehan, in a brief response, said the reception of his Paper had amply compensated him for the trouble he had gone to in preparing it.

ON THE USE OF HIGH-DUTY CAST IRON IN THE MANUFACTURE OF TEXTILE MACHINERY

By A. Roeder (Chief Chemist, Société Alsacienne de Construction Mécaniques, Mulhouse)

(*Presented on behalf of the Association Technique de Fonderie*)

[French Exchange Paper]

Mechanical engineers have been led of late to pay greater attention than in pre-war years to the researches carried out by metallurgists in the realm of cast iron. The application of these researches soon had the effect of bringing about notable improvements in the mechanical and physical properties of the material. The influence of two important factors have been ascertained, namely, the constitution of the metal and its structure. When due weight is attached to these factors, the cast iron obtained is of superior quality, eutectoid or pearlitic, distinguished from other brands of cast iron in that it has a quasi-isotropic structure, a feature that may be considered as the one which confers to machine parts their high mechanical resistance to external stresses. Various methods of manufacture have been perfected, and are now in current use in France and in other countries. Space does not allow of reviewing in the present instance the various processes followed; moreover, foundrymen are well acquainted with them.

High-grade cast iron was used in the first place in the manufacture of heavy machine parts, such as gas-engine and steam-engine cylinders, piston rings, and so forth. It was, however, soon found advisable to give to other branches of the engineering trade the benefit to be derived from the use of this same material. The International Foundry Exhibition held in Paris, in 1927, contained a number of spinning and weaving machine parts, namely, worm gears, intersecting and self-acting spool mechanisms,

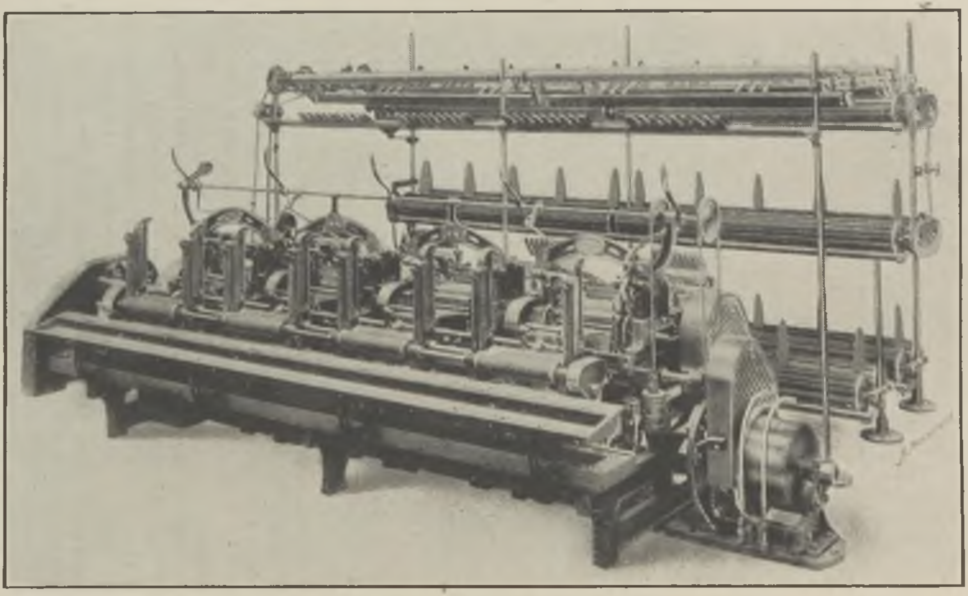

Fig. 1.—Modern Textile Machine which Utilises High-Duty Iron for Its Components.

levers, calender and fluted roller gears, brake pulleys, etc., of high-duty cast iron. Fig. 1 illustrates a textile machine embodying such elements.

For a long time past two brands of cast iron were resorted to in the manufacture of the very many spinning and weaving machine parts as are illustrated in Fig. 2, these brands being:—(1) Cast iron of good quality; and (2) cast iron of an improved quality, to which there has been added high-duty iron as a third brand.

Two considerations govern the use of this third brand. In the first place, its mechanical properties are much above those of the other cast irons. Further, it enables engineers to deal with the problem of reducing the weight of moving parts, a great advantage in view of the increasing speeds and stresses to which machine elements are now subjected.

The superior quality of the metal ensures a higher resistance to tensile and bending stresses, to shearing and impact stresses; it also confers to the pieces a considerably higher fatigue limit. It should be noted in this connection that some component parts of textile machinery have to undergo in service endurance stresses having varying rates of high frequency, stresses the direction of which is constantly alternating between extensive positive and negative values.

Hence, the builders of textile machines have taken great interest in the very high increase in fatigue limit here referred to, and are using machine parts made of high-duty cast iron.

A second consideration is the no less important property of high-duty cast iron to yield castings which are highly resistant to wear. Although the problem of resistance to wear still remains a somewhat involved one, yet it may be stated that the structure of high-duty cast iron forms a comparatively safe criterion to go by.

A maximum resistance to wear may be said to be ensured by the presence in the metal of graphite in long and thin laminæ, and of a lamellar pearlitic matrix. A similar structure is

Fig. 2.—A Group of Textile Engineering Castings made from High-Duty Iron.

met with particularly in the pearlitic cast irons of the Lanz system.

The object of the present Paper is to point out the resistance values of the high-duty cast irons in question, by showing the results obtained in the course of tests on specimens which were not cast separately but were taken from the castings themselves. For comparison, the results are given of similar tests on similar castings (see Fig. 3), but made of the other brands. The brands tested are marked A, B and C, and have the following significance:—A to cast iron of good quality; B to cast iron of improved quality; C to high-duty cast iron.

Mechanical Tests

I.—*Shearing tests*, with the Fremont-S.A.C.M. machine, on test specimens 5.64 mm. (0.220 in.) in diameter, taken from the casting shown in Fig. 3.

A cast iron :
R_c = 24 24 24.9 25.5
Average = 24.6 k. per sq. mm.
= 15.62 tons per sq. in.

B cast iron :
R_c = 30.4 29.9 30.9 30.3
Average = 30.4 k. per sq. mm.
= 19.30 tons per sq. in.

C cast iron :
R_c = 37.1 43.7 40.9 43.1 38.9
Average = 40.9 k. per sq. mm.
= 25.97 tons per sq. in.

II.—*Transverse tests*, with the combined Fremont-S.A.C.M. machine, on standard test specimens 35 × 10 × 8 mm. (1.378 × 0.393 × 0.315 in.); distance between supports 30 mm. (1.181 in.).

A cast iron :
Total breaking load = 665 695
Average = 680 k. = 1,500 lbs.
Deflection previous to rupture = 0.18 0.20
Average = 0.19 mm. = 0.0074 in.

B cast iron :
Total breaking load = 915 953
Average = 934 k. = 2,060 lbs.

Deflection previous to rupture = 0.20 0.22
Average = 0.21 mm. = 0.0078 in.

C cast iron :
Total breaking load = 1,264 1,320
Average = 1,292 k. = 2,850 lbs.
Deflection previous to rupture = 0.22 0.24
Average = 0.23 mm. = 0.0089 in.

III.—*Repeated impact tests,* with the S.A.C.M. machine, on test specimens 10 mm. (0.393 in.) in diameter, unnotched.

A cast iron :
Number of blows causing rupture = 15 25

B cast iron :
Number of blows causing rupture = 180 240

C cast iron :
Number of blows causing rupture = 1,200 1,500

IV.—*Fatigue tests under alternate stresses* (rotary bending) with the S.A.C.M. machine (Woehler system), on test specimens turned to a diameter of 10.65 mm. (0.419 in.).
Total length = 157 mm. (6.180 in.).
Length between reference marks = 140 mm. (5.512 in.)

A cast iron :
Alternate stress : $\sigma = \pm 14.8$ k. per sq. mm.
= 9.40 tons per sq. in.
Alternations : $n = 61{,}983$ (up to rupture).

B cast iron :
Alternate stress : $\sigma = \pm 14.8$ k. per sq. mm.
Alternations : $n = 404{,}380$ (up to rupture).

C cast iron :
Alternate stress : $\sigma = \pm 14.8$ k. per sq. mm.
Alternations : $n = 10{,}000{,}000$ (not ruptured).

The above results clearly show the superiority of the C cast iron over the two other brands A and B, which, formerly, were the only ones used in the making of castings for spinning and weaving machines. The high-duty brand of cast iron has greatly contributed to the progress achieved in the construction of textile machinery.

DISCUSSION

High-Duty Iron Deemed Unnecessary

Mr. E. Longden said an impression might be conveyed that British textile-engineering founders were not competent, but he did not think that was so. It was true that the constitution and structure (which might mean the same thing) of cast iron had had much closer attention during the past ten years than formerly, and that if due regard was paid to the physical make-up as well as to the chemical composition, metals

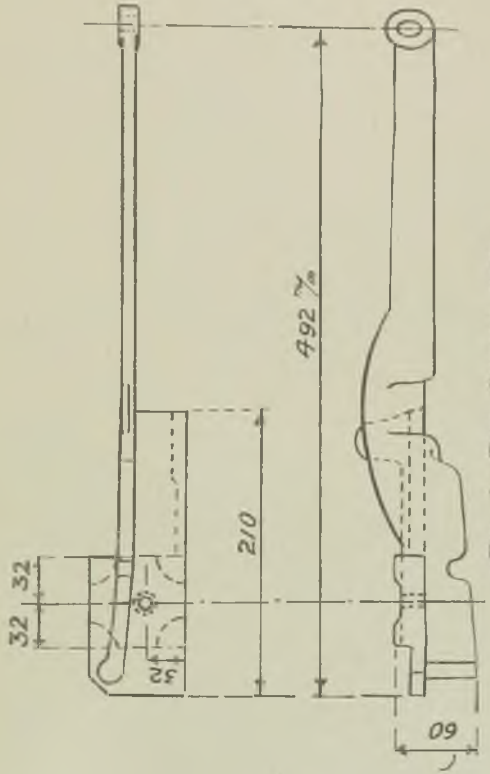

Fig. 3.—Test Casting used.

of improved strength could be produced, as the author had stated, by increasing the pearlitic area (as the result of special processes) beyond that obtained by ordinary casting methods. It was also true that such material possessed greater mechanical resistance to external stresses.

For many decades British textile-machinery makers had produced very high-class machines from castings made of high-grade material. The sections of castings had been cut down to very fine limits. Again, he had still to learn that there was any need for the reduction of sections, since actual replacements were not frequent; nor were there so many moving parts as to warrant re-designing machines and parts, because when once such members were set in motion they required very little power to continue their movement. There was probably more strain set up by incorrect setting of parts or mal-alignment and faulty machining than by the carrying of a comparatively small additional weight of metal.

However, he suggested that it was not practicable to use high-duty iron in more than 5 per cent. of the textile-machine castings—and he assumed that " high-duty " iron was intended to mean metal whose constituents and structure were controlled within very fine limits. Such metal must be made by such processes as the Lanz hot-mould method, or processes used for the production of Emmel iron, Meehanite, nickel iron, and low-carbon iron (the latter produced by rotary furnaces). With the exception of Emmel iron and the low-total-carbon iron, these metals were essentially of low-total-silicon content and might contain very little phosphorus; and the low-total-carbon iron, whether produced by the rotary furnace or by the Emmel process, could be brought within the same category as being metals which could not be cast with the degree of ease necessary in the production of textile-machinery castings.

For the 5 per cent. of textile-machine castings which might be made by special processes, probably steel castings would be less expensive. Mr.

Longden ventured to suggest that costs of production would increase very considerably if high-duty castings were substituted for the high-grade cast iron now used in textile machines. The reasons he gave were the higher initial cost of high-duty iron; the increase in the general manufacturing cost of the castings due to extra moulding operations, and greater hazards due to the comparative viscosities or fluidity of the metal, which would create a greater percentage of waster castings; and that machining speeds would be seriously reduced due to the greater density and hardness of the cast iron.

From 6 to 8 per cent. of textile-machinery castings were annealed at a temperature of approximately 850 to 900 deg. C. for from 6 to 8 hrs. in order to create dead-soft machining properties, and most remarkable machining speeds were attained with the annealed metal. Such dead-soft metal could not be obtained even with nickel. It might be suggested that the high-duty iron could be annealed, and he agreed that it could, but he also pointed out that annealing seriously reduced the strength of cast iron, so that the purpose of introducing the high-duty iron would be defeated. Again, it would entail further expense.

In a British textile machine similar to that shown in Fig. 1 there were not many parts warranting the use of high-duty iron. The underframes were required to have sufficient rigidity and body to absorb or prevent vibration, but at the same time their thickness did not average more than from $\frac{3}{8}$ in. to $\frac{5}{8}$ in. The thickness of stretchers and beams were from about $\frac{1}{4}$ in. to $\frac{7}{16}$ in. The thickness in the thin areas of some of the fluted rollers shown in the foreground of Fig. 1 was not more than $\frac{1}{8}$ in. when machined, and the general section of many more parts was not much more than $\frac{1}{4}$ in. The thickness of the bodies of various types of cast-iron spindles, when machined, varied from $\frac{1}{8}$ in. to $\frac{1}{4}$ in.

On the other hand, there were rollers of from $\frac{1}{2}$ in. to 5 in. dia. and up to 9 in. long, highly polished, which were required to possess weight and body. The main cylinders of a carding engine might have a diameter of 42 in., and 42-in. face, giving a surface area of 5,540 sq. in. The black castings were $\frac{3}{8}$-in. section, except where strengthened by shallow bands, and machined down to $\frac{1}{4}$ in. thickness. Such castings were difficult to produce in any other iron than that which had already proved successful, and the use of modern high-duty iron would be very risky and expensive. There was another casting, named a " flat," which stretched across the face of the cylinders (there were usually about 100 on each machine) and acted like a comb; this casting was of T section, and the general thickness was $\frac{1}{4}$ in. These castings were the most sensitive of any that a foundryman could have to make, and quickly responded to chilling by a departure from the metal mixture, or in the moulding, such as by the use of damp sand, or flash or fin, however slight, forming on the joint of the mould which created white iron, such chill pentrating into the section of the casting preventing group machining.

The whole range of textile-machinery castings could be included in the following four ranges of analysis:—

T.C.	Si.	Mn.	P.	S.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
3.35	2.75	0.7	0.6	0.08
3.3	2.50	0.7	0.8	0.09
3.3	2.25	0.7	0.9	0.09
3.3	1.50	0.7	0.9	0.09

He maintained that British textile engineers had been using the very best metal possible; their metals were considered to be of good quality and very suitable for the duties they had to perform. The complaint is that British textile machinery lasts too long and does not induce the purchase of the more recent type of machines.

Mr. Sutcliffe mentioned that one British firm was using 25 per cent. pig-iron and 75 per cent. scrap for textile-machinery castings.

Mr. J. H. Cooper said that the author—who was obviously a clever man, judging by his status in France should be given credit for having tried to put them on a line which might result in improvement. Although they might not be using high-duty iron in this country, they had seen textile machinery made with a good deal of scrap which was not always up to the 100 per cent. efficiency mark. Doubtless the author had quite good answers to the points made in the discussion; it could be accepted that he would not have prepared the Paper unless he had had good reason for putting forward his arguments.

STUDIES ON CAST RED BRASS FOR THE ESTABLISHMENT OF A BASIC CLASSIFICATION OF NON-FERROUS INGOT METALS FOR SPECIFICATION PURPOSES

By C. M. Saeger, Junr.

(Presented on behalf of the American Foundrymen's Association)

[AMERICAN EXCHANGE PAPER]

Abstract

An investigation was sponsored by the Non-Ferrous Ingot Metal Institute at the Bureau of Standards to collect data to be used in the simplification of the number of compositions of copper-base ingot metals. The present research is restricted to red brass, having the nominal composition of 85 per cent. copper and 5 per cent. each of tin, zinc and lead.

A comparison was made of the alloys prepared from virgin and remelted metal with four distinct types of test-bars cast at temperatures from 1,040 to 1,260 deg. C. The results for tensile strength, Brinell hardness, electrical resistivity and density divided the test-bars into three classes:—(1) bars from chill ingots; (2) bars from ingots obtained by the "immersed-crucible" method, and (3) sand-cast bars. There were only slight variations in the values obtained for any type of bar cast from virgin or remelted metal. The shrinkage and the running properties of the alloy were also determined. The metallographic structure of the bars poured at 1,205 and 1,260 deg. C. led to the conclusion

that, in general, a marked columnar structure is accompanied by inferior physical properties. Pronounced non-uniformity of structure was found in one type of sand-cast test-bar. Microscopic examination showed that sand-cast bars poured at high temperatures were subject to high stresses during the cooling, and had inferior physical properties. An expansion of the alloy occurred immediately after solidification.

In the second phase of the work the separate effects of sulphur and iron were studied. Casting at a high temperature lowered the physical properties more than did the addition of sulphur up to 0.1 *per cent. The addition of iron up to* 0.6 *per cent. improved all of the physical properties of this brass with the exception of the electrical resistivity. The running properties were improved and the shrinkage was unchanged by the addition of either sulphur or iron.*

The co-operative investigation is conducted at the Bureau of Standards by Mr. H. B. Gardner, a Research Associate for the Non-Ferrous Ingot Metal Institute, under joint direction of the Bureau and an Advisory Committee, appointed by the Institute, consisting of Dr. G. H. Clamer, President, The Ajax Metal Company, Philadelphia, Pennsylvania, Mr. F. L. Wolf, Chief Engineer and Technical Superintendent, Ohio Brass Company, Mansfield, Ohio, and Mr. J. W. Bolton, Metallurgist, The Lunkenheimer Company, Cincinnati, Ohio. This advisory committee has aided considerably, especially when the commercial aspects of the problem were involved. This Paper shows a type of research conducted at the Bureau of Standards in co-operation with industry to bring about simplification of standard specifications.

The author wishes to express his appreciation to Mr. H. B. Gardner, Research Associate, who made the tests and correlated the data contained in this Paper.

INTRODUCTION

A Special Committee on Promotion of General Use of Specifications for Copper Alloys in Ingot Form was organised by the American Society for Testing Materials in 1929. This committee, consisting of representatives of producers and consumers of copper-base ingot metals, had for its purpose the study and promulgation of the use of specifications for copper alloys in ingot form and to recommend to the Society such revisions in American Society for Testing Materials Specifications affected by these studies indicating the desirability towards reducing the number of specific non-ferrous ingot-metal alloys in commercial use.

Producers of non-ferrous ingot metals organised an institute, known as the Non-Ferrous Ingot Metal Institute. Through the co-operative efforts of the members of this Institute with the American Society for Testing Materials and other technical bodies definite progress has been made toward the standardisation of the non-ferrous alloys in use. As a result of a survey made, it was found that over 600 so-called common alloys were in use, and in addition many special alloys that are usually classed as high strength alloys. Tentative specifications have been promulgated and approved by the American Society for Testing Materials covering twenty non-ferrous alloys. It is believed that these, to a very large degree, may be used in place of the more than 600 now in use. Steps along educational lines will be necessary in order to make this work useful and effective. It is, of course, not believed that the industry will in five or ten years from now be producing only 20 non-ferrous alloys, but at least a goal has been set and constructive efforts should be made to approach it as closely as possible. It has been found that there are 40 different specifications for one of the most widely-used alloys of the industry, namely, 85 per cent. copper, 5 per cent. tin, 5 per cent. lead, 5 per cent. zinc. The variation between specifications is in all cases slight, either in allowed tolerances of the main constituents or in the impurity content, namely, nickel, sulphur, phosphorus, iron, antimony, etc. It appeared in this case that these forty specifications could probably be replaced by one.

The Non-Ferrous Ingot Metal Institute has been instrumental in bringing about co-operative arrangements with the Bureau of Standards, whereby technical research is now being conducted at this Bureau for the purpose of providing additional and better information regarding copper-base casting alloys than is at present available.

SCOPE OF INVESTIGATION

In the tentative programme, red brass of the nominal composition, 85 per cent. copper and 5 per cent. each of zinc, tin and lead, which is one of the most widely-used commercial alloys, was selected as the first alloy to be studied.[1] The important variables include the form of the test-bars the method of casting them, the pouring temperatures, any possible differences between virgin metal and remelted metal, and the effects of definite amounts of known impurities. The effects of these factors upon the physical properties are summarised in this Paper.

Pouring temperatures of 1,040 deg. C., 1,095 deg. C., 1,150 deg. C., 1,205 deg. C. and 1,260 deg. C. were used in the study of virgin metal, remelted metal and the effect of sulphur. For the effect of iron, pouring temperatures of 1,065 deg. C., 1,150 deg. C. and 1230 deg. C were used. The following properties were determined in sequence on each bar: Electrical resistivity, tensile properties, density and Brinell hardness. In addition, the shrinkage from above the maximum pouring temperature to room temperature, and the running properties at each of the pouring temperatures were determined. Metallographic examinations of the structures were also made.

MATERIALS AND METHODS

Materials

When the virgin metals used for making the alloy were analysed chemically, the only impurities found that might have any real significance were: 0.0052 per cent. of iron in the copper; 0.01 per cent. of iron in the zinc; 0.016 per cent. of iron and 0.12 per cent. of bismuth in the lead; and 0.023 per cent. of iron in the tin. The alloys were made up in heats varying from 80 to 100 pounds, and each constituent metal was weighed to within 1 per cent. The term "remelted metal" is used throughout the Paper to refer to the 85-5-5-5 alloy which was made from virgin metals, cast into ingot form, remelted and recast into test-bar moulds. The extreme range of composition as determined by analysis of the various heats was as follows, although in most of the heats the variations were much smaller. The slightly larger variation in zinc content, especially in the remelted metal, was caused by the greater volatility of the zinc:—

Metal.	Copper.	Tin.	Lead.	Zinc (by diff.).
	Per cent	Per cent	Per cent	Per cent
Virgin ..	84.52—85.56	4.91—5.26	4.80—5.28	4.64—5.21
Remelted	84.45—86.06	4.91—5.23	4.77—5.25	4.50—5.42

"Stick sulphur" and a copper-iron "hardener," which contained 52 per cent. of iron and was prepared from virgin copper and commercial open-hearth ingot iron, were used in preparing alloys containing sulphur and iron respectively.

Moulding, Melting and Pouring

Green-sand moulds were prepared from grade 00 Albany sand. A permeability number of 12 to 16 (American Foundrymen's Association units), a compressive strength of 5 to 7 lbs. per sq. in. and a moisture content of 6 to 6.5 per cent. were maintained throughout in preparing the sand for the moulds.

The metal was melted in a high-frequency induction furnace of the "lift-coil" type in a double-wall clay-graphite crucible. Each melt was heated to a temperature of 56 deg. C. higher than the temperature at which it was to be poured. A double-wall crucible was used to minimise the drop in temperature during the pouring. The greatest difference in pouring temperature between the first and last of a series of test-bars from one heat poured at 1,040 deg. C. was 5 deg., and was approximately twice as great at 1,260 deg. C.

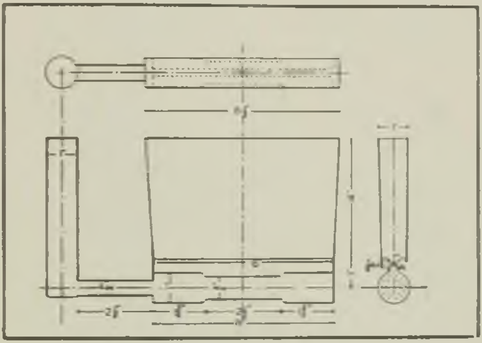

FIG. 1.—SAND-CAST TEST-BAR DESIGNATED AS THE "FIN-GATE" TYPE.

The thickness of the web, A, was varied as follows: $\frac{1}{8}$, $\frac{3}{16}$ and $\frac{1}{4}$ in.

The sulphur additions were made by placing the necessary amount of stick sulphur, as determined by analysis of preliminary melts, in a perforated graphite container, which was submerged in the molten metal until all agitation resulting from the reaction of the sulphur with the metal had ceased. In making an addition of iron, the copper-iron hardener was added just before the charge was completely melted. Subsequent analysis of the alloys showed that in every case the content of sulphur or iron was within 0.05 per cent. of that desired.

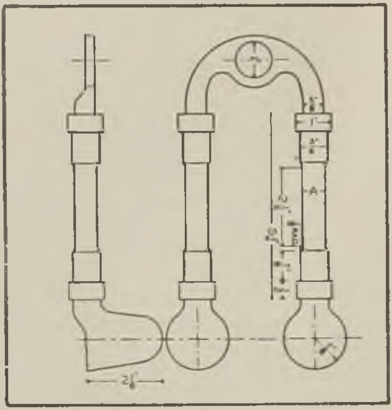

Fig. 2.—Sand-Cast Test-Bar Designated as the "End-Gate" Type.

In cast-to-size bar, A = 0.505 in. in machined-to-size bar, A = 0.625 in. Poured uphill at an angle of 7 deg. with a 1-in. round pouring gate 5 in. high.

Types of Test-Bars

Two forms of sand-cast bars, a chilled ingot, and ingots obtained by immersing a graphite crucible beneath the surface of the molten metal were made from each heat.

Fin-Gate Sand-Cast Bar.—This type of test-bar, often designated as the Webbert bar, is shown in Fig. 1. Its use is required in the specifications of the American Society for Testing Materials for brass castings.[2] Test specimens each having a web thickness of $\frac{1}{8}$, $\frac{3}{16}$ or

$\frac{1}{4}$ in. respectively were used in the study of virgin and remelted metal, whilst specimens having a web thickness of $\frac{1}{4}$ in. were used in the study of the effect of sulphur and iron.

End-gate Sand-cast Bar.—A characteristic feature of this type of casting, shown in Fig. 2, is the absence of the heavy riser which tends to retard the cooling of the test-bar. This method furnished two bars poured under identical conditions which were used to study the "skin effect" by comparing the properties of bars cast to size with those machined to size. This type of bar has been used with pronounced success in commercial foundry work on non-ferrous alloys.[3]

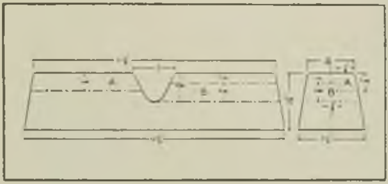

Fig. 3.—Position of Test-Bars in the Chill-Cast Ingot.

A, Two-side Chill; B, No-side Chill.

Coupon from Chill-cast Ingot.—Two specimens were cut from each chill-cast ingot as shown in Fig. 3. One specimen was taken from that portion of the ingot which included two adjacent chill faces and the other from the portion farthest removed from the chill faces. These have been designated as "two-side chill" and "no-side chill" respectively.

Coupon from "Immersed-Crucible" Ingot.—This method of obtaining a test-bar consists essentially in withdrawing a sample of metal by means of a graphite crucible submerged beneath the surface of the liquid metal, as illustrated in Fig. 4. The method permitted the sampling of any heat without contamination that may be

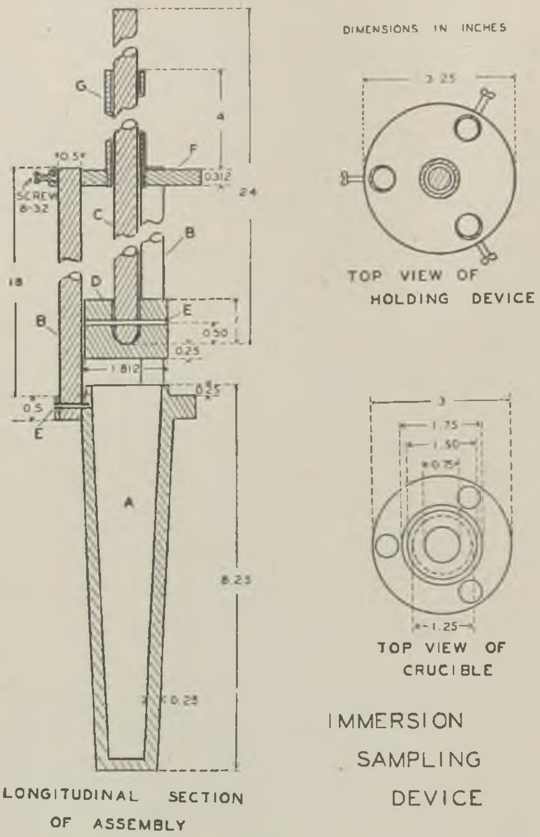

Fig. 4.—Device for Obtaining Test-Bars by the Immersed-Crucible Method.

All parts were made of graphite. The tightly closed crucible, A, of known volume, was immersed beneath the surface of the molten metal and allowed to come to the temperature of the metal. The top, E, was then raised by means of the rod, C, and the crucible was filled. The cover was then replaced and the crucible containing the sample of metal was removed, placed in a dry-sand mould and allowed to cool to room temperature. The ingot was used in the determination of shrinkage as well as in other tests.

caused by the moisture of sand moulds. The "gassing" of metals and the possible source of such contamination are of interest to the foundry industry. The method also permitted a comparison between metal as ordinarily cast and the same metal that was not subjected to pouring and to mould conditions. Immersed-crucible samples were taken from each crucible of metal before the other forms of test-bars were cast. The ingot thus obtained was used to furnish data

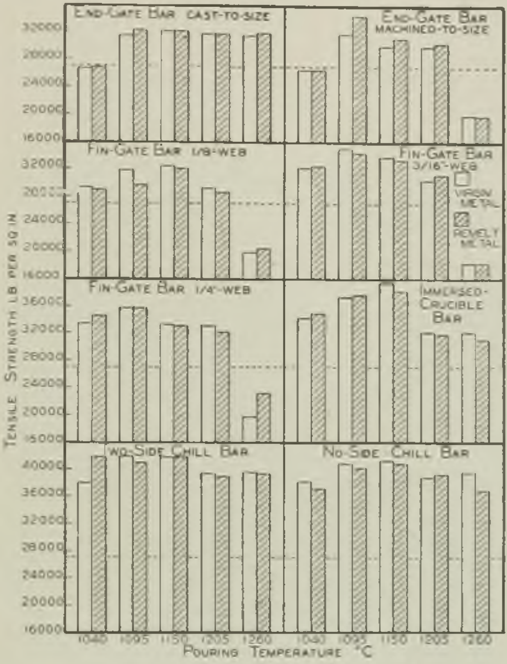

Fig. 5.—Relation between the Tensile Strength and Pouring Temperature of Test-Bars made from Virgin Metal and Remelted Metal.

The minimum tensile strength for this alloy (A.S.T.M. Designation B30-32T) is shown by the broken line.

on the shrinkage of the liquid metal, after which it was machined to a conventional test specimen.

Measurement of Tensile Strength

The tensile properties were determined with an Amsler universal testing machine of 22 tons capacity, the load being applied uniformly with a rate of travel of the moving head of 0.1 in. per min. The test specimen used was 0.505 in. in diameter, with threaded ends and a 2-in. gauge length.

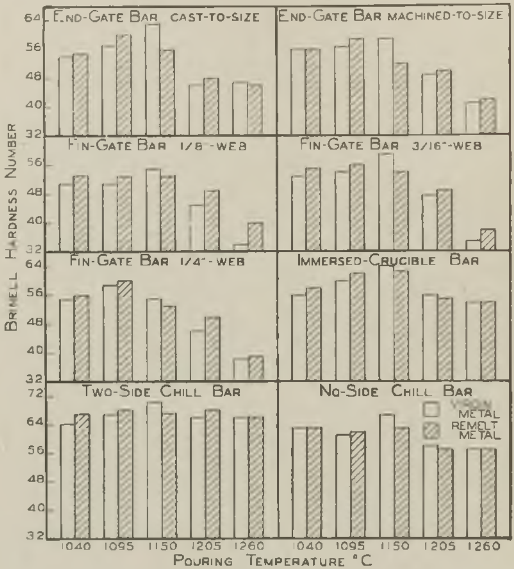

Fig. 6.—Relation between the Brinell Hardness and Pouring Temperature of Test-Bars made from Virgin Metal and Remelted Metal.

The reported results are the averages of duplicate determinations, usually on bars from the same heat. In most cases the tensile strengths of the duplicate bars agree within about 1,000 lbs. per sq. in. (about ± 3 per cent.), although there were a few larger variations. In such cases the higher values were accepted as being more authentic. Observed differences of less than 1,000 lbs. per sq. in. are probably not significant.

Measurement of Shrinkage

The shrinkage of the alloy from a temperature of 1,315 deg. C., which exceeded the highest pouring temperature used, 1,260 deg. C., to room temperature was determined by the method described by Saeger and Ash.[4] It included the determination of the shrinkage (*a*) of the liquid metal, (*b*) during solidification and (*c*) in the solid state.

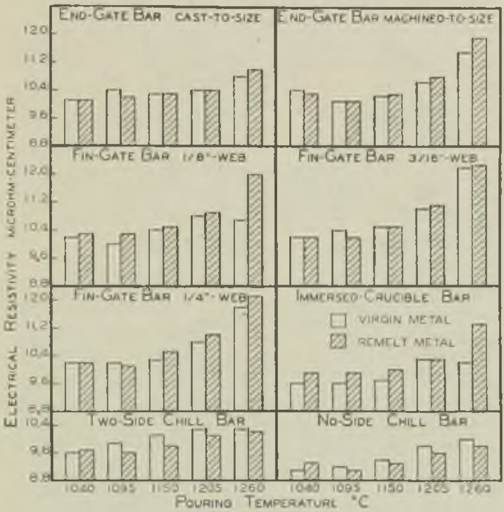

Fig. 7.—Relation between the Electrical Resistivity and Pouring Temperature of Test-Bars made from Virgin Metal and Remelted Metal.

Measurement of Running Properties

The running properties of the alloy were studied by the method described by Saeger and

Krynitsky,[5] which consists essentially in casting in a green-sand mould a small spiral strip of uniform parabolic cross-section. The length of the spiral is taken as an indication of the relative flowing properties of the metal under the conditions used.

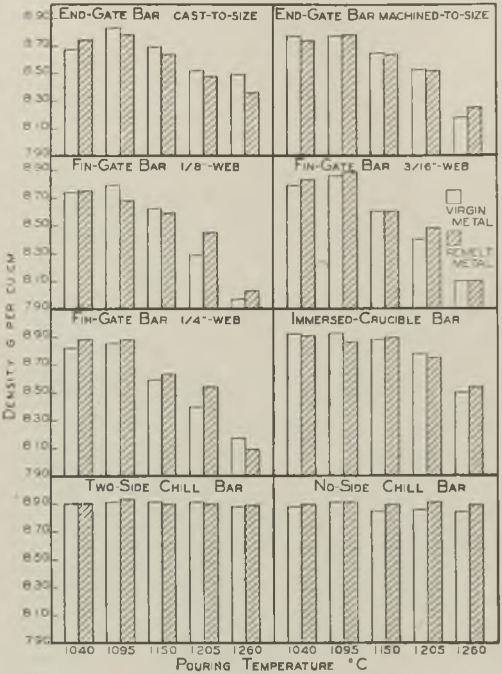

FIG. 8.—RELATION BETWEEN THE DENSITY AND POURING TEMPERATURE OF TEST-BARS MADE FROM VIRGIN METAL AND REMELTED METAL.

RESULTS AND DISCUSSION

For purposes of discussion the investigation may be divided into two parts: (1) the properties of the alloy made from virgin metal and from remelted metal, and (2) the effects of small percentages of sulphur or iron on these properties.

Virgin Metal and Remelted Metal

Tensile Strength.—In Fig. 5 are presented the data obtained for ultimate tensile strength. For each type of test-bar maximum tensile strengths were obtained at pouring temperatures of 1,095 and 1,150 deg. C. A marked drop in tensile strength was observed for the machined sand-cast specimens poured at 1,260 deg. C. No pronounced beneficial "skin effect" on cast-to-size specimens was observed except for bars cast at 1,260 deg. C.

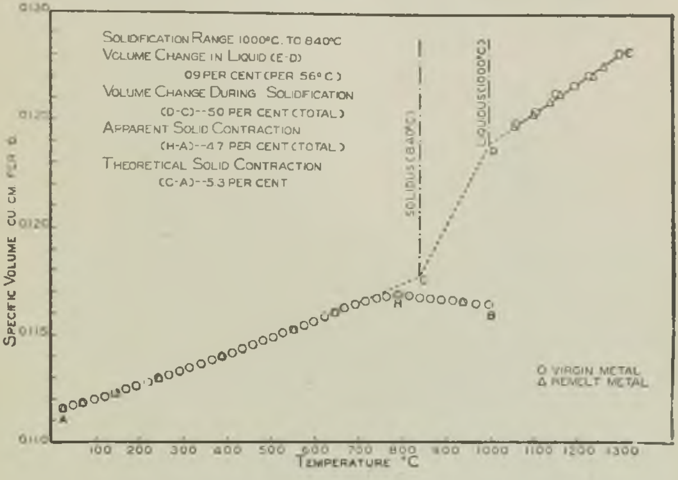

Fig. 9.—Shrinkage of Red Brass from 1,315 deg. C. to Room Temperature.

On the basis of tensile strength, the various types of test-specimens may be arranged in three groups. The highest tensile strength was obtained on specimens cut from the chill-cast ingots. Next in order were those cut from the ingots made by the immersed-crucible method. The sand-cast bars, except those cast to size, were uniformly lower in tensile strength. No significant differences were noted between the virgin and the remelted metal in the same form of test-bar.

Brinell Hardness.—Brinell-hardness determinations were made on one of two parallel flat faces, $\frac{5}{8}$ in. in width, machined on the sides of the threaded portions of the broken test specimen. Each result shown in Fig. 6 is the average of three determinations. The results for Brinell hardness show the same general trend as do the corresponding values for tensile strength.

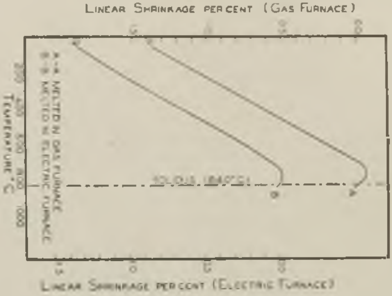

FIG. 10.—LINEAR CONTRACTION OF RED BRASS FROM SOLIDIFICATION TO ROOM TEMPERATURE.

Electrical Resistivity.—The determination of electrical resistivity was made on the specimens used subsequently for tensile tests. These determinations[6] were made according to the procedure recommended by the American Society for Testing Materials.[7] The results, presented graphically in Fig. 7, show that the specimens having superior tensile strength and hardness invariably had lower resistivities. The resistivity increased decidedly as the pouring temperature was increased above 1,150 deg. C. This change in resistivity was more uniform for the remelted metal than for the virgin metal.

Density.—The density was determined on the ends of the broken tensile test specimens by the conventional method of displacement of water. The results are given in Fig. 8. No marked differences in density between the virgin metal and the remelted metal were found. All of the sand-cast bars showed a decided decrease in density as the pouring temperature was increased. The densities of specimens from the chilled ingots, which were uniformly higher than those of the sand-cast bars, were independent of pouring temperature. The density of specimens obtained by the immersed-crucible method for pouring temperatures of 1,205 deg. C. and above was intermediate between the corresponding values for the chilled ingot and the sand-cast bars. The maximum density was obtained in practically all cases with a pouring temperature of 1,095 deg. C.

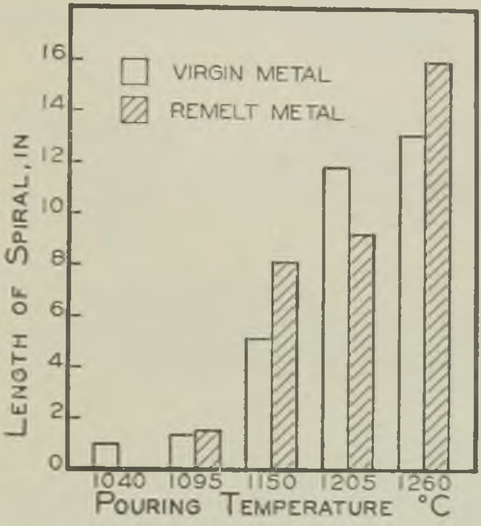

FIG. 11.—RUNNING PROPERTIES OF RED BRASS MADE FROM VIRGIN METAL AND REMELTED METAL CAST IN GREEN-SAND MOULDS.

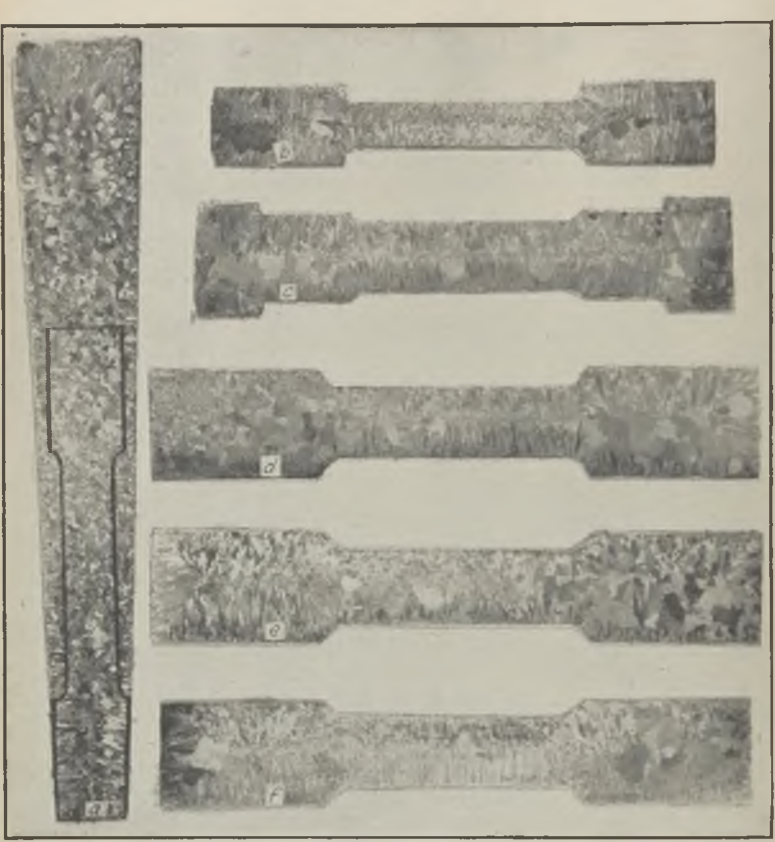

Fig. 12.—Medial Longitudinal Section of Test-Bars of Virgin Metal, Cast at 1,205 deg. C., the Section being Perpendicular to the Parting Face of the Sand Mould.

Etched with ammoniacal solution of copper-ammonium chloride; reduced one-half in reproduction.

(*a*) Ingot obtained by immersed-crucible method.
(*b*) End-gate sand-cast bar, cast-to-size
(*c*) End-gate sand-cast bar, machined-to-size.
(*d*) Fin-gate bar, ⅛-in. web.
(*e*) Fin-gate bar, 3/16-in. web.
(*f*) Fin-gate bar, ¼-in. web.

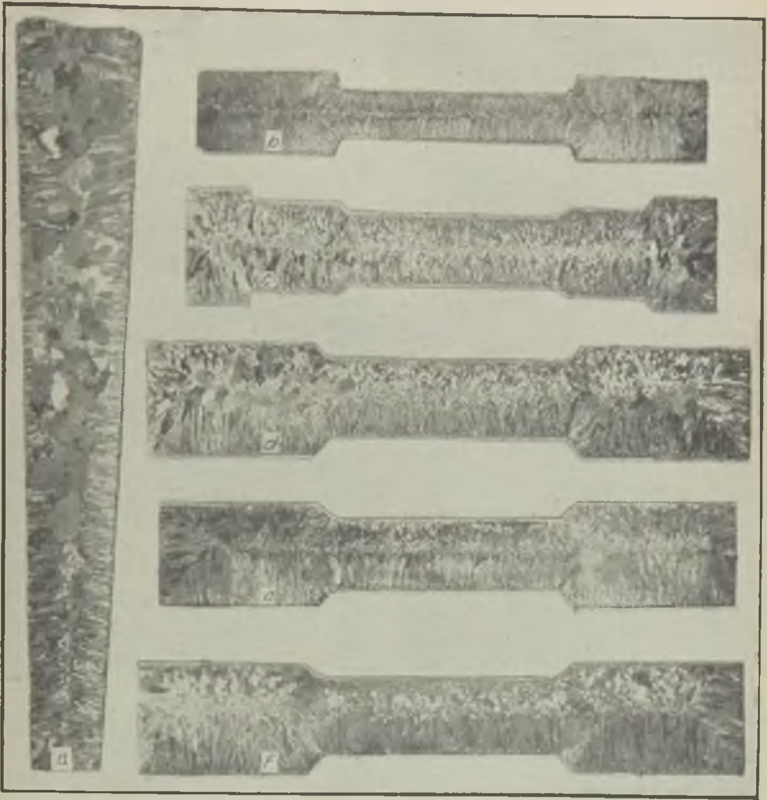

Fig. 13.—Medial Longitudinal Section of Test-Bars of Virgin Metal, Cast at 1,260 deg. C., the Section being Perpendicular to the Parting Face of the Sand Mould.

Etched with ammoniacal solution of copper-ammonium chloride; reduced one-half in reproduction.

(*a*) Ingot obtained by immersed-crucible method.
(*b*) End-gate sand-cast bar, cast-to-size.
(*c*) End-gate sand-cast bar, machined-to-size.
(*d*) Fin-gate sand-cast bar, ⅛-lb. web.
(*e*) Fin-gate sand-cast bar, $\frac{1}{16}$-in. web.
(*f*) Fin-gate sand-cast bar, ¼-in. web.

FIG. 14.

Shrinkage.—The shrinkage of the liquid metal (E—D, Fig. 9) expressed in terms of the changes in specific volume was determined by the immersed-crucible method. Data on the shrinkage of the solid metal (C—A, Fig. 9) were obtained by direct observations of the change in length with change in temperature of a special sand-cast rectangular bar. To determine the shrinkage during solidification (D—C, Fig. 9), it was necessary to determine the solidus, C, and the liquidus, D, for this alloy. By thermal analysis, an average value of 840 deg. C. was obtained for the liquidus and of 1,000 deg. C. for the solidus. The difference between the specific volumes corresponding to these two temperatures is designated as the shrinkage of solidification. No significant differences in shrinkage were observed between alloys made from virgin metal and from remelted metal.

FIG. 14.—MICROSTRUCTURE OF TEST-BARS OF VIRGIN METAL. (× 100.)

Etching reagent, mixture of ammonium hydroxide and hydrogen peroxide.

(*a*) Ingot obtained by immersed-crucible method at 1,205 deg. C.
(*a'*) Ingot obtained by immersed-crucible method at 1,260 deg. C.
(*b*) End-gate sand-cast bar, cast-to-size, poured at 1,205 deg. C.
(*b'*) End-gate sand-cast bar, cast-to-size, poured to 1,260 deg. C.
(*c*) End-gate sand-cast bar, machined-to-size, poured at 1,205 deg. C. (*c'*) End-gate sand-cast bar, machined-to-size, poured at 1,260 deg. C.

There was observed, however, in the determination of the linear shrinkage of the solid metal, a definite expansion at a temperature just below the solidus. This is shown in Fig. 9 by the portion of the curve H—B. To determine whether or not this expansion was the result of "gassing" of the metal from the charcoal which formed a part of the protecting covering used in the ordinary procedure, charges were melted in the induction furnace, and in a gas-fired furnace with a protective covering of fused sodium carbonate. The same phenomenon was observed in all cases, for remelted metal as well as for virgin metal. These results are given in Fig. 10. The cause and significance of this behaviour are still uncertain.

Running properties.—The running properties were determined on both virgin and remelted metal with the results shown in Fig. 11. The remelted metal, cast in green sand, was more fluid than virgin metal cast under the same condition.

Metallographic structure.—In an endeavour to explain the reason for the pronounced influence of the pouring temperature on the physical properties of sand-cast bars and specimens obtained by the immersed-crucible method, the macrostructure of bars cast at 1,205 and 1,260 deg. C. was studied. Photographs of etched medial longitudinal section perpendicular to the parting line of the mould are shown in Figs. 12 and 13. The tendency for the formation of a columnar crystalline structure in the bars cast at the higher temperatures was much more pronounced than in the corresponding bars poured at the lower temperatures. A comparison of these results with those previously given indicates that a marked columnar structure is accompanied by inferior physical properties.

Very little difference in structure was found in the two types of sand-cast bars that were cast to size; in both, the columnar structure predominated. In the larger specimens of this type, machined to size, the difference in structure caused by the pouring temperatures was more pronounced. In all of the fin-gate sand-cast bars, a marked non-uniformity of structure across the section of the bar existed. The portion of the bar formed in the " drag " of the mould had a pronounced columnar structure, whereas the remainder, which was undoubtedly influenced by the relatively large mass of metal in the attached riser, had an equiaxed crystalline structure. Such a marked non-uniformity of structure across the section of a test-bar is not desirable and should be avoided.

The observed difference in physical properties of bars obtained by the immersed-crucible method at 1,205 and 1,260 deg. C. is believed to be due largely to the difference in grain-size.

The effect of pouring temperature on the microstructure of the various test-bars is shown in Figs. 14 and 15. In each case the micrograph shows a representative area in the reduced section of the bar just within the inner surface layer of the columnar crystals. Within the individual grains of all the sand-cast specimens were found markings consisting of groups of parallel lines which were considered to be the result of deformation or strain during cooling. This structural feature was not found in the bars obtained by the immersed-crucible method. This fact indicates that no strains are set up in the latter bars on cooling, such as exist in the sand-cast bars when the gates and risers are in a fixed position within the sand mould. These apparently cause permanent straining of the bar by shrinkage during cooling, while the metal is in a very " tender " condition immediately after solidification.

Effects of Small Percentages of Sulphur or Iron

The second phase of the investigation was the effect of specific amounts of impurities on the physical properties of the alloy. In this part of the study a reduction was made in the number of types of test-bars. Those used were the immersed-crucible bar, the end-gate bar, both " cast to size " and " machined to size," the fin-gate bar with $\frac{1}{4}$-in. web, and the " no side chill " bar from the cast ingot. These bars were cast from heats of remelted metal to which had been added from 0.025 to 0.10 per cent. of sulphur or 0.10 to 0.60 per cent. of iron. The effects of sulphur and iron on the physical properties were determined by comparison with those of remelted metal. The values for remelted metal at pouring temperatures of 1,065 and 1,230 deg. C. were obtained by averaging the values previously given for 1,040 and 1,095 deg. C. and for 1,205 and 1,260 deg. C., respectively.

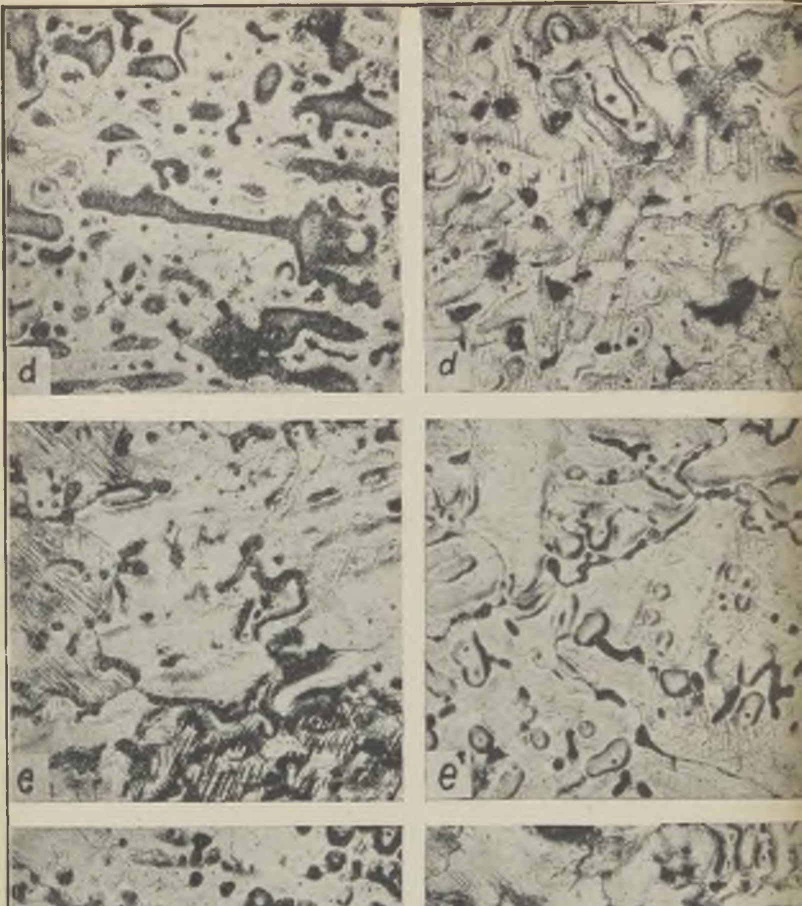

Fig. 15.

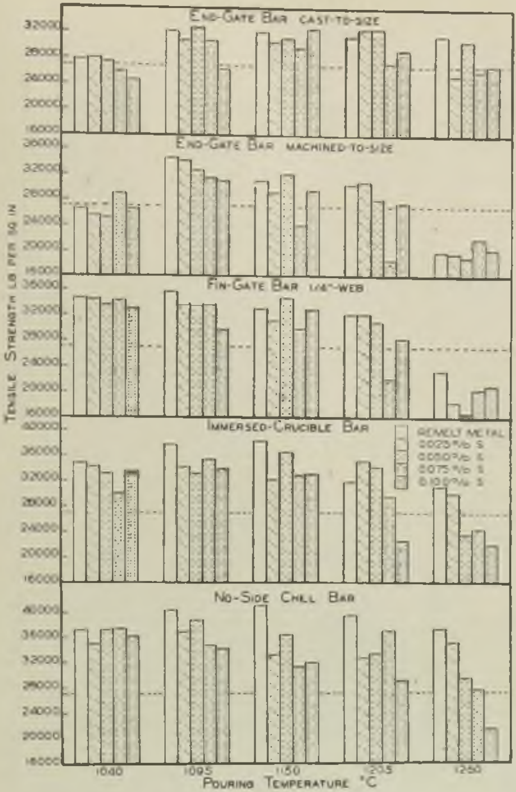

FIG. 16.—EFFECT OF POURING TEMPERATURES UPON THE TENSILE STRENGTH OF RED BRASS CONTAINING SULPHUR.

The minimum tensile strength for this alloy (A.S.T.M. Designation B 30-32T) is indicated by the broken line.

FIG. 15.—MICROSTRUCTURE OF TEST-BARS OF VIRGIN METAL. (× 100.)

Etching reagent, mixture of ammonium hydroxide and hydrogen peroxide.

(*d*) Fin-gate sand-cast bar, $\frac{1}{8}$-in. web, poured at 1,205 deg. C.
(*d'*) Fin-gate sand-cast bar, $\frac{1}{8}$-in. web, poured at 1,260 deg. C.
(*e*) Fin-gate sand-cast bar, $\frac{3}{16}$-in. web, poured at 1,205 deg. C.
(*e'*) Fin-gate sand-cast bar, $\frac{3}{16}$-in. web, poured at 1,260 deg. C.
(*f*) Fin-gate sand-cast bar, $\frac{1}{4}$-in. web, poured at 1,205 deg. C.
(*f'*) Fin-gate sand-cast bar, $\frac{1}{4}$-in. web, poured at 1,260 deg. C.

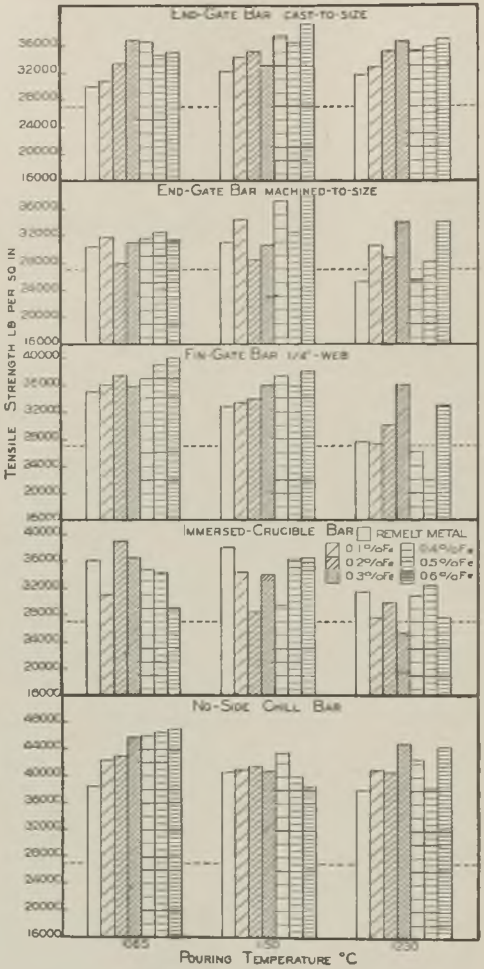

Fig. 17.—Effect of Pouring Temperature upon the Tensile Strength of Red Brass containing Iron.

The minimum tensile strength for this alloy (A.S.T.M. Designation B 30-32T) is indicated by the broken line.

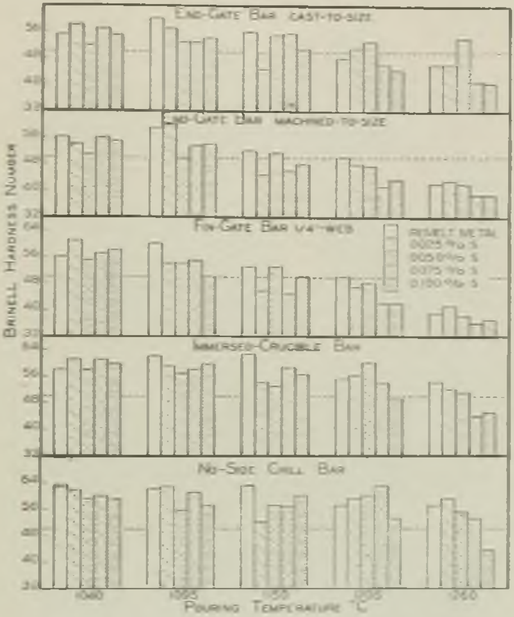

FIG. 18.—EFFECT OF POURING TEMPERATURE UPON THE BRINELL HARDNESS OF RED BRASS CONTAINING SULPHUR.

The minimum Brinell hardness for this alloy (A.S.T.M. Designation B 30-32T) is indicated by the broken line.

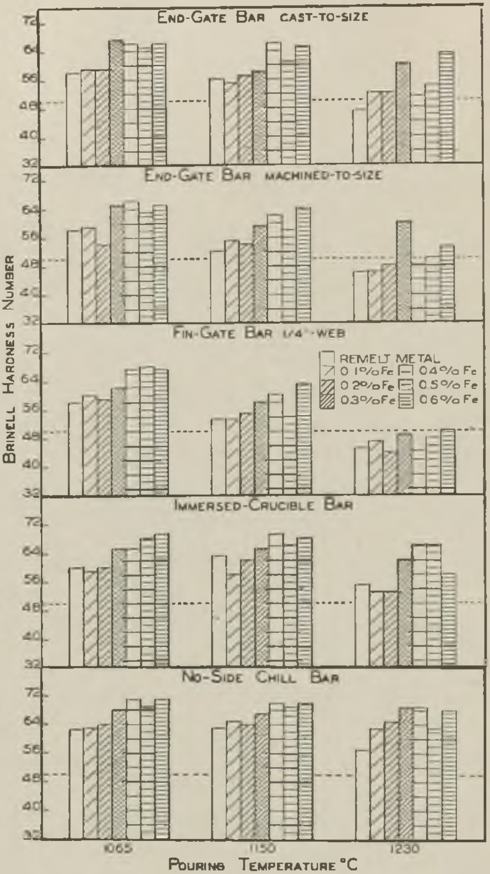

FIG. 19.—EFFECT OF POURING TEMPERATURE UPON THE BRINELL HARDNESS OF RED BRASS CONTAINING IRON.

The minimum Brinell hardness for this alloy (A.S.T.M. Designation B 30-32T) is indicated by the broken line.

Tensile strength.—The results in Fig. 16 indicate a slight decrease in tensile strength as the sulphur content was increased. Comparison of the values for the four types of bars with reference to " the minimum tensile strength expected for this alloy,"[8] indicated by the broken line in Figs. 16 and 17, shows that most of the bars which had tensile strengths much below this " minimum " were cast at 1,205 and 1,260 deg C. From these results it appears that the pouring temperature had more influence on the tensile strength than had the sulphur content.

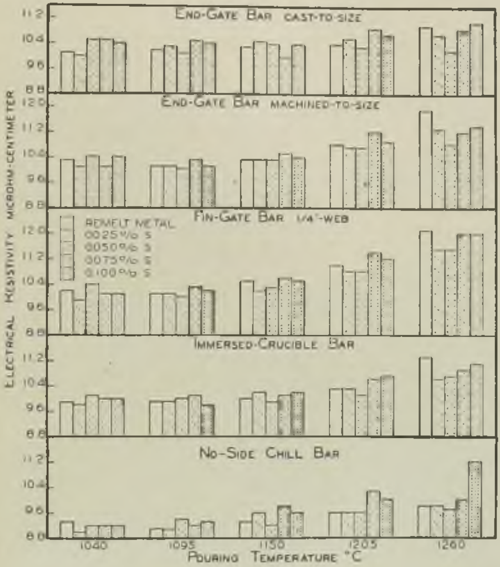

Fig. 20.—Effect of Pouring Temperature upon the Electrical Resistivity of Red Brass containing Sulphur.

The results in Fig. 17 indicate that the addition of iron tended to increase the tensile strength, especially of the sand-cast bars. This effect may be caused by the iron acting as a deoxidiser. Hanson and Ford,[9] in their investigation on the effect of impurities in copper, found that in an oxidising atmosphere iron acts as a deoxidiser for copper. Dews[10] has reported that this same reaction occurs in bronzes.

Brinell hardness.—The results of the Brinell hardness determinations are shown in Figs. 18 and 19. In the American Society for Testing Materials specification for this alloy[11] a Brinell hardness number of 50 to 60 is required. In Figs. 18 and 19 the minimum value of 50 is indicated by a broken line. In the curves showing the effects of sulphur, it may be noted that many of the bars containing sulphur and poured at 1,205 or 1,260 deg. C. have hardness numbers below 50.

The addition of iron appeared to raise the Brinell hardness, and the values were well above the required minimum value of 50, with the exception of some of the sand-cast bars poured at 1,230 deg. C.

Electrical Resistivity.—The data in Figs. 20 and 21 show that sulphur has little effect on the resistivity of the test-bars poured at or below 1,150 deg. C. Higher resistivities were obtained, however, on the bars poured at 1,205 and 1,260 deg. C. This increase in resistivity is apparently caused by the increase in the pouring temperatures rather than by the increase in the sulphur content.

A marked increase in electrical resistivity was found for all test-bars containing 0.1 per cent. iron, but no significant further increase was found for iron contents up to 0.6 per cent.

Density.—The data in Figs. 22 and 23 show that the density of this alloy was affected to a greater extent by the pouring temperature than by changes in the content of sulphur or iron.

Running Properties.—The data in Figs. 24 and 25 show that sulphur somewhat increased the running quality of the alloy at all pouring temperatures, and especially at the higher temperatures. The alloy poured at the higher temperatures (1,150 and 1,230 deg. C.) showed

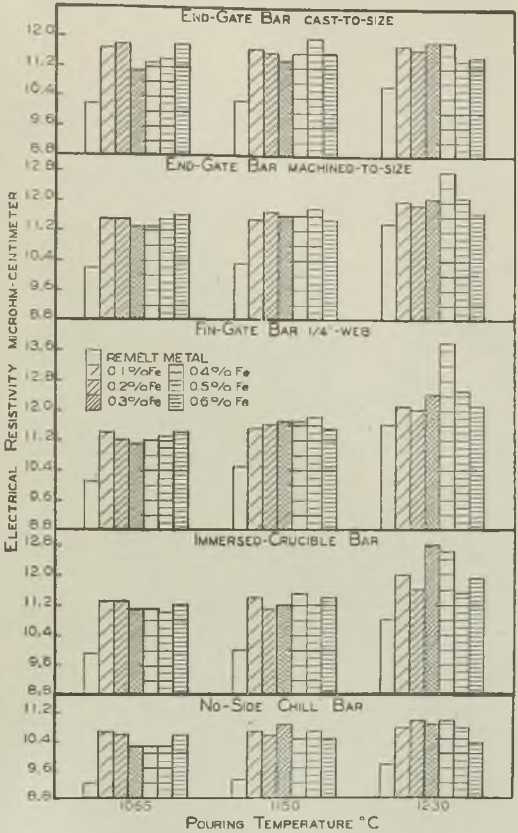

FIG. 21.—EFFECT OF POURING TEMPERATURE UPON THE ELECTRICAL RESISTIVITY OF RED BRASS CONTAINING IRON.

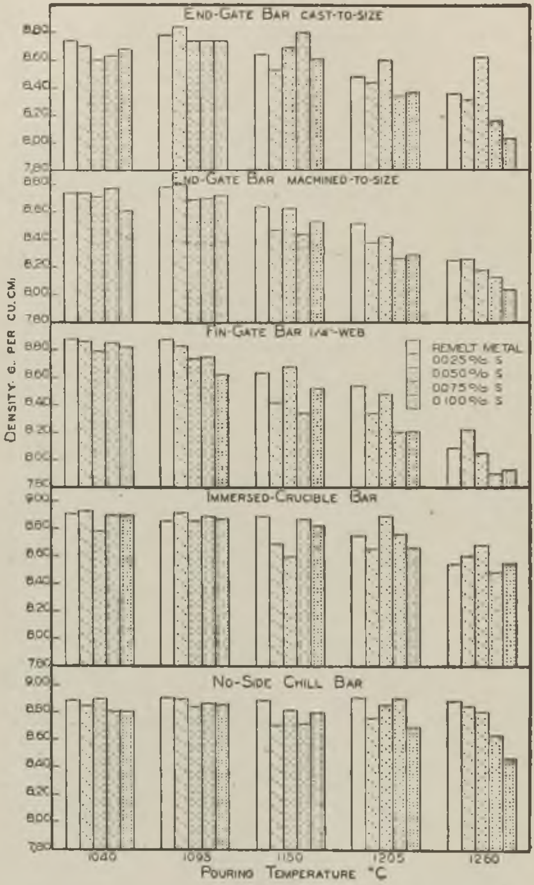

FIG. 22.—EFFECT OF POURING TEMPERATURE UPON THE DENSITY OF RED BRASS CONTAINING SULPHUR.

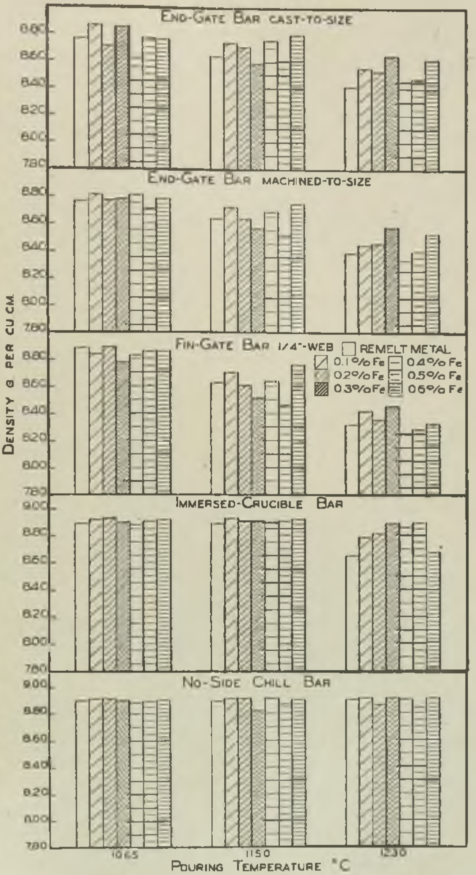

Fig. 23.—Effect of Pouring Temperature upon the Density of Red Brass containing Iron.

slightly increased running properties, with an increase in iron content up to 0.3 per cent., but above this iron content the running properties decreased.

Shrinkage.—The data in Figs. 26 and 27 show that there was an increase in the specific volume with increase of sulphur content at all pouring temperatures. The effect of iron on the specific volume was not so definite or so uniform as that of sulphur. The shrinkage of the alloy in the solid state was not influenced to any significant extent by the additions of either sulphur of iron.

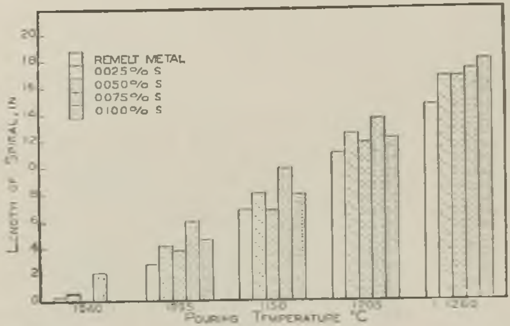

FIG. 24.—EFFECT OF POURING TEMPERATURE UPON THE RUNNING PROPERTIES OF RED BRASS CONTAINING SULPHUR.

Neither sulphur nor iron appreciably influenced either the *solidus* or the *liquidus* temperature of this alloy. Although the sulphur or iron produced a slight change in the specific volume of the liquid and solid metal, the slopes of the specific volume-temperature curves are the same as those reported for virgin and remelted metal. Hence, there was no significant change in the shrinkage.

It is evident from these data that sulphur or iron in the amounts used are not necessarily injurious to the alloy 85-5-5-5 if the pouring temperature is kept below 1,205 deg. C.

SUMMARY

The tensile strength, electrical resistivity, hardness and density of cast red brass (Cu, 85; Sn, 5; Zn, 5; Pb, 5) were determined on four types of test-bars—two sand-cast, a chill ingot and a special bar dipped from the molten metal. The pouring temperature was varied from 1,040 to 1,260 C. Data on the shrinkage and running properties were also obtained. The most important results are as follow:—

(1) The properties of test-bars made of virgin or of remelted metal of the same nominal composition, cast at the same temperature, were alike.

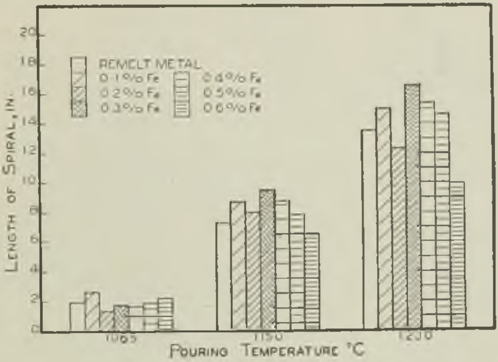

Fig. 25.—Effect of Pouring Temperature upon the Running Properties of Red Brass containing Iron.

(2) The pouring temperature affected the properties of all the test-bars much more than any other factor. In general, the best results for the sand-cast bars were obtained with a pouring temperature below 1,205 deg. C.

(3) These effects of pouring temperature on the physical properties of test-bars were the same for alloys containing either sulphur (maximum 0.10 per cent.) or iron (maximum 0.6 per cent.).

(4) The physical properties of test-bars poured at 1,150 deg. C. or below were not appreciably affected by the presence of sulphur up to 0.10 per cent. In bars poured at higher temperatures 0.10 per cent. of sulphur adversely affected the properties, particularly of the sand-cast bars. Additions of iron up to 0.6 per cent. had similar but much less pronounced effects.

(5) The detrimental effects of high pouring temperatures and of impurities were much more pronounced in the sand-cast bars than in the other types. The non-uniform grain structure of the sand-cast bars and the existence in them of a strained condition during cooling are probably related to these effects.

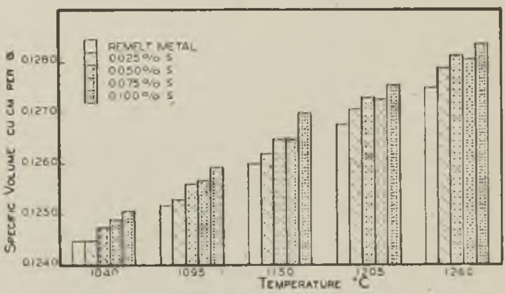

FIG. 26.—EFFECT OF TEMPERATURE UPON THE SPECIFIC VOLUME OF RED BRASS CONTAINING SULPHUR.

(6) The flowing properties increased with the pouring temperature. The presence of sulphur, up to 0.10 per cent., improved the flowing properties, while iron had no consistent influence. Similar statements apply to the shrinkage.

(7) A comparison of the results for tensile strength and hardness with the minimum requirements for this alloy in ingot form set forth by the American Society for Testing Materials shows (*a*) that the end-gate sand-cast bar is unsuitable for low pouring temperatures; (*b*) that, with this exception, all sand-cast bars of virgin

or remelted metal poured at a temperature not exceeding 1,205 deg. C. easily meet these minimum requirements; and (*c*) the presence of sulphur up to 0.10 per cent., or of iron up to 0.6 per cent., is not objectionable in sand-cast bars. The adverse effect of pouring temperatures above 1,205 deg. C. was not so pronounced in the chilled-ingot and other bars as in the sand-cast bars.

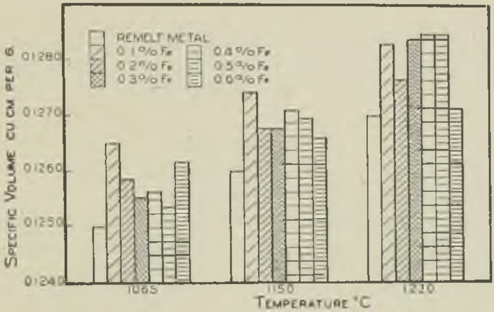

FIG. 27.—EFFECT OF TEMPERATURE UPON THE SPECIFIC VOLUME OF RED BRASS CONTAINING IRON.

(8) The relatively wide variation in the physical properties of different types of test-bars obtained from the same heat of metal forcibly emphasises the need for a standard method for obtaining the test-bars. In many respects the sand-cast bars were not so suitable as those obtained by other methods.

REFERENCES.

[1] The alloy is referred to in this Paper as "Red Brass 85-5-5-5."

[2] Standard Specifications for Composition Brass or Ounce Metal Sand Castings (A.S.T.M. Designation B62-28), "A.S.T.M. Standards," Part I, Metals, p. 678, 1930.

[3] R. W. Parsons, Deep Etching of Brass Applied to Gating Problems. "Trans. Am. Fdymen's Assoc.," Vol. 39, p. 843, 1931.

[4] C. M. Saeger, jr., and E. J. Ash. A Method for Determining the Volume Changes occurring in Metals during Casting. Res. Paper No. 399, "Bureau of Standards Jour. of Research," Vol. 8, No. 1, p. 37, 1932.

[5] C. M. Saeger, jr., and A. I. Krynitsky, A Practical Method for Studying the Running Quality of a Metal Cast in Foundry Moulds. "Trans. Am. Fdymen's Assoc.," Vol. 39, p. 513, 1931.

[6] Made by Dr. J. L. Thomas, Associate Physicist, Bureau of Standards.

[7] Standard Method of Test for Resistivity of Metallic Materials for Resistors (A.S.T.M. Designation: B63-29), "Am. Soc. Test. Mats. Standards," Part I, Metals, p. 869, 1930.

[8] Appendix to Tentative Specifications for Copper-Base Alloys in Ingot Form for Sand Castings (A.S.T.M. Designation: B30-32T), "Proceedings, Am. Soc. Test. Mats.," Vol. 32, Part I, p. 677, 1932; also A.S.T.M. Tentative Standards, p. 237, 1932.

[9] D. Hanson and G. W. Ford, "Investigation of the Effects of Impurities on Copper," Part II. The Effect of Iron on Copper, "Jour. Inst. of Metals, Vol. 32, p. 335, 1924.

[10] H. C. Dews, "The Metallurgy of Bronze." Sir Isaac Pitman & Sons, Lond., 1930.

[11] Appendix to Tentative Specifications for Copper-Base Alloys in Ingot Form for Sand Castings (A.S.T.M. Designation: B30-32T). "Proceedings, Am. Soc. Test. Mats.," Vol. 32, Part I, p. 677, 1932, Also "1932 Book of A.S.T.M. Tentative Standards," p. 237

DISCUSSION

Cast Red Brass

Mr. J. E. Hurst (Vice-President) was in the chair, and said that before the discussion opened he thought it was very necessary to place on record an appreciation of the Institute of British Foundrymen of the American Foundrymen's Association kindness in sending the Exchange Paper. He presumed that Mr. Delport would be able to convey that expression of appreciation, and he suggested that it should be shown in the usual manner. A unanimous expression of thanks to the American Foundrymen's Association was then carried by acclamation.

The Chairman, continuing, said that the second thing they ought to do was to show their appreciation of the very able abstract that Mr. Delport had presented of the Paper. He had picked out, with unerring accuracy, the salient points of the Paper.

Mr. J. S. G. Primrose said that as Convener of the Non-Ferrous Castings Sub-Committee of the Technical Committee of the Institute he had much pleasure in welcoming the Paper from their American colleagues. It covered to a very large extent one of the series of alloys which came in the purview of their present investigations. As a Committee they would very carefully consider it and endeavour to incorporate some of its thoroughness into the work that they were at present doing.

The author of the Paper had given details in a way which proved very clearly how many factors of variation could take place in the casting and testing of the materials dealt with. One point he was very pleased to notice was that he had eliminated any possible doubt of his tensile values by using a precision-testing machine, concerning the merits of which there could not be any doubt at all.

Graphic Representation

Another point he would like to raise was that the author had presented his graphs in a slightly different way from that associated with British practice. In order fully to realise what those graphs meant some of them would have to replot them on points and join them. Instead of having one graph showing four things they would have to prepare four graphs in order to obtain an idea of how the properties varied with the different conditions.

Casting Stresses

He was very pleased to see the macrophotographs and photomicrographs produced. These seemed to indicate that the American type of test bar did leave an internal stress in the middle, with, of course, correspondingly slight reduction in the recorded tensile due to this factor. Against that he would like to mention that the Institute's Sub-Committee had adopted two sizes of test bars, not to represent the castings, but with the object of getting what they hoped would be the maximum value out of the alloy so cast. So far the results obtained from the various members of the Committee had gone to prove that they were effective test bars for similar alloys to those dealt with in the Paper, and that in the case of the leaded gunmetals and of the leaded phosphor bronzes, much higher tests had been obtained than had ever before been recorded for such materials.

A very great number of specifications had been brought to the notice of the Sub-Committee, and the general object of the work done had been to reduce that number. The author of the Paper had mentioned that about 40 American specifications could be concentrated into the one dealt with. The Sub-Committee, in a wider field, had taken about 200 British specifications, and had endeavoured to get them within the space of five alloys which were at present being investigated. It had been hoped to give some of the findings of the results at the present meeting, but the ramifications of the tests were so great that it was felt that the Sub-Committee would not be justified in making any publication at present. The work was still going on.

One point he thought he might mention was that they were making a comparison of bars made as both dry-sand casting and green-sand casting. Mr. Saeger had confined most of his bars to green sand and chill cast. The Sub-Committee had not done chilled cast or immersed crucible work, which latter seemed to overcome the difficulty that stresses were left in the test bar, and these were, of course, rather detrimental to getting uniform or accurate results.

The Test Bar Position

Mr. F. W. Rowe also wished to join in the general hearty appreciation of the excellent work that had been described in Mr. Saeger's Paper, and also of the attitude of the American Foundrymen's Association in letting them have such a very excellent piece of work for the consideration of the members of the Conference, and an opportunity to digest in detail all the multitudinous results Mr. Saeger had obtained. Mr. Primrose had mentioned the work which was being done in this country by the Non-Ferrous Castings Sub-Committee of the Institute of British Foundrymen. Speaking as a member of that Sub-Committee he desired to amplify, and possibly to clarify, one or two of the remarks Mr. Primrose had made with regard to the work of the Sub-Committee. He did not entirely agree with his remarks regarding the work which was being done with respect to the designation and selection of a more suitable size and form of test piece for non-ferrous metals. Primarily, he, the speaker, considered that it was not essential to select the size and form of test piece particularly to give the highest physical properties of which the alloy was capable. He had not understood that that was one of the objects of the Sub-Committee. The main idea was to produce a form of test piece which would give the most uniform results when used in a large number of foundries, and to give also a type of test piece which was easily made under standardised conditions by any type of foundry. Personally, had he been setting out to design a test piece which would give the maximum physical properties of the alloy under specified conditions, he thought he could have got something rather more complicated, and which would give rather better physical properties, but one which would not be adaptable to put out to all classes of foundry.

He was pleased to find that the Paper had demonstrated clearly what the members of the Non-Ferrous Sub-Committee of the Institute of British Foundrymen had felt for some time, namely, that the fin-gate type of test piece which had been sponsored and used by the American Foundrymen's Association was not one which was calculated to give a really good result under all conditions, and that it possessed several inherent defects which were shown up in the Paper.

He thought also that the American Foundrymen's Association would be well advised to consider if the specifying of test bars cast in green sand was not likely to lead to non-uniform results throughout the industry. Personally, he considered that if a dry sand mould was used, one was much more likely to secure uniform conditions in various foundries than if a green sand mould were used.

Effect of Sulphur

He would like also to utter a word of warning with regard to the results of the effect of sulphur on this particular alloy, and also on brasses and cast brasses and bronzes in general. Anyone not fully acquainted with the subject in respect to the effects of sulphur would be likely, on reading the Paper, to consider that sulphur up to 0.1 per cent. had no appreciable effect on this type of alloy provided the casting temperature was kept below 1,260 deg. C. He submitted that this was not proved in the Paper. It had been certainly proved that by adding stick sulphur to a melt no deleterious results were obtained, but he suggested that this method of adding sulphur did not bear relationship to what actually occurred in a foundry. Anyone reading the Paper would be apt to presume that sulphur was not detrimental. The most usual form in which sulphur was introduced into a bronze was by contamination with sulphurous fuels, in which case the sulphur usually entered the metal in the form of sulphur dioxide or sulphur trioxide as a gas. Under such conditions, if the author of the Paper had studied the effect of the addition of sulphur by means of sulphur dioxide or sulphur trioxide, the results would have been very different, and would have shown that a deleterious result was obtained. Adding stick sulphur was hardly likely to obtain in any form of foundry practice.

He agreed with Mr. Primrose that the presentation of the results of the author's research work in the form in the Paper was one to which they were unaccustomed in this country. While for many types of results, it was one that was admirable, he did not think that it was one which was the best for this particular class of work, nor was it the best way of indicating the differences which arose. The presentation of the results in the form of curves would have been more easily understandable, and, personally, he would have to do what Mr.

Primrose had already suggested, namely, re-plot the figures in the form of the more usual graphs.

Casting Temperature

There was also another point he would like to make, that in studying the effect of casting temperature with this alloy the minimum casting temperature used might have been extended a little lower down in the scale, because the Paper did not so far give any great indication as to the troubles which might arise from sinking too low. The low strengths and low general physical properties which arose from a high casting temperature were very well known, but there was also a similar sort of happening at the other end of the scale which was not even hinted at in the Paper.

He did not wish to set himself up as disagreeing with the results which had been obtained, nor in any way detracting from the very great value of the Paper. A further continuance of the work would be of very great service to the industry at large.

Is Standardisation Desirable ?

Mr. V. C. Faulkner (Past-President) observed that it seemed to be assumed that standardisation was a thing to be welcomed. Correlated with standardisation of non-ferrous alloys was the dual question of patents and trade marks. He threw out the suggestion that a foundry manager would take a greater personal interest in an alloy bearing a trade mark rather than one which was just called red brass. He was not quite convinced in his own mind that they were going on right lines in translating all alloys into common or garden B.S.I. specifications, and he would like some of the speakers who followed him to touch on that point.

The Chairman (Mr. J. E. Hurst) remarked that Mr. Faulkner had raised quite an important point. He wondered if any of the other speakers, or perhaps some members of the Non-Ferrous Committee, would comment on the immersed crucible method of making test bars?

Too Many Specifications

Mr. A. Logan said that Mr. Faulkner had raised a very important point. Personally, he had marked a passage in the Paper which he thought was a very remarkable parallel to the work of the Non-Ferrous Sub-Committee. It was stated in the introduction that " As a result of a survey made, it was found that over 600 so-called common alloys were in use, and, in addition, many special alloys that are usually classed as high strength alloys. Tentative specifications have been promulgated and approved by the American Society for Testing Materials covering twenty non-ferrous alloys. It is believed that these, to a very large degree, may be used in place of the more than 600 now in use." He thought that statement was an answer to Mr. Faulkner. If it were possible to reduce 600 alloys, by means of standardisation, down to 20 alloys which would do exactly all, and probably even more than, the 600 would, then a great step forward had been taken. Take the case of a non-ferrous foundry. Orders were being received from day to day from a variety of customers, involving 600 compositions which sometimes varied by only a quarter per cent. Buyers specified what they wanted, and exactly the properties required, and insisted upon getting them. Imagine the chaotic position of a foundry with 600 compositions to deal with.

This aspect of the work of the Non-Ferrous Sub-Committee had been particularly pushed forward during the past two years with the object of simplifying every-day foundry working. There were dozens of different compositions in common use, and, being asked for every day, many of which were quite unnecessary, half-a-dozen alloys would do all that these multi-compositions would do. It was a very important point in regard to economical working, and generally speaking the standardisation of alloys would simplify matters all round. It would give engineers, for instance, a definite picture of what they could expect and of what they would know they would get; whereas he was certain that in many cases people who were specifying certain compositions had no idea what they were asking for or why they were asking for it. Probably other speakers would indicate more completely to Mr. Faulkner exactly what was involved in the standard alloys idea, nevertheless he felt very strongly about it, as it was a problem that was being met every day.

Running Properties

The next point he wished to raise was quite a new one as far as he was concerned. He had not seen it mentioned in connection with non-ferrous work before. He referred to the Measurement of Running Properties. It was becoming common ferrous practice to have a "running" or "flow" or "fluidity" test. He understood that the actual term was still a matter of controversy in the Cast Iron Committee of the Institute; but he thought this was the first indication he had had of it being actually applied in a brass foundry. "The running properties of the alloy were studied by the method described by Saeger and Krynitsky, which consists essentially in casting in a green-sand mould a small spiral strip of uniform parabolic cross-section. The length of the spiral is taken as an indication of the relative flowing properties of the metal under the conditions used." One remarkable thing to which he wished to direct attention was shown in Fig. 11—"Running properties of Red Brass made from Virgin metal and Remelted Metal cast in Green-Sand Moulds." Apparently the remelted red metal had a greater fluidity than the original virgin material. There was an exception at 1,205 deg. C. about which no comment was made. It seemed to be a remarkable exception. The general experience was for the re-melted metal to be higher in fluidity than the virgin metal. He would like further information upon the point. It was a moot point whether the fluidity test was of any practical value in the foundry.

As a result of the many uncontrolled variables, it could not be the criterion of pouring temperature. He did not see any real practical foundry significance in a fluidity test, though possibly it was of academic value.

Casting Temperatures

The summary of the Paper set out the conclusions very clearly. One of the main features mentioned with the alloy was common to all non-ferrous alloys, and that was the importance of the pouring temperature. This was the one factor in non-ferrous work which was of paramount importance.

One strange thing was that the properties of test bars made of virgin metal or re-melted metal were alike. It was not stated, however, how many re-melts the material had had; presumably only one re-melt. Would the same conclusions apply if the material was re-melted 10 times?

The question of sulphur in connection with red bronze had been dealt with already by Mr. Rowe, and he too would like to query the author's conclusions. As Mr. Rowe had pointed out, this rather minimised the effect of sulphur, and one might get the impression that the sulphur was of little or no importance or practical effect. This might be correct with regard to the particular method adopted for adding sulphur, but it was rather dubious as to universal application.

B.S.I. Standards Advocated

Dr. J. W. Donaldson said that with regard to standardisation of alloys, he could not agree with Mr. Faulkner, and he thought Mr. Logan had referred to the matter in a very satisfactory manner. As metallurgist to a large engineering firm, he was frequently consulted as to the composition of alloys required for various specifications, and he always advised the adoption of the B.S.I. Specification where such a specification existed. He was of the opinion that there ought to be more standard specifications for alloys both ferrous and non-ferrous. In testing, test bars ought also to be standardised as well as the method of testing. Much of the work which had been done of recent years was useless, because it was not suitable for comparative purposes.

The Non-Ferrous Sub-Committee were considering not only standardisation of certain alloys, but also standard test bars and standard methods of casting.

In the Paper reference had been made to the influence of sulphur on the alloys tested. He could not agree with the conclusions arrived at. He had always found sulphur to be detrimental. The manner in which the sulphur had been added to the alloys and the form in which it occurred in the alloys was not the manner in which sulphur was absorbed and retained in non-ferrous alloys, when prepared in the foundry under normal conditions.

Standardising Casting Temperatures

Mr. A. Hopwood wished to remind the previous speaker that the standardisation of casting temperatures for any type of alloy depended on the type of casting and foundry technique. It was, however, a practical proposition to standardise for any one job, including the method of moulding and running.

Dr. Donaldson said he did not wish to standardise casting temperatures in the foundry, but to standardise casting temperatures when various workers were making comparative tests on an alloy or alloys.

Mr. A. Harley (Past-President) referred to the multiplicity of alloys. The whole of the copper alloys required in the automobile industry, as far as the firm with which he was associated was concerned, amounted to six. That covered all the requirements not only for commercial vehicles but also for ordinary touring cars. It was quite obvious they could not afford to have many more in a foundry where the scrap had to be carefully segregated. More than six would raise almost an impossible problem. When one considered the hundreds of parts of a car or a motor coach that were made in copper alloys it was evidence that 95 per cent. of the 600 alloys mentioned were unnecessary.

Dr. Donaldson had corrected a point he was going to raise with regard to the standardisation of pouring temperatures. Every job seemed to require its own temperature, and it was necessary to find the most suitable temperature for that job. This consideration was, of course, influenced by the method of running; getting the metal in at the proper temperature without mis-running the casting.

Although perhaps it was not altogether a matter which was relevant to the Paper, yet, as a brass founder, he felt that more attention should be concentrated on the melting of the metal. It was not good to over-heat the metal, and then pour at the right temperature. Very much better results could be obtained.

Limiting Initiative

Mr. W. Dunkerley, speaking in reference to standardisation, asked was it to be assumed that if there were six alloys for the whole range that all necessary research with regard to alloys had been completed? He was a chemist, and, on occasion, was given problems in the foundry which necessitated a certain amount of local research work being done. It might be found necessary to add nickel, or other metal, to an alloy. If it were to be assumed that all that was necessary was to go to the six alloys which had been recommended by the various speakers, it would militate against individual effort in any particular works in connection with alloys.

Mr. Primrose said that in alloys for which the Sub-Committee had drawn up tentative specifications for passing in time for the B.S.I., they had been very careful to give, as far as possible, ranges of the metal added to the alloys, which, in some cases, with the higher lead contents, included as much as 2 per cent. of nickel. Even the No. 2 or No. 3 alloy would have quite a range in which to achieve individual effort, and it was hoped to give the limit of a minimum tensile and other values that would be attainable by ordinary methods of casting. While standardisation was the keynote it was not what might be termed a "cast iron" standardisation that must be "dead on" to the exact composition. There would be a range of variation of two or three added metals.

It would be noticed that the alloys cast and mentioned in the Paper had all been made in an induction electric furnace. This was an ideal method which eliminated a great many of the practical difficulties Mr. Harley had mentioned, and it was slightly academic, possibly ruling out some effects such as that of sulphur due to oil-fired or pit-fired furnaces.

Mr. A. Logan, also referring to the question of standardisation, thought that Mr. Harley's remarks touched the crux of the whole point. It had been stated that the motor industry could do the whole of their bronze work by means of six copper alloys. He (the speaker), as a metallurgist, would say that the marine engineering industry could do their work also with the same number, at any rate it could be done in the case of his own works where they had only their own internal castings to consider. Nevertheless, when dealing with outside work, they were forced to make a tremendous number of alloys which they knew were of no practical significance or importance at all, and particularly so with regard to locomotive work.

Mr. J. E. O. Little, speaking from the locomotive point of view, stated that the L.N.E.R. Company had just issued instructions to all their brass foundries to use six standard alloys. Apparently standardisation would have to be national, as standardisation by individuals would lead to greater chaos than before. The spiral test for fluidity was an interesting point. He had been trying to compare accurately the furnaces in four different brass foundries belonging to his Company. These furnaces differed from one another. He included the spiral test, but he found that if he went from one foundry to another with the same pattern he could not get the same casting. The moulders did not make them the same thickness or with the same finish.

Interlinking Requirements

Mr. C. E. Williams (Ex-President) noticed that Mr. Harley did not say that six alloys would be sufficient for all industries. Was it possible for the Institute of British Foundrymen to become a useful link for joining up the locomotive, the electrical, the shipbuilding, and other industries, and if they were all going on sixes to see how far those sixes might be interlinked?

Mr. A. Logan said that each different industry usually used a bronze or bronzes of the gunmetal type and they might also use a leaded bronze. Those two types were the types standardised, or attempted to be standardised. There was a range of six straight gunmetals and a range of six leaded phosphor bronzes; and when these alloys were put through would be applicable to any industry. There was no question of an industry requiring six different types for their own industry; the six different standards would be available or suitable for any industry. There would be no over-lapping.

Mr. S. G. Harrison inquired whether, if standardisation was not to be of the " cast iron " category, he would not be right in saying that before very long there would be a lot of rather mixed scrap again, thus defeating the object of standardisation.

Mr. J. S. G. Primrose said that an attempt had been made to establish a sufficient difference between the various standard alloys so that variations would still remain within the classification. A No. 3 alloy scrap, within its variations, could still be used as No. 3 alloy; it would not drop into No. 2 or No. 1. While a range was being established there would be a sufficient distinction between it and another range.

Mr. V. Delport, speaking on behalf of the author of the Paper, said that he would have very great pleasure in conveying to the American Foundrymen's Association the very kind expressions of opinion which had been stated with regard to the Paper. Personally, he had been particularly delighted at the interest shown in it by the discussion. Perhaps the Paper could not be referred to as being of a scientific character, but it was certainly a highly technical one, whilst at the same time it presented wide practical aspects and results in the simplification of the work of the foundry, and especially so when coupled with the investigations of the British Non-Ferrous Sub-Committee.

The CHAIRMAN, in closing the discussion, said he could quite sympathise with the attitude of mind of both Mr. Faulkner and Mr. Dunkerley, having regard to what had happened to standardisation in the past. Specifications had been standardised in the past, and as years went on variations crept in, and there was a tendency for a chaotic state to supervene once more. It had happened, in certain directions, with regard to cast iron.

The author's reply to the discussion on this Paper is given in Appendix A at the end of this volume.

STUDIES IN CAST BRONZES

By F. W. Rowe, B.Sc. (Associate Member)

Despite the fact that the cast bronzes are extensively used in all classes of engineering products, the information and data available concerning them are still lacking in many important particulars. Reliable figures are relatively scarce concerning the precise effect of variations in composition on the physical properties and the effect of mass under various conditions of casting.

The following *resume* and data have been selected from work by the author as representative of the physical properties obtaining with cast bronzes of various composition and under varying casting temperature and varying mass. They have been selected in an attempt to give a clear working idea of what happens under normal foundry conditions, and the variables have been reduced to the simplest to avoid undue complications.

For casting purposes for engineering use the amount of tin varies from about 5 per cent. to a maximum of from 15 to 16 per cent. The two other constituents usually present in varying quantities, besides copper, are zinc and lead, and to a lesser extent nickel. Where the cast bronze is needed for anti-frictional or wear-resisting purposes, zinc should be absent, in which case phosphorus is added sometimes purely for deoxidising purposes and sometimes also for increasing the hardness and the anti-frictional and wear-resisting properties. It may be present in quantities varying from 0.3 to 1.4 per cent.

Where the bronze is required for these duties, lead may be added in amounts varying from 1 to 15 per cent. (or in certain specific instances as high as 20 or 30 per cent.) to increase the plasticity of the alloy and increase its fitness for its work in certain conditions. In this particular Paper it is proposed to consider only tin and phosphorus as alloying elements.

Interpretation of Equilibrium Diagram

Whilst a full and detailed knowledge of the copper-tin equilibrium diagram is essential for serious research work, the fact that none of the commercially-used alloys is in the state which would be indicated by the diagram when cast, renders this diagram of no straightforward use to foundrymen.

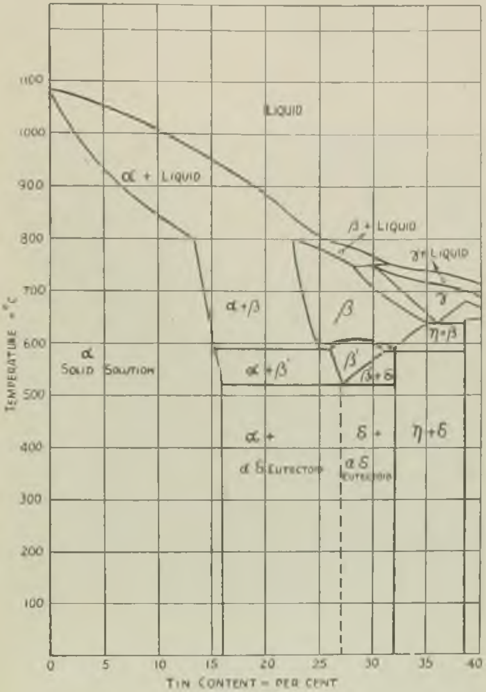

Fig. 1.—Equilibrium Diagram of the Sn-Cu Series of Alloys.

For instance, the diagram (Fig. 1) indicates that all alloys up to 15 per cent. tin are plain solid solutions of tin in copper. That is, consist entirely of single crystals of homogeneous composition, and, as such, these alloys, like most solid solutions, should be comparatively soft, malleable and ductile, whereas it is known that, say, the 15 per cent. tin bronze is relatively hard, brittle and not malleable, either hot or cold.

This is due to the state of the unstable equilibrium in which the cast alloys persist, due to their comparatively rapid rate of cooling after solidification, in commercial foundry practice. In fact, the 15 per cent. tin alloys need several weeks of careful annealing at predetermined temperatures to bring them to a state as indicated on the diagram, *i.e.*, a single solid solution.

FIG. 2.—ALPHA-DELTA EUTECTOID IN CAST BRONZES.

Thus it should be fully realised that the diagram does not hold for bronzes between 5 and 15 per cent. tin in the cast state. Nor, unfortunately, could an empirical diagram be drawn showing the make-up in the cast state, as the amount of variation from true equilibrium varies almost entirely with the rate of cooling after solidification, which in turn depends on three variables—mould material, casting temperature and the mass of the casting.

Alpha-Delta Eutectoid

Practically all the cast-bronzes made under normal conditions containing above about 5.5 per cent. tin show the presence of the alpha-delta eutectoid increasing as the quantity of tin rises until at about 28 per cent. tin the whole alloy consists entirely of this constituent.

The alpha-delta eutectoid (a typical patch of which is shown in Fig. 2) is hard and brittle. Its Brinell hardness (3,000 kg.-10 mm. ball) is in the neighbourhood of 400. This is equal in hardness to a 90-ton steel and is commercially unmachinable with ordinary high-speed steels. Its brittleness is such that a piece shatters into a powder with light taps of a hammer. All foundrymen are familiar with the brittleness of 15 per cent. phosphor-copper, and the 28 per cent. tin alloy possesses brittleness of a similar but lesser order.

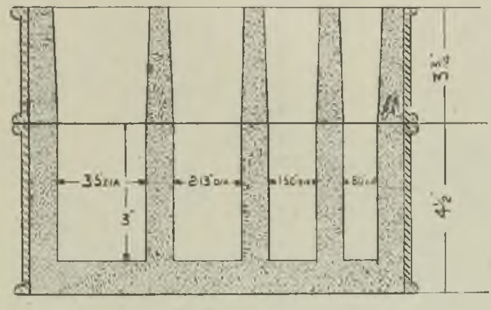

Fig. 3.—Method of Moulding Test-Bars.

Thus it will be appreciated that varying quantities (varying with the tin content of the alloy) of this compound materially affect the physical properties of the bronzes. Whilst a cast bronze with 7 per cent. tin may have an elongation of 40 to 50 per cent., a 14 per cent. tin bronze rarely shows an elongation of more than 2 per cent. under tensile strain, and is often less than this. Similarly, an impact test-piece (20 mm. by 20 mm. notched to standard B.S.I. proportions) from a cast bronze of 10 per cent. tin requires a blow of 80 to 90 ft.-lbs. to fracture it, whilst one from a bronze of 15 per cent. tin requires only 17 ft.-lbs.

As regards Brinell hardness (1,000-kg. 10-mm. ball), the 7 per cent. tin bronze cast under specified conditions has a hardness of 70, whilst the

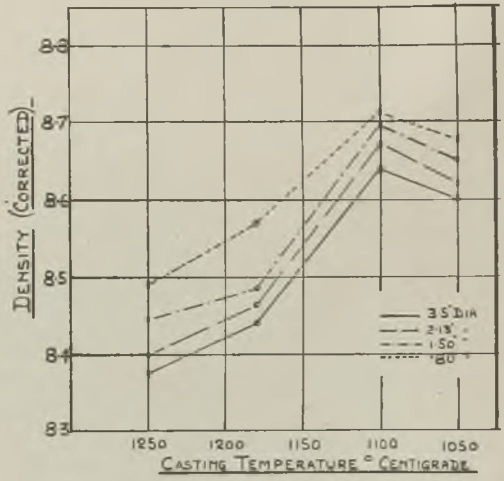

FIG. 4.—DENSITY CURVES FROM SERIES I BARS (7 PER CENT. SN).

15 per cent. tin bronze cast under exactly similar conditions has a hardness of 110. These important differences and their effect on the service results are due entirely to the different amounts of this alpha-delta eutectoid present in the bronze. Apart from the differences indicated above, due entirely to composition, there then come the large differences which may be present due to casting conditions and mass of the casting.

Experimental Data

To avoid confusion, all variations to melting conditions, gas and oxide content and deleterious impurities have been eliminated in this Paper. Such test results as are quoted are from initially pure metals melted under good average foundry conditions, and the resultant bronzes contain neither more nor less amounts than normally obtain of oxide, gas or deleterious impurities when using virgin raw materials.

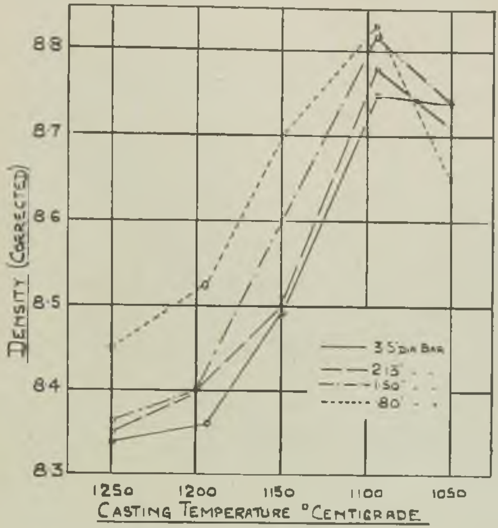

Fig. 5.—Density Tests on Series II Bars (10.5 per cent. Sn).

The first series given are a 7 per cent. tin bronze containing no other element beyond a slight amount of phosphorus to ensure deoxidation. Actually, an amount equal to 0.1 per cent. was added and 0.04 per cent. was left in the finished castings. From the same pot of metal, six boxes were poured. One box contained a simple ring casting, 8 in. diameter, with 5¼-in.

bore and 1½ in. deep. Each of the other boxes contained four bars respectively, 0.80 in. diameter (area 0.5 sq. in.), 1.5 in. diameter (approximate area 1.75 sq. in.), 2.125 in. diameter (approximate area 3.5 sq. in.), and 3.3 in. diameter (approximate area 8.5 sq. in.).

All the bars were 3 in. long and placed vertically in the box, and each with a head of 3¾ in. long, as shown in the sketch in Fig. 3.

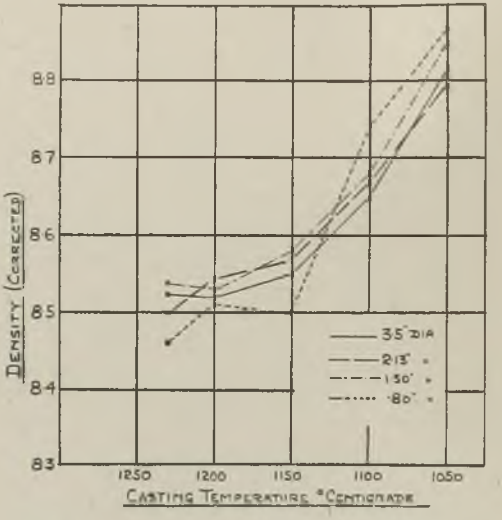

Fig. 6.—Density Tests on Series III Alloy (15.5 per cent. Sn).

These four boxes of bars were cast at 1,250, 1,160, 1,100 and 1,050 deg. C. Thus, these gave the relative effect of both casting temperature and mass. The boxes were dry-sand moulded and dried under specified conditions.

The results of the density tests on this first lot of bars are shown in Fig. 4. The first interesting feature of these curves is that the alloy has followed obvious laws, namely, that rate of solidification, as influenced both by mass and casting temperature, has an appreciable effect on the packing of the grains. The variation in density from the smallest bar to the largest (0.5 sq. in. and 1.75 lbs. wt. to 8.5 sq. in. and 18 lbs.) is, on the average in this series, of 0.12, or about 1.5 per cent. On the other hand, variation in casting temperature from 1,245 to 1,100 deg. C. shows an average variation of 0.25, or 3 per cent. The usual drop in density as the casting temperature approaches the freezing point of the alloy is noticeable. This indicates the precautionary measures necessary in foundry practice if the greatest degree of soundness is to be secured.

In the next series of similar bars cast, the tin content was raised to just over 10 per cent. (the actual analysis being 10.53 per cent.) with a similar small quantity of phosphorus added for deoxidising purposes. Similar casting temperatures were employed and the density results are shown in Fig. 5. Whilst not so regular (due probably to slight departures from the uniformity of conditions) the same trend is observed as in Fig. 4, with the difference that the extended period of solidification, due to the higher tin content of the alloy, has widened the possible variation in density due to difference in casting temperature. With the casting temperature employed, the 7 per cent. tin alloy showed a variation of 0.25 due to casting temperature, but in this series the variation average of 0.40. Just why this should be is not clear, as there is very little difference in the maximum calculated theoretical densities.

In the third composition of alloy used in this series, the tin content was raised to 15.45 per cent., the other conditions being similar.

The density determinations are shown in Fig. 6. Here the same large difference due to casting temperature as was observed in Series II (Fig. 5) is evident, but the difference due to mass is very small. Also due to the same casting temperatures being employed for a lower melting point alloy, the point where the density, after rising with falling casting temperature begins to fall again, has not been reached.

The fourth series (Fig.7) was made on an alloy containing 6.37 per cent. of tin and 1.02 per cent. of phosphorus. This showed, as regards

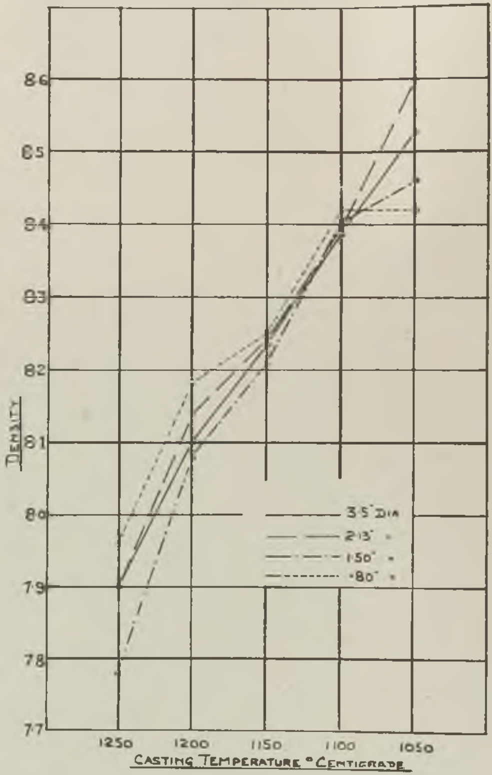

Fig. 7.—Density Tests on Series IV Alloy (6.4 per cent. Sn, 1.0 per cent. P).

density, the well-marked characteristics of the heavily-phosphorised bronzes, namely, extraordinarily large differences due to variation in period of solidification due to casting temperature. It will be seen on comparing this series of density curves with the previous ones (and particularly with that of a somewhat similar tin-content alloy but without phosphorus—Series I) the marked effect of 1 per cent. of phosphorus.

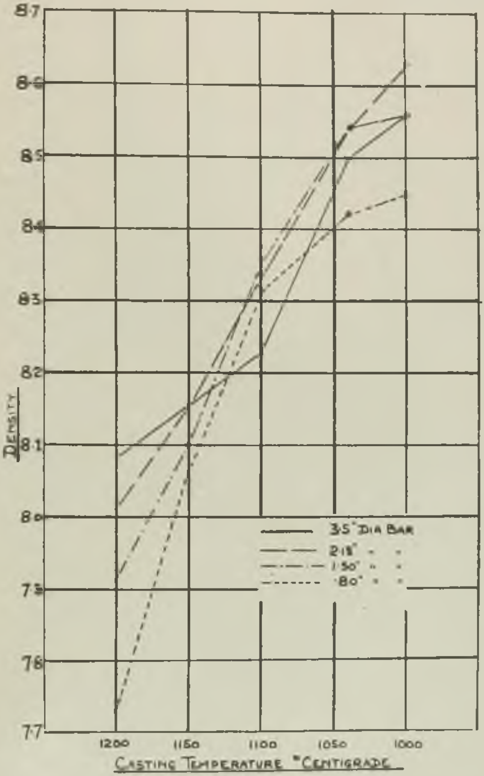

Fig. 8.—Density Tests on Series V Alloy (10.0 per cent. Sn, 1.0 per cent. P).

Whilst the average difference in density due to casting temperature in the first series was 0.25, in this series it is 0.6. The lower casting temperature employed, whilst in the smaller bars has had some effect on the progressive rise in density due to falling temperature, has not been sufficiently near the solidus to cause marked unsoundness.

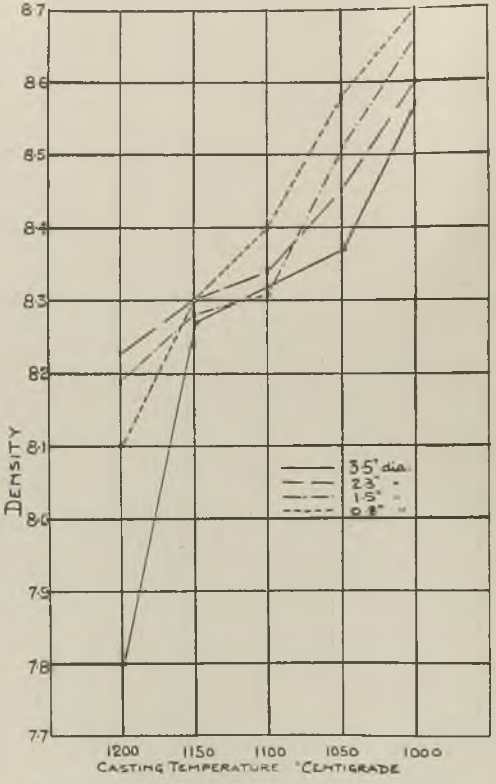

FIG. 9.—DENSITY TESTS ON SERIES VI ALLOY (14.8 PER CENT. SN, 1.0 PER CENT. P).

The next series, No. V, were made on an alloy similar to that used in Series II but with 1 per cent. of phosphorus. The tin content was 10 per cent. As the addition of 1 per cent. of phosphorus materially lowers the solidifying point of a 10 per cent. tin alloy, it was felt that the results obtained (Fig. 8) with the same casting temperatures as used for the previous series would give results incomparable with those obtained with this class of alloy, and the maximum

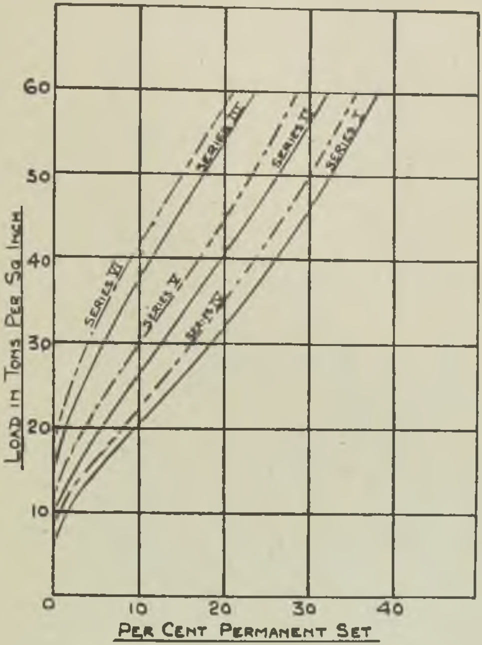

Fig. 10.—Curves of Compression Tests on Pieces cut from Test-Rings Cast with Bars.

and minimum casting temperatures were lowered by 50 deg. C. Its general trend, however, is similar to that of Fig. 7, but the points appear 50 deg. C. further on the scale. The same wide variation in density with a casting temperature variation of 200 deg. C., as in Fig. 7, is very noticeable.

TABLE I.—*Results of Physical Tests on Bars Cut from Test Rings Cast with Various Series of Bars.*

Series.	Composition.		Casting temp. deg. C.	Y.P. tons per sq. in.	M.S. tons per sq. in.	Eln.	Impact.	Brinell 1,000 kg.	Density.
	Tin.	Phosphorus.				Per cent.	20 mm. × 20mm. notched.		
							ft./lb.		
I	7.0	—	1,160	8.2	19.6	36	120 U.B.	69	8.66
II	10.5	—	1,150	12.4	19.8	20	81	83	8.63
III	15.5	—	1,150	—	17.3	1	17	109	8.68
IV	6.4	1.0	1,150	10.0	17.6	14	93	71	8.20
V	10.0	1.0	1,070	13.2	16.6	12	45	87	8.38
VI	14.8	1.0	1,100	—	14.0	1	13	114	8.29

The next alloy, Series VI, was similar to that used in Series III, but with 1 per cent. phosphorus. The density results are shown in Fig. 9. The tin content was 14.75 and the same range of casting temperatures was used as for Series V.

The same general outline is observable as in the other two series of high-phosphorus alloys, but the very low density of the 3.5-in. dia. bar cast at 1,200 deg. C. is rather inexplicable. It serves, however, to emphasise the sensitivity of this class of alloy and the low density (and soundness) which may follow other than the most rigid standardisation of conditions in the foundry.

Along with these test-bars out of each mixing was cast a test-ring 8 in. dia. with 5.25-in. bore and 1.25 in. wide. The weight of this casting was 11 lbs. and the mould was a normal dry-sand mould run in a conventional manner. From this ring was cut tensile, impact, density and Brinell test-pieces, and the results of these tests are shown in Table I. These are not presented as maxima of which the various alloys are capable, but form an interesting guide when taken in conjunction with the previous graphs of the results to be expected from the various alloys in this range.

It should be specially noted that the impact values obtained are purely empirical, since they are taken on bars 20 mm. square and notched with the usual B.S.I. notches. Higher densities and possibly improved physical properties would probably have been obtained had lower casting temperatures been employed for the alloys Series IV, V or VI.

An interesting illustration on the effect of phosphorus as a hardening agent is shown in Fig. 10, where the results of compression tests on pieces cut from the six sand-cast test-rings from which the tensile figures were obtained.

The author's thanks for permission to present the results of this work are due to his directors at Messrs. David Brown & Sons (Huddersfield), Limited, and to his assistants, by whom these data were collected.

DISCUSSION

After the author (Mr. Francis W. Rowe) had introduced his Paper, **Mr. V. C. Faulkner** inquired whether the author of the Paper could give any reference which would confirm his figure that the Brinell hardness of the alpha-delta eutectoid in cast bronze was of the order of 400. Personally, he had been unable to confirm that figure, and from inquiries made in the London area the usual figures appeared to be of a much lower order. Had Mr. Rowe made any " life " tests which were now erroneously being called fluidity tests, in so much as it had been tacitly admitted by one speaker that " life " was the same as fluidity, in his correlation with temperature. The object of the spiral test was to differentiate between the fluidity and " life." " Life " was the ability of the liquid metal to fill a mould. Apparently, one member present found such a test useless. He would like to suggest that if that member desired to ascertain the best dressing for a mould there could be no better way to do so than by means of the spiral " life " test. He could then ascertain which of the mould dressings influenced the property of life or ability to fill a mould with the metal. That was the kind of work for which foundrymen were looking.

Hardness of Alpha-Delta Bronze

Mr. Rowe stated that the Brinell hardness figures cited were entirely his own, with regard to the hardness of the alpha-delta eutectoid such as was present in more or less amount in all gunmetals and bronzes containing above 6 or 7 per cent. of tin, and he did not know any reference which could be mentioned with respect to them, though he had searched in past years for some actual hardness determinations on such various constituents as appeared in a bronze. In the foundries and laboratories of the firm with which he was associated a considerable amount of time and money had been devoted to obtaining some reasonably accurate determinations of the hardnesses of the various constituents in bronzes. Quite sufficient work had been done, and figures computed, to form the subject of a separate Paper.

An Outstanding Feature

The figures were rather startling. It would be appreciated that it was the hardness of the constituents in the bronze which formed the whole explanation as to why the tin-bronzes and the gunmetals were of such great value in the engineering industry, and also why so many of the so-called cheaper alloys which were put forward to replace bronzes were more or less bound to fail.

The type of bronze referred to in the Paper would never be replaced unless metallographic features, or features of differential hardness, and similar type of structure could be duplicated. The value of a bronze and of a gunmetal in industry did not depend on its ordinary physical characteristics, such as tensile strength and hardness. Those could be quite easily duplicated by other alloys. The value of a bronze depended almost entirely on the fact that it had the same sort of structure as a macadam road; namely, that there were particles of granite-like hardness immersed in a relatively soft and plastic structure, and it could not be replaced by material all of the same hardness.

Utility of the Spiral Test

So far he had not done any work on the fluidity test as regards bronze, but he did appreciate the point of Mr. Faulkner's remarks that when testing the value of various mould materials " life " tests, such as were being discussed and propounded, would be of great value. With regard to the comparison of various bronzes by means of their " life " tests, he was bound to sympathise with Mr. Logan in that, so far, other points had proved of much greater value and the determination of other properties was needed much more than the so-called fluidity tests.

The Chairman (Mr. J. E. Hurst) thought it would have been preferable if Mr. Rowe had stated that the value of bronze was due to the fact it had a structure more like cast iron.

Density Curves and Impact Values

Dr. J. W. Donaldson, in thanking Mr. Rowe for his very interesting and practical Paper, said that the value of the Paper would have been increased, if a maximum point had been obtained in the density curves of the alloys in Series III to VI by the lowering of the casting temperature.

With regard to the impact values given in Table I, these had been obtained on a 20-mm. square bar. He would be glad to know how these values compared with values obtained on a 10-mm. square bar or a 0.45-in. round bar. Such values would certainly be lower, but would be of greater value for comparison with values obtained for steels.

Reasons for the Ranges Chosen

Mr. Rowe said that an attempt had been made to compare the physical properties of the alloys when cast over the same range of casting temperature. Had time and facilities permitted, the range might have been extended for the lower melting-point alloys, whereas five casting temperatures for the higher melting-point alloys had been used.

Regarding the impact tests shown in Table I, it was not possible at the moment to give the information with respect to comparative values obtained on the standard 10-mm. square bar. The 20-mm. square bar had been adopted many years ago, because it was found that, in the case of the relatively brittle alloys, the differentiation which was obtained with a standard 10-mm. square bar was not sufficiently high. The larger bar was also adopted for cast iron in order to give a greater amount of differentiation among the relatively brittle alloys, such as the brittle bronzes and the cast irons.

Divergent Results

Mr. A. Harley also raised a point in regard to Table I. Looking at Series 2 and Series 5, it would be found in the case of the two alloys mentioned, the only difference was that one was 1 per cent. of phosphorus. The casting temperature was a little lower than for phosphor bronze, and there were extraordinary variations in the results. In the case of the phosphor bronze, the yield-point gained about a ton. The ultimate stress lost about 3 tons, while the impact value of phosphor bronze was only 50 per cent. of the ordinary tin bronze. The Brinell hardness was practically identical, and the density of the phosphor bronze was definitely less than the ordinary tin bronze. Could Mr. Rowe throw any light upon why the difference in composition should produce such values?

Influence of Phosphorus

Mr. Rowe said that Mr. Harley had raised the very relevant question of the difference in physical properties shown in Table I between Series 2 Alloy, which was a straight tin bronze of 10.5 per cent. tin, and a similar alloy with the addition of 1 per cent. phosphorus in Series 5. As a hardener, tin was preferable to phosphorus. An ordinary bronze could be hardened by either increasing the tin content or increasing the phosphorus content. Generally speaking, the main difference between two alloys of relatively similar hardness, or one which contained no phosphorus and one which contained a fairly large proportion of phosphorus, was that the higher phosphorus alloy was more brittle. There was no corresponding advantage beyond cheapness in hardening with phosphorus, while there was a definite loss as regards shock strength and liability to fracture under similar conditions to those obtaining in the impact test-bar.

The results were, of course, not strictly comparable, because the tin content in Series 2 was 0.5 per cent. higher than in Series 5, and there was, of course, the variation in casting temperature.

He would not like to say that this difference of 80 deg. in casting temperature was sufficient to make the two alloys relatively similar. It was known, of course, that with a 1 per cent. phosphorus the casting temperature should be lowered because the freezing point was depressed, but he would not say the two series were strictly comparable. They indicated the general trend which was obtained as regards phosphorus, that the alloys did become more brittle when hardening with phosphorus than when hardening with tin.

With regard to the density tests, 1 per cent. of phosphorus, even on theoretical calculations, made a considerable difference to the density. The results as regards density were more or less comparable with hundreds of other similar classes of alloys, namely, that alloys with high phosphorus content had definitely a lower density, even under the best conditions, than the tin bronzes without phosphorus.

Mr. Harley inquired how the density test was carried out.

Mr. Rowe replied that the bottom half of the middle portion of each of the test-bars was taken in total, the cross-section of the test-bars was taken half-way from top to bottom, and a determination made by the usual weighing in air and weighing in water for specific gravity.

True Equilibrium Diagram

Mr. J. S. G. Primrose said he could not recognise the equilibrium diagram in Fig. 1. He would like to ask for the authority for the latest ones. He knew the diagram by Shepherd, given in 1896, and he knew the one produced in the Institute of Metals Paper by Prof. Hoyt in 1913, who definitely brought in the gamma and ignored the beta. Mr. Rowe showed that the delta came in somewhere in the region of 10 per cent. and put it as actually beyond 15 per cent. according to the diagram.

Early in the Paper it was stated that to obtain equilibrium with 15 per cent. tin alloys they needed several weeks of careful annealing. He did not think any of them would contemplate the annealing of phosphor bronzes for a few weeks, and he believed it would spoil all Mr. Rowe's alloys as bearings if he did so.

They had been shown what no doubt Mr. Rowe would describe as a true equilibrium diagram, but what was wanted was a working diagram which brought in the gamma range in cooling and in which the delta came in much nearer 10 per cent. as in actual practice.

Foundry Use of Equilibrium Diagrams

Mr. Rowe said that the equilibrium diagram had been compiled by himself from all the existing data on the copper-tin series. He had endeavoured to embody, as far as was possible, a reasonable compromise between conflicting views. He had at other times, and in other places, given some idea as to how the normal foundry alloys differed from the equilibrium diagram, and a fair indication had been given to foundrymen as to how much alpha-delta eutectoid was to be expected in sand-castings of various compositions, and the differences which could be expected in foundry practice as regards metallographic structure as contrasted with the true equilibrium diagram of alloys in a stable condition.

Density of Bronzes

Mr. A. Logan pointed out that the only physical property results reported in the Paper were densities, which to the foundryman were, of course, of vital importance. The question of the maximum possible density of any alloy was of very practical importance in non-ferrous work, and from that point of view the Paper had struck a new note. It gave a number of alloys to refer to where the densities under various conditions were very clearly stated. Fig. 3 was a diagram of a mould containing four bars, but he assumed that it was not drawn to scale. The dimensions of the bars were given, but the space in between the bars was obviously too small. What would have amplified the Paper very much, and added to its interest, would have been complete macro etchings of the bars as cast, showing also the sink of the heads. He assumed that the density quoted was the average density of the whole bar. Had Mr. Rowe ascertained the densities of the outside and centres of the bars, and, if so, were the figures available?

Phosphorus and Porosity

The outstanding points of the Paper led to two very definite conclusions. By adding phosphorus to a bronze there was an undoubted increase in the chances of unsoundness and porosity. The other important feature, which was equally obvious, was that the fact of mass variation was not of such importance as casting temperature. Both the Papers read that morning led to the same conclusion. The systematic checking of casting temperatures was greatly neglected, and until it was realised by non-ferrous foundrymen to be necessary the value of the various research Papers read from time to time would be largely neutralised.

He would not like to be understood to state that the "life" test or fluidity test was of no value at all, but that as a practical control test it was of little use in a non-ferrous foundry.

Average Density Determinations

Mr. Rowe replied that macro-etchings were prepared from the whole of the bars, but that it was not thought necessary to go to the cost of reproducing them.

The density tests were only taken as a whole cross-section of the bar, and, therefore, were average density tests. Complete Brinell hardness determinations were taken over the whole area of the bars, but owing to the sort of ideal way in which they were cast, with the whole of the bar being utilised as a runner and a riser, there was very little difference between the centre and the outside in all of the bars. Therefore, the Brinell figures were not published, because with them being more or less even throughout they did not add greatly to any knowledge which was likely to be imparted by the Paper.

Foundry difficulties were undoubtedly increased when an alloy contained a large amount of phosphorus, and there was a greater probability of unsound castings resulting therefrom together with low density.

Mass Variations

He accepted Mr. Logan's remarks with respect to mass variation with diffidence, because he did not consider the results stated in the Paper, in so far as they affected the question of mass on the physical properties, were figures which could be rigidly interpreted and quoted. He thought there was, of course, less variation due to mass than might have been expected, but he did not think the conditions would obtain in ordinary foundry practice, due to the fact that the bars had been cast under more or less ideal conditions. Taking, say, a ring casting, the average cross-section of which was similar to that of the ordinary small size bar, and run by the ordinary foundry methods, and a ring casting of similar cross-section as the largest size, there would probably be a greater variation due to mass effect.

The diagrammatic sketch (Fig. 2) did not show the full amount of space between the bars.

Inter-Crystalline Cracks

Mr. W. Dunkerley mentioned the case of a bronze valve which leaked, and which, upon microscopic examination, exhibited a considerable number of inter-crystalline cracks which penetrated even into the eutectoid part as well. A perusal of Primrose's book on " Gun-metals " led him to assume that if the casting had been at a lower temperature the cracks would have been eliminated. Was it possible, by casting at a lower temperature, to get a denser material, and therefore one less likely to show inter-crystalline cracks?

Mr. Rowe replied that temperature, *per se*, had no effect on density; what mattered was the rate of solidification of the alloy. If the rate of solidification was made sufficiently rapid as in the case of the chilled bar shown in the red brass Paper there was very little difference caused by the variation of casting temperature. Actually, variation in casting temperature in a sand mould caused greater alteration. The more rapid the rate of solidification the more dense was the alloy.

The inter-crystalline fissures noticed by Mr. Dunkerley were not due to high casting temperature, but were probably due to gas content in the bronze, which generally revealed itself more markedly with a low rate of solidification. It was not certain that the trouble would be cured by depression of the casting temperature. If the casting were made in a chilled mould it was doubtful if the gas content would show its bad effect, but that, of course, was not always practicable; and one had to rely on getting metal reasonably free from gas content (which was likely to come out of solution) in order to eliminate any chance of inter-crystalline fissures occurring.

The CHAIRMAN wished to refer to the alpha-solid solution range; particularly with reference to the liquidus and solidus curves. There was a view gaining ground that the liquefaction of a solid solution, provided it was perfectly homogeneous, occurred when the critical speed of the vibration of the atoms in the space lattice was exceeded. Therefore the view was that the solidification point of a series of solutions should be just a single line and not a range. If Mr. Rowe was interested in the theoretical aspect of the matter, had he come across any experience that might lead him to expect that the solidus line was variable, and, perhaps, under centrifugal casting conditions was much more closely approaching the liquidus line than had been shown in the diagrams.

Vote of Thanks

The CHAIRMAN then proposed that a very hearty vote of thanks be accorded to the authors of the Papers for their extremely interesting communication, which was carried unanimously by acclamation.

Vibratory Effect on the Liquidus-Solidus Line

MR. ROWE said that with regard to the question of the equilibrium diagram shown upon page 3 of the Paper, the alpha solid solution line at practically 16 per cent. was one which he felt was quite right, and which had been definitely determined by other workers. It had been gradually pushed up as the years went on, and the full limit might not have been reached, but he did not think it was far off now. Regarding the difference between the liquidus and solidus lines, there was a good deal in the new theory that under a critical speed of vibration the liquidus and solidus would be merged into one line, but so far he had not observed anything in his experience of centrifugal casting, involving a good deal of vibratory effect, which led him to support the theory dogmatically. One of the proved features of centrifugal casting was that, due to the vibratory effect, the crystal size was kept extremely small. This was due to no other reason except the vibratory effects set up during the whole period of solidification, but that would not lead him to advance a theory that the solidus and liquidus did stand entirely in a straight line.

PAPERS PRESENTED TO THE BRANCHES

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COMMERCIAL MOULDING SAND CONTROL FOR THE MODERN IRONFOUNDER

By F. Hudson (Member)

Commercial moulding sand control, properly applied, should be looked upon as a sound investment by every founder. Obtaining the highest degree of control will probably depend principally upon the consideration of two factors—firstly, the suitability of the sand-handling and preparation equipment available, and, secondly, upon the initiation of a suitable scheme of sand-testing methods. The question cannot be answered by any statement of broad principals, as it also involves discovering by observation and experiment the properties of sand most satisfactory for the type of castings being made and the moulding methods in use.

The determination of proper characteristics, furthermore, is not an easy matter. There are so many variables involved that definite conclusions can only be drawn after every factor has been taken into account and when averages are taken over long periods. Consequently it is not intended that this Paper should outline generalities or theories upon the subject, but rather to describe a concrete example of the application of sand control in a modern foundry. Accordingly, it is proposed to divide the Paper into two sections, the first part dealing with the installation of suitable plant and control methods, and the second part dealing with the problems that are likely to arise and the final benefits gained. Perhaps in the first case it may be as well to state that all following remarks refer to the manufacture of high-class engineering castings, such as valve bodies for the control of all classes of fluids, their accessories such as headstocks and other operating mechanisms, hydrants, sluice gates and pumps as specialised in by Messrs. Glenfield & Kennedy, Limited.

PART I

Plant and Control Methods

Previous to the installation of sand control it was customary to employ both facing and backing sands. The facing for green-sand work was made up from approximately:—57.1 old floor sand, 21.4 new rock sand, 14.3 red sand, and 7.2 per cent. coal dust. This was mixed by hand and then put through a Herbert aerating machine, nicknamed the "Joy Wheel," and delivered to the moulder. The moulder was responsible for the preparation of backing sand, which consisted of old green-sand floor sand, plus the addition of rock sand, according to discretion and the type of casting being made. This duty was conducted at the end of each day's cast, after the moulds had been "knocked out," the sand being tempered, mixed by hand and then put through a portable Royer aerating machine.

Accordingly it will be observed that the moulder, as well as making moulds, had to strip his own castings and prepare, and be responsible for, the bulk of his sand.

Conditions in regard to the preparation of dry sand were also far from satisfactory. Similar to green-sand practice, both facing and backing sands were used, the sand being prepared in an old type of pug mill, a piece of equipment most suitable for crushing bricks but far from being satisfactory as a means of preparing moulding sand. Consequently consistent supplies of sand were like ideals in a dream and reality demanded recourse to a variable mixture according to the views of the foreman in charge and the size of castings being made. Roughly speaking, the facing mixture would be along the following lines:—1 barrow dry-sand floor sand; ¾ barrow rock sand; 3 shovels loam, and 2½ shovels ashes.

Happily, however, the management had been giving consideration to the question of sand control for some time, and it was decided to go ahead with the installation of a centralised sand-preparation and distributing plant with the view of bringing the foundries up to date as demanded by present economic conditions. By taking this step it was felt that it would allow the green-sand moulder to produce a greater output of castings, as all this time could then be utilised for moulding purposes instead of part being occupied for sand preparation. Furthermore, it was considered that a centralised plant would most readily lend itself to a scheme of control whereby sand could be produced at lowest cost having those properties best suited to safe casting production. It was also appreciated that in a scheme of this nature it would be advisable to work with the minimum number of sand mixtures possible, the ideal being in the production of a sand that could be used with minor modifications, for both green- and dry-sand purposes.

Broadly speaking, it would appear that in modern foundry practice green-sand moulding is becoming a lost art, particularly where the larger sizes of castings are concerned, yet now when industry needs this form of moulding most, due to its lower cost, there are few skilled artisans available. Furthermore, present-day mass-production methods militate against the revival of the highly-skilled man, and if the industry is to revive this branch, it would appear to be essential to produce a " foolproof " sand which does not require the individual skill of the trained moulder. In the Glenfield foundries there are many castings made in dry sand which one would like to see made in green sand, and in their study leading up to the production of a standard sand—call it a green-dry sand if you like—it was decided that in order to obtain success it would be necessary for the green sand to have the properties of dry sand.

The foregoing remarks give a fair idea of the firm's aims and ambitions leading up to the installation of commercial moulding-sand control.

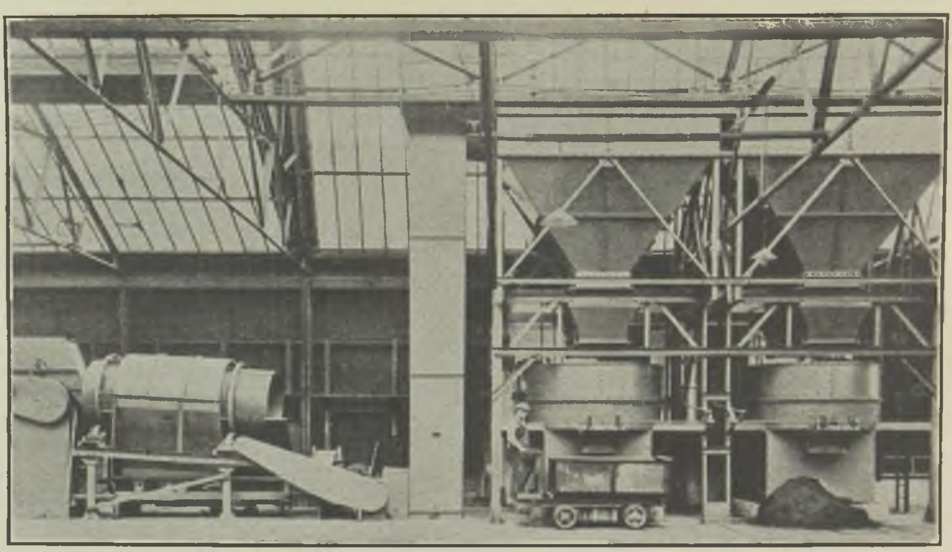


Fig. 1.—General View of Sand Plant installed at Messrs. Glenfield & Kennedy, Limited.

Sand-Preparation Plant

Fig. 1 gives a general view of the plant. The operation of the plant, as shown, is for the return sand to be delivered either on to the grating over the boot of the knock-out elevator or direct by means of the underground conveyor which traverses all the moulding bays in the foundry. The elevator delivers the sand into a rotary screening and breaking drum fitted inside with lifting blades which pick up and then drop the lumps, thus breaking them up. The fines pass through wire mesh plates, and the refuse is collected and discharged at the end of the screen.

When the sand falls through the screen it is collected on a flat india-rubber and canvas belt conveyor and then passes under a magnetic separator as shown in Fig. 2. This separator is rather out of the ordinary, as it consists of a dual magnetic system. The magnets are arranged both below and above the main conveyor belt, and the material first comes under the influence of the magnets below the belt. Ferrous material travelling on the belt is thus retarded, and this reduction in speed enables a second set of magnets, placed above the belt, to exert their full attractive force. The iron is extracted, and by means of a cleaning belt is deposited to one side. The sand, which has now been screened and freed from sprigs and iron particles, is elevated to a flat belt conveyor running over four storage hoppers. This conveyor is fitted with adjustable ploughs for directing the sand into the required storage hopper, each having a capacity of about 10 tons.

At the bottom of each storage hopper are fitted double chop gates operated by levers which control the supply of sand into the measuring hoppers fixed immediately below. These measuring hoppers are also fitted with double chop gates, and have 10-cwt. batch capacity discharging into 8-ft. mills. The mills are of the stationary-pan type fitted with renewable wear plates and equipped with two rollers carried on rocker arms to allow of rise and fall for bulky materials. The rollers may be adjusted to run either on the pan bottom or with any clearance required according to the extent of kneading action necessary for the sand being treated. In addition to the rollers there are two sets of beaters, positively driven, as they revolve around the pan as well as the usual ploughs. It will be understood that the positively-driven beaters have an agitating action on the sand and provide a more intense mixing than can be obtained from the ploughs and rollers alone.

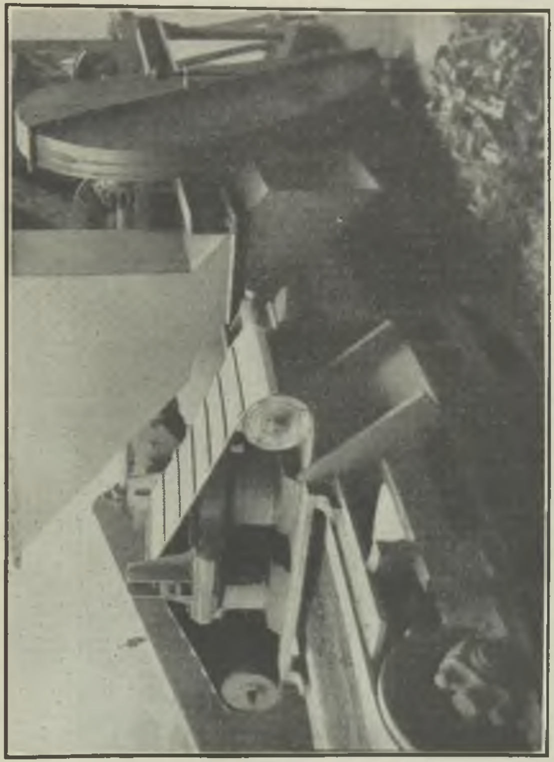


FIG. 2.—MAGNETIC SEPARATOR INCORPORATED IN THE SAND PLANT SHOWN IN FIG. 1.

Water is added through sprinklers running round the inside of the pan and the quantity controlled by Glenfield rotary water meters. The new sand is measured and added by hand from storage bunkers level with and adjacent to the working platform.

The working capacity of the plant is about 20 tons per hour, and it has been specially designed to work in conjunction with a continuous moulding system which will be a future development of the firm. At present, however, the sand-distribution conveyors required by the completed scheme are not yet installed, and the delivery of sand to the moulders is conducted by means of tipping stillages. The mixing time

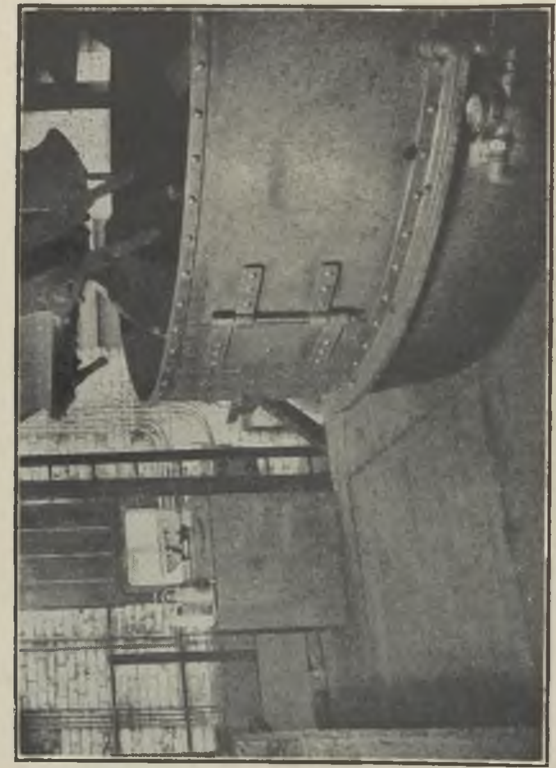
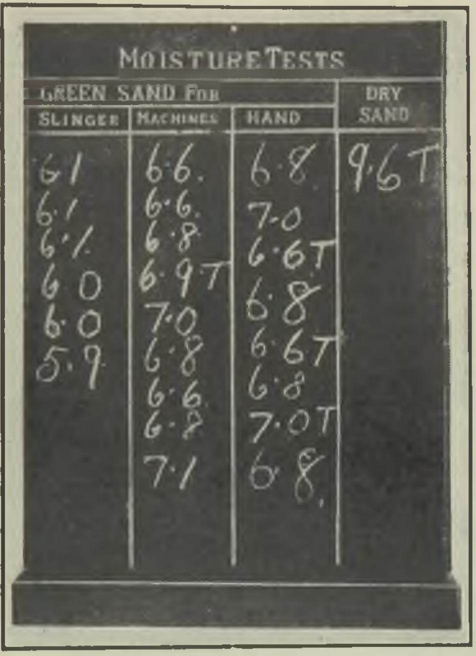


FIG. 3.—VIEW OF THE WORKING PLATFORM, SHOWING THE "SPEEDY" MOISTURE TESTER AND MOISTURE-CONTROL BOARD.

for a batch of sand is around 3 min., and before it leaves the mill the moisture content is checked by means of the "Speedy moisture tester" and the figure obtained marked up on a special control board for future reference. Fig. 3 illustrates the working platform and the



MOISTURE TESTS

GREEN SAND FOR			DRY SAND
SLINGER	MACHINES	HAND	
6·1	6·6.	6·8	9·6T
6·1	6·6.	7·0	
6·1	6·8	6·6T	
6·0	6·9T	6·8	
6·0	7·0	6·6T	
5·9	6·8	6·8	
	6·6.	7·0T	
	6·8	6·8.	
	7·1		

FIG. 4.—SHOWING MOISTURE-CONTROL BOARD AT THE END OF THE DAY.

methods adopted for moisture control, and Fig. 4 shows the moisture control board at the end of the day's work. It will be observed that the moisture content is varied according to the purpose for which the sand is used and the type of machine it is to supply. Every batch of sand mixed is not tested on the "Speedy" tester, as it is considered unnecessary in view of the added water being metered for each batch. There is no disintegrator or aerator fitted to the plant.

Test Methods Used for Sand Control

A good deal of thought was devoted to this problem, and after trials covering the best part of a year with all available equipment, it was decided to standardise principally on those methods recommended by the American Foundrymen's Association as covered in the Report* of the Sub-Committee on Sands and Refractories given at the last Conference. The main points responsible for the decision being made in this direction are as follow:—(1) The methods are applicable for testing sands having widely-different properties; (2) test results are rapidly obtained and representative of practical conditions, whilst not being affected by minor test inaccuracies; (3) results are directly comparable with the bulk of reference work available; and (4) the equipment is simple and robust in operation and is capable of being used by the average practical worker.

After the testing equipment had been selected the routine control tests proper were put into the hands of a laboratory assistant and work commenced. An example of the schedule adopted, say for the control of green sand, can be outlined as follows:—

The operator on the sand plant takes a sample of the sand as it leaves the mill and puts it through an $\frac{1}{8}$-in. mesh sieve and then into a canvas sampling bag, and immediately despatches it to the sand laboratory. He also takes particular care to see that the main sand batch has been tested for moisture on the "Speedy" apparatus. As soon as the sample reaches the laboratory, a small portion of it is weighed out and put into an electric oven at 105 deg. C. to determine the true moisture content and to check the mill operator and his more rapid methods. The sand chemist then rams up any test-pieces required for determining the dried strength of the sand, puts these into the oven and, when this is completed, determines

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* Proceedings I.B.F., Vol.xxvi, page 61.

the green compressive strength and permeability on the remainder of the sample. The actual methods employed and the apparatus required are fully described elsewhere, so it is not proposed to spend much time on this aspect, but the sequence of thought certainly demands a brief outline in this direction.

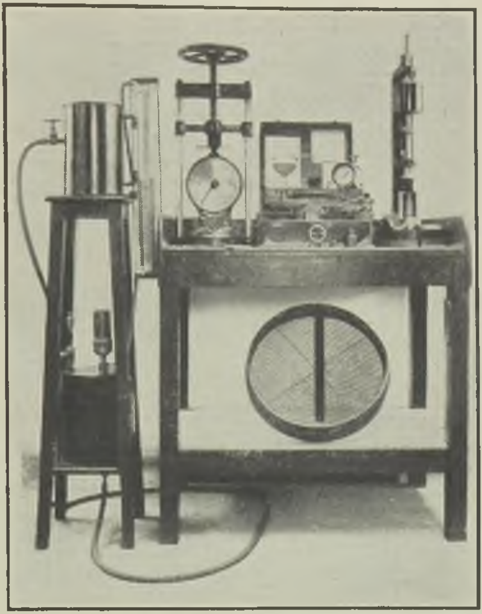


FIG. 4A.—APPARATUS REQUIRED FOR GREEN-SAND CONTROL, WHICH INCLUDES SIEVE, "SPEEDY" MOISTURE TESTER, BALANCE AND WEIGHTS, A.F.A. RAMMING DEVICE, COMPRESSION - TESTING MACHINE AND RICHARDSON'S PERMEABILITY APPARATUS.

Compressive Strength

Exactly 151 grammes of green sand are weighed out and introduced into a split cylindrical metal corebox, which is set into position on the ramming device, as shown in Fig. 4A. The sand is then rammed by energy obtained from three blows of a 14-lb. weight falling through a distance of 2 in., when a uniformly-rammed cylindrical test-piece should be obtained exactly 2 in. in dia. by 2 in. high, as indicated by the gauge marks fitted to the top of the rammer-frame casting.

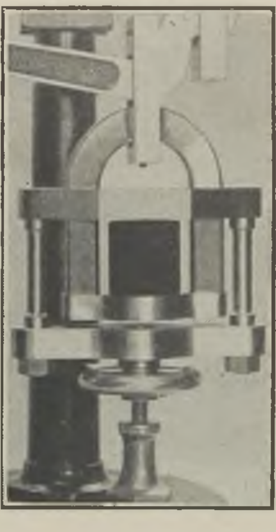


FIG. 5.—COMPRESSION LINK FITTED TO STANDARD CEMENT-TESTING MACHINE FOR OBTAINING DRIED COMPRESSION STRENGTH OF MOULDING SANDS.

The rammed test-piece is now removed from the corebox and broken on a compression testing machine, as shown in Fig. 4A, and the load required to effect fracture divided by 3.14 gives the green compression strength in lb. per sq. in. The spring balance on the machine reads up to

50 lb. If the dried compressive strength is desired, a similar test-piece is rammed up, dried in the stove, and then broken on another form of testing machine of greater loading capacity. In the author's firm they have devised a special compression link for fitting to a standard cement-testing machine for service in this direction, and this is illustrated in Fig. 5. Using this attachment, loads up to ½ ton can be applied.

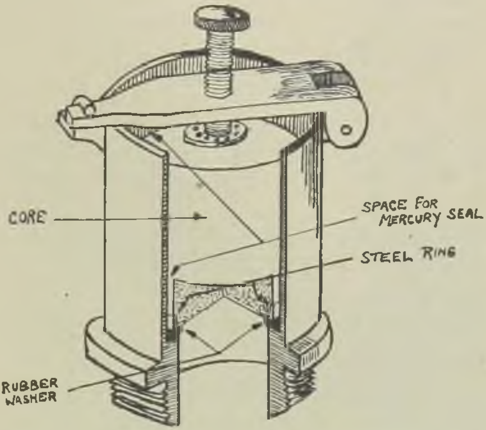
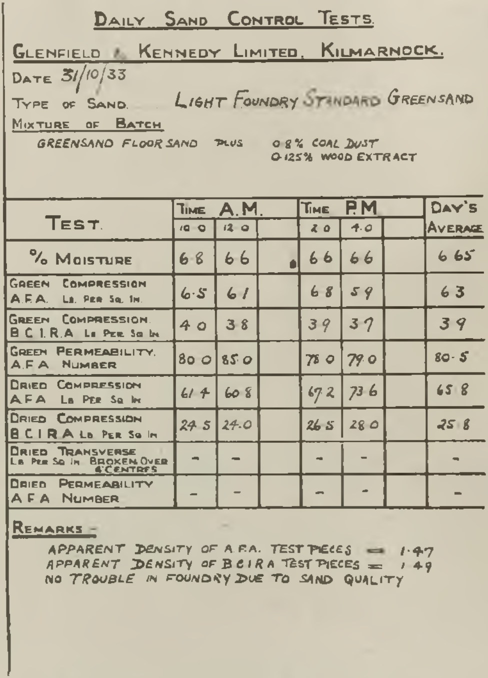


Fig. 6.—Modified A.F.A. Mercury-Seal Attachment for Richardson's Permeability Apparatus for obtaining Index of Dried Permeability.

Permeability

The same test-piece as used for compression tests is also used for permeability, but instead of using the split form of corebox the sand sample is rammed up in a tubular form of box. This tube is then attached to Richardson's permeability apparatus, as shown in Fig. 4A, and 2,000 c.c. of air is blown through the core by allowing this amount of water to fall from the top tank into the bottom. The pressure of the air being blown through the core is indicated on the manometer, and this is recorded, together with the time of air flow, for calculating the A.F.A. permeability number by the use of the formula given in the previously-mentioned Report of the I.B.F. Sub-Committee on Sands and Refractories.



DAILY SAND CONTROL TESTS.

GLENFIELD & KENNEDY LIMITED. KILMARNOCK.

DATE 31/10/33

TYPE OF SAND. LIGHT FOUNDRY STANDARD GREENSAND

MIXTURE OF BATCH

GREENSAND FLOOR SAND PLUS 0·8% COAL DUST
0·125% WOOD EXTRACT

TEST.	TIME A.M.			TIME P.M			DAY'S AVERAGE
	10·0	12·0		2·0	4·0		
% MOISTURE	6·8	6·6		6·6	6·6		6·65
GREEN COMPRESSION A.F.A. LB. PER SQ. IN.	6·5	6·1		6·8	5·9		6·3
GREEN COMPRESSION. B.C.I.R.A LB PER SQ IN	4·0	3·8		3·9	3·7		3·9
GREEN PERMEABILITY. A.F.A NUMBER	80·0	85·0		78·0	79·0		80·5
DRIED COMPRESSION A.F.A LB PER SQ IN	61·4	60·8		67·2	73·6		65·8
DRIED COMPRESSION B.C.I.R.A LB PER SQ IN	24·5	24·0		26·5	28·0		25·8
DRIED TRANSVERSE LB PER SQ IN BROKEN OVER 4" CENTRES	-	-		-	-		-
DRIED PERMEABILITY A.F.A NUMBER	-	-		-	-		-

REMARKS –

APPARENT DENSITY OF A.F.A. TEST PIECES = 1·47
APPARENT DENSITY OF B.C.I.R.A TEST PIECES = 1·49
NO TROUBLE IN FOUNDRY DUE TO SAND QUALITY

FIG. 7.—DAILY SAND CONTROL TESTS.

If the permeability of a dried sample is required, we employ a modified form of the A.F.A. mercury-seal attachment for holding the sand sample under test, as shown in Fig. 6. The size of the core is the same as given for all the previous tests, except that the precaution is taken to ram up a steel ring in the bottom of the core to ensure a satisfactory joint with the rubber washer and prevent leakage of mercury. It is personal practice to take at least four samples of sand per day, and the results obtained are entered upon a daily control sheet, as shown in Fig. 7.

In commercial moulding-sand control it is essential that the results obtained by test should definitely be representative of practical conditions, and it is good practice to satisfy oneself that this is so, at required intervals. The method employed to effect this is by a comparison of the apparent density of moulds rammed up in the foundry with the apparent density of the daily test samples. Table I illustrates the way of doing this. Various moulds are rammed up by different methods and then sand sections are trepanned by means of a steel cutter of exactly the same size as the control test-piece. This sand section is then weighed and it must agree

TABLE I.—*Influence of Methods of Ramming on Physical Properties of Sands.*

TYPE OF SAND.	METHOD OF RAMMING.	MOULD HARDNESS PENETROMETER READING IN CMS USING 200GRM WEIGHT.	APPARENT DENSITY OF 2-2 SECTION TREPANNED FROM MOULD	WEIGHT OF SAND OBTAINED IN TREPANNING TOOL.
GREEN SAND	HAND	2·1 2·5	1·50 1·48	155 GRMS 152 GRMS.
GREEN SAND	HERMAN JOLTER	2·6 3·3	1·37 1·37	141 GRMS.
GREEN SAND	OSBORNE JOLTER	4·1, 4·5, 4·1, 3·5	1·34 1·33	138 GRMS. 137 GRMS.
GREEN SAND	SQUEEZE	3·1 3·5	1·46 1·45	150 GRMS. 149 GRMS.
DRY SAND	HAND	2·2 2·1	1·63	168 GRMS.
DRY SAND	JOLT	1·4, 2·1, 2·0	1·64	169 GRMS.

VOLUME OF 2" DIAM × 2" EXTRACTION TUBE IS 103 C.CS.
TEST CORE TREPANNED FROM 8" VALVE BODY MOULD JOLTED 130 TIMES GAVE A GREEN COMPRESSION STRENGTH OF 5·5 lbs PER SQ. INCH A F A ROUTINE CONTROL TEST CORE MADE FROM THE SAME SAND AS THE MOULD. GAVE A GREEN COMPRESSION STRENGTH OF 5·4 lbs PER SQ. INCH

with the weight of sand used for ramming up the test-piece. In some cases it is even possible to actually test the extracted samples for compression.

In ramming up the test-pieces for green-sand work, the standard ramming conditions give an apparent density of 1.47 using 151 grms. of sand, and it will be observed that this agrees quite well with the average ramming conditions obtained in practice on hand and squeeze-rammed jobs. It is preferable to base the average on this class of ramming rather than on jolted work, as this latter method gives a variable apparent density according to the relation of the sample with the pattern face. For jolt-rammed jobs it is convenient to use a penetrometer as devised by Buchanan for obtaining an indication of the comparative densities as obtained in practice with those from test methods. In this Table, one will also observe the comparative results obtained by trepanning compression test-pieces from moulds, against the methods of ramming employed in the routine control tests. It can be definitely assumed from these results that the recommended A.F.A. routine control test methods are comparable with practice.

There are other helpful tests likely to be of value for control purposes, but these have been more fully described elsewhere, and for those interested reference should be made to available literature. In this present Paper probably the only other test likely to receive reference will be the question of gas evolved on heating, and this has been fully covered in previous Papers by the author.

PART II

Benefits to be Gained by Moulding Sand Control

After the installation of suitable plant and methods, one is confronted by many problems, and the first aim, no doubt, will be in the direction of producing a suitable sand for safe casting production at lowest cost. Obviously, the best way to undertake this problem is first of all to obtain some reliable idea of those properties required in a moulding sand to produce good castings, and when these have been obtained and standardised, experiments in cost reduction can go ahead. In the particular case of the author, he first referred to all published literature available and abstracted all sand-test values given, relative to the manufacture of general engineering castings. Secondly, the existing sand mixtures which had been in service for several years previously, and known to give fairly efficient results, were thoroughly tested and their physical characteristics determined. Thirdly, the sand practice of other foundries who were operating with similar control methods and producing efficient results, was sought and compared with the results already obtained by the two previous lines of investigation.

Some of the results obtained by these methods are illustrated in Tables II and III. Note should be taken that in the green-sand values given by Dietert in Table II a distinct difference is made according as to how the sand is rammed. For example, if a sand slinger be used for ramming up the moulds, the sand will require to have less moisture and a lower green compression strength than if a jolting machine is employed. This is entirely due to the difference in ramming velocities imparted by the two types of machines. Personal experience entirely confirms the need of this distinction, and, if it is not recognised, trouble will result. Particular note should also be made of the average test limits at the bottom of the Table, especially that referring to the dried compression strength required of 40.0 to 60.8 lbs. per sq. in. for comparison with the sand values given in Table III obtained from dry-sand practice. It will be observed that the limits of dried compression strength obtained on the green sand fall within the limits obtained from dry sand.

Obviously, if one could increase the dried strength of green sand by a certain margin there would be no need for using a separate sand mixture for dry-sand work, and it should be possible to develop a single sand mixture for both duties. After all, why should green sand be any weaker in the dried condition than a dry-sand mixture? The only difference affecting this question is in regard to the coal-dust additions and in methods of mixing, and after due consideration it was decided that this point constituted a valuable line of thought for future research work.

It will, no doubt, be agreed that Tables II and III give some definite idea of those properties required of the sand to produce good castings and permit sand.tests to become a definite means of control. It will be appreciated that all this was not done in a few days. In fact, to be perfectly candid, before the Laboratory had decided on what test methods to adopt, and the necessary test limits required for control, the best part of twelve months had elapsed. In the meantime, the new sand plant had been operating steadily on green sand, using a temporary standard mixture consisting of approximately:—

TABLE II.—*Green-Sand Values known to give Good Results.*

AMERICAN

KIND OF CASTING.	TYPE OF RAMMING	% MOISTURE	COMPRESSION STRENGTH lbs per sq. inch				PERMEA- [illegible] (GREEN)	GAS EVOLVED [illegible] *	% LOSS [illegible] IGNITION	AUTHORITY.
			GREEN.		DRY					
			AFA	BCIRA	AFA	BCIRA				
FLY WHEELS	JOLT	6·3/7·3	4·6	-	40·0	-	90·0	-	-	DIETERT.
FLY WHEELS	SAND SLINGER	6·0/7·0	4·1	-	40·0	-	100·0	-	-	DIETERT
PIPES	JOLT	8·0/9·0	4·0	-	48·0	-	500·0	-	-	DIETERT.
CAR WHEELS	JOLT	7·5/8·5	4·7	-	40·0	-	130·0	-	-	DIETERT.
CYLINDER BLOCKS	JOLT	6·0/7·0	5·0	-	44·0	-	80·0	-	-	DIETERT
CYLINDER BLOCKS	SAND SLINGER	5·5/6·5	4·0	-	42·0	-	80·0	-	-	DIETERT.
BRITISH (APPARENT DENSITY OF BRITISH SAMPLES ALL 1·55)										
RAILWAY CHAIRS	HAND	6·5	5·1	2·9	52·7	19·4	30·2	63·3	8·1	BEN HIRD.
HYDRAULIC VALVES	HAND + MACHINES									
FACING SAND		7·0	4·6	3·0	60·8	21·0	49·1	70·0	7·2	F. HUDSON
BACKING SAND		7·0	5·0	3·5	48·7	15·5	43·4	68·3	7·1	F. HUDSON
AVERAGE LIMITS	FROM	5·5	4·0	2·9	40·0	15·5	30·2			
	TO	9·0	5·1	3·5	60·8	21·0	300·0			

* DRIED AND HEATED TO 1200°C FOR ½ HOUR.

94 green-sand floor sand; 3 rock sand; 1½ red sand, and 1½ per cent. coal dust.

The cost of new sand additions and coal dust in this mixture worked out at about 1s. 6d. per ton, and at the time this was thought to be quite economical. Unfortunately one is apt to forget the capacity of the plant, and even whilst running at reduced capacity of around 80 tons per day it was soon found out that so far as the reduction of new sand costs were concerned it was fallacious. In fact, after some months' running it was found that the cost of the sand additions was going to be well above that used in the old system of working when facing sand was employed, backed up with the floor sand prepared by the moulders. Fortunately the sand-control tests had now started, and very soon we found out that the "economical mixture" was most un-economical, and the position at this time is clearly exemplified in Table IV. It will be observed that when routine daily control tests commenced it was found that the green sand in service was altogether too rich, and it was decided to reduce bond. Obviously the most economical way of doing this was to

Table III.—*Dry-Sand Values known to give Good Results.*

BRITISH GENERAL ENGINEERING CASTINGS UP TO 10 TONS

KIND OF CASTING	% [illegible]	COMPRESSION STRENGTH lbs PER [illegible]				PERM- [illegible]	[illegible]	% [illegible]	AUTHORITY
		GREEN		DRY					
		A.F.A.	B.C.I.R.A.	A.F.A.	B.C.I.R.A.	(DRIED)*	OF SAND		
MEDIUM WEIGHT	(THE APPARENT DENSITY OF TESTS IS 1·65)								
FACING SAND	9·3	8·3	6·4	125·1	112·0	79·0	56·8	4·9	F. HUDSON
BACKING SAND	9·0	6·1	4·5	68·1	34·0	68·3	55·7	4·5	F. HUDSON
HEAVY WEIGHT									
FACING SAND	9·0	9·0	2·8	114·3	25·0	61·5	53·9	4·4	F. HUDSON
BACKING SAND	10·2	5·3	2·5	40·1	12·5	67·5	56·3	4·2	F. HUDSON
AVERAGE FROM	9·0	5·3	2·5	40·1	12·5	61·5			
LIMITS TO	10·2	9·0	6·4	125·1	112·0	79·0			

* DRIED AND HEATED TO 1200°C FOR ½ HOUR

run the plant without any additions whatsoever, and this course was accordingly adopted. At the end of one month the sand was still in satisfactory condition after handling between 400 to 500 tons of light to medium-weight castings. At the end of two months about 1,000 tons of castings had been made, and in the light of present knowledge the sand did not really need any additions so far as its value for safe casting production was concerned; however, at that time the atmosphere in the foundry was highly charged with tension and liable to explode figuratively at any moment, and it was decided that some addition had better be made to the sand to prevent the risk of a sudden increase in defective castings.

The only property of the sand which needed adjustment, according to the routine tests, was the dried strength, which recorded a test figure at the end of this two-month period of 28.4 lbs. per sq. in. compression, using the B.C.I.R.A. form of test-piece rammed by Buchanan's double-compression method. This had to be increased without increasing the green-bond strength, and thus the first problem was born, and overcome by the use of a small addition of liquid wood extract. It is obvious that additions of new sand, or of clay, would have increased the green-bond strength as well as the dried strength, and this was undesirable, as some slight trouble had already been experienced due to the sand lacking that property of "flowability" so essential for rapid production on jolting machines, and which constituted the main percentage of mould output. Much more could be said about our trials and tribulations in these earlier stages of sand control, but in view of other considerations the subsequent developments can probably be more readily seen by a survey of Table IV.

To summarise the question of the necessary additions required to keep green sand in safe working order, one must first have absolute faith in the results shown by the control equipment, and the required additions can then probably be divided into three groups, as follow:—(1) To increase the green-bond strength, add clay either in the form of one of the colloidal clays on the market such as Bentonite, or alternatively in the form of finely-ground fireclay or new moulding sand; (2) to increase the dried strength use wood extract; and (3) adjust coal dust to suit the sand according to the percentage of gas evolved.

TABLE IV.—*Illustrating Methods of making Green Sand Additions Based on the Results obtained from Daily Control Tests.*

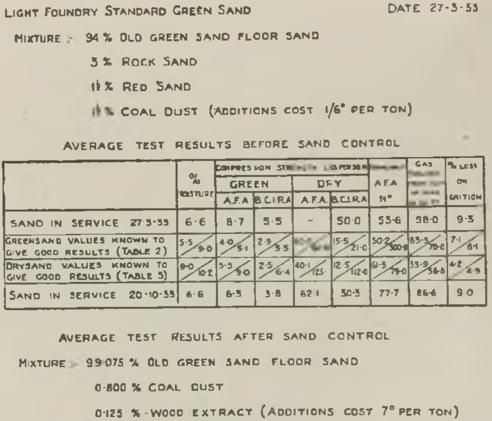
[illegible]	GREEN COMPRESSION lbs per □"		[illegible]	[illegible] lbs per □"	GAS [illegible]	[illegible] IGNITION	REMARKS
	A F A	BCIRA	A F A Nº	BCIRA			
6·56	8·7	5·5	53·6	50·0	98·0	9·3	27/6/33 CONTROL STARTED. SAND TOO STRONG, SO PLANT ALLOWED TO RUN UNTIL TESTS SHOWED NEED OF ADDITIONS.
6·0	7·3	5·0	72·2	36·4	88·8	7·8	[illegible] DRIED STRENGTH BEGINNING TO DETERIORATE ADDITION OF ¼% WOOD EXTRACT MADE.
5·82	6·5	4·4	78·4	33·0	64·3	6·72	7/6/33 DRIED STRENGTH REGAINED SO WOOD EXTRACT ADDITION OMITTED. GAS EVOLVED SHOWS NEED OF EXTRA COAL DUST. 0·6% COAL DUST ADDITION MADE.
6·9	6·6	4·0	57·0	28·5	90·9	8·3	22/7/33 COAL DUST ADDITION STOPPED PLANT ALLOWED TO RUN WITHOUT ANY ADDITIONS.
6·58	6·0	3·8	69·3	24·0	79·4	8·4	24/7/33 GREEN AND DRIED STRENGTH BEGINNING TO DETERIORATE SO 0·75 – 1·5% ROCK SAND ADDED AND 0·125 to 0·25% WOOD EXTRACT
6·55	7·0	4·5	95·1	42·4	68·5	7·0	18/8/33 GREEN AND DRIED STRENGTH REGAINED BUT GAS EVOLVED SHOWS NEED OF COAL DUST SO 0·6 ADDITION RECOMMENDED

If sand-control tests are properly applied, and if satisfactory and efficient methods of preparation are available, it should definitely be possible to produce a green sand suitable for the bulk of general grey-iron engineering castings from a mixture containing 99 per cent. of floor sand, and from personal experience of the sand practice of many foundries such a result cannot but be a considerable economic advantage as well as a striking argument for a greater interest in sand control.

It is considered, however, that the success of this result depends to a large degree upon the removal of iron particles from the returned sand, and the fitting of some form of magnetic separator as an integral part of sand-preparation plants is essential.

Before leaving Table IV, it is interesting to note that after five months' service the permeability of the sand has progressively improved. This is partly brought about by the fact that we do not worry about the green sand becoming contaminated with burned oil sand from cores, within reasonable limits, and also due to the fact that the mixing mills are of an efficient design. It would appear that the "silting up" of moulding sand, so far as cast iron is concerned, is largely dependent upon the sand-preparation methods employed and the intelligent use of control tests.

Table V.—*Result of Sand Control on Physical Properties.*



LIGHT FOUNDRY STANDARD GREEN SAND — DATE 27-3-53

MIXTURE :- 94 % OLD GREEN SAND FLOOR SAND
3 % ROCK SAND
1½ % RED SAND
1½ % COAL DUST (ADDITIONS COST 1/6ᵈ PER TON)

AVERAGE TEST RESULTS BEFORE SAND CONTROL

	% MOISTURE	COMPRESSION STRENGTH LBS PER [illegible]				A.F.A. N°	GAS [illegible]	% LOSS ON IGNITION
		GREEN		DRY				
		A.F.A.	B.C.I.R.A.	A.F.A.	B.C.I.R.A.			
SAND IN SERVICE 27-3-53	6·6	8·7	5·5	–	50·0	53·6	98·0	9·3
GREENSAND VALUES KNOWN TO GIVE GOOD RESULTS (TABLE 2)	5·5/9·0	4·0/5·1	2·9/5·5	[illegible]	15·5/21·0	50·2/100·0	83·3/70·0	7·1/8·1
DRYSAND VALUES KNOWN TO GIVE GOOD RESULTS (TABLE 3)	9·0/10·2	3·3/9·0	2·5/6·4	40·1/125·	12·5/112·0	61·3/79·0	33·9/56·8	4·2/4·9
SAND IN SERVICE 20-10-53	6·6	6·5	3·8	62·1	50·3	77·7	86·6	9·0

AVERAGE TEST RESULTS AFTER SAND CONTROL

MIXTURE :- 99·075 % OLD GREEN SAND FLOOR SAND
0·800 % COAL DUST
0·125 % WOOD EXTRACT (ADDITIONS COST 7ᵈ PER TON)

In Table V is appended a comparison of results before and after the installation of sand-control methods. No claim is made to have reached perfection in this direction, but it is thought it will be admitted that by the use of systematic tests it is possible to effect very substantial cost reduction in new sand supplies. For comparison there is included in this Table the sand values already shown as giving good results, and it is interesting to observe that after seven months' service the sand is still much better than it requires to be notwithstanding the economical additions, and this point but gives added emphasis to the need for every foundryman to take a keener interest in the subject which forms the text of this Paper to-night.

In working with such small additions of new materials the problem of making up sand losses is an important one, and it is, no doubt, obvious that this aspect must also be under careful control. Undoubtedly, the first point is to ensure as little sand loss as possible, and much can be done in this direction by the adoption of proper supervisory methods by the foundry staff. With due care sand losses can be kept at a low level, and at certain intervals the loss can be made up by the reclamation of burned core sand. The practice adopted by the author entails the rebonding of this sand with colloidal clay, and a typical mixture giving satisfactory service is as follows:—40 green-sand floor sand; 60 burned core sand; 2 Bentonite; and 1 per cent. coal dust.

Such a mixture will cost around 7s. per ton. The idea of using a certain percentage of floor sand in conjunction with the reclaimed core sand is to reduce the amount of Bentonite required, and so effect rebonding at the lowest possible cost. The use of colloidal clay has many economic advantages in modern methods of sand control, and, if time had permitted, many interesting applications could be discussed. It may be of interest to mention, however, that a recent survey of rebonding clays available to the foundry trade indicate that there are about three types showing promise for service in this direction, and if these be arranged in order of merit, placing Bentonite first with 100 per cent. rebonding efficiency, the comparison is as follows:—Bentonite, 100 per cent.; Colbond, 50 per cent.; certain dry ground fireclays, 20-25 per cent.

Whilst perhaps the greatest value of proper sand control lies in regard to conservation and reclamation, there are many other directions in which systematic tests can benefit the practical worker. A good sand is essential for modern economic production methods in at least two major directions. Firstly, a good sand makes the moulder's work easier and consequently tends to increase output. Secondly, a good sand is essential for good castings.

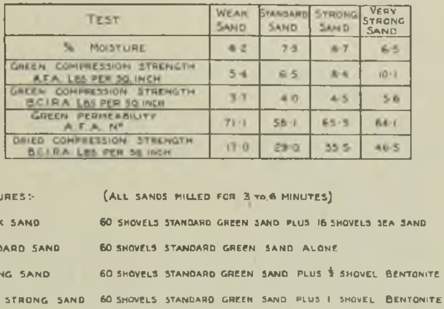
Good Sand Makes the Moulder's Work Easier

If a census be taken of the most widely-used moulding machine, probably it will be found that the " jolter " heads the list, and from the sand point of view it is certainly the most interesting. At a foundry social event an apt conundrum would be something like this:— " Why doesn't the jolter jolt," and the answer might be: " Because the moulder will ram, and the sand won't." No doubt the meaning is obvious, but it is surprising how much auxiliary hand ramming is required to supplement the action of this type of machine using the natural sands of Britain, whilst observations abroad, particularly in the United States, definitely show that production is invariably obtained without this extra ramming. Undoubtedly the reason lies in the physical properties exhibited by the sand and particularly by that property called " flowability."

" Flowability " is an index of the ability of the sand to flow under ramming energy to form a smooth, uniform surface against the pattern. Obviously, if a sand possesses too much green bond the " flowability " will be low, and if such a sand is used on " jarring " machines one is apt to obtain soft patches or voids, unless the hand rammer is brought into play. Conversely, if the sand has too little bond, whilst the ramming may be conducted satisfactorily, it will be probable that bad pattern draws will be experienced, extra gaggers will be required to hold the sand together and probably drop-outs will occur on top parts when turned over for closing.

The suitability of any particular sand for service on jolting machines is primarily dependent upon individual practice, and no definite test limits can be offered, but it may be of interest to outline a typical example of the effects of "flowability" in this direction. A new Herman machine was recently installed in the foundry for the manufacture of valve bodies over a range of sizes and to save cost a standard moulding box was designed to take the necessary range of casting sizes. It will be appreciated that when the smallest size of casting was made the sand "hang" was considerable, and when the top half was turned over for closing, very often partial "drop-outs" occurred. Accordingly, an investigation was conducted in order to determine the most suitable sand for production purposes, and the methods adopted were as follow:—A series of half boxes of the smallest valve body made on the machine were rammed up in four sands having various green-bond strengths, and these were jolted for different times. Hardness tests were then conducted on the mould face by means of Buchanan's Penetrometer and the "hanging" properties of the sand gauged by turning the rammed box parts over and striking

TABLE VI.—*Physical Properties of Sands used for Flowability Tests on Herman Jolting Machine.*



TEST	WEAK SAND	STANDARD SAND	STRONG SAND	VERY STRONG SAND
% MOISTURE	8·2	7·3	6·7	6·5
GREEN COMPRESSION STRENGTH A.F.A. LBS PER SQ. INCH	5·4	6·5	8·4	10·1
GREEN COMPRESSION STRENGTH B.C.I.R.A. LBS PER SQ INCH	3·7	4·0	4·5	5·6
GREEN PERMEABILITY A.F.A. Nº	71·1	58·1	65·5	64·1
DRIED COMPRESSION STRENGTH B.C.I.R.A. LBS PER SQ INCH	17·0	29·0	35·5	46·5

MIXTURES:-	(ALL SANDS MILLED FOR 3 TO 6 MINUTES)
WEAK SAND	60 SHOVELS STANDARD GREEN SAND PLUS 16 SHOVELS SEA SAND
STANDARD SAND	60 SHOVELS STANDARD GREEN SAND ALONE
STRONG SAND	60 SHOVELS STANDARD GREEN SAND PLUS ½ SHOVEL BENTONITE
VERY STRONG SAND	60 SHOVELS STANDARD GREEN SAND PLUS 1 SHOVEL BENTONITE

the box sharply on alternate sides with an iron bar, the number of blows required to cause the sand to drop being accepted as an index in this direction. Table VI illustrates the physical proporties of the sands used, varying in green-bond strength from a weak sand having only 5.4 lbs. per sq. in. compression strength up to a very strong sand having a strength of 10.1 lbs. per sq. in.

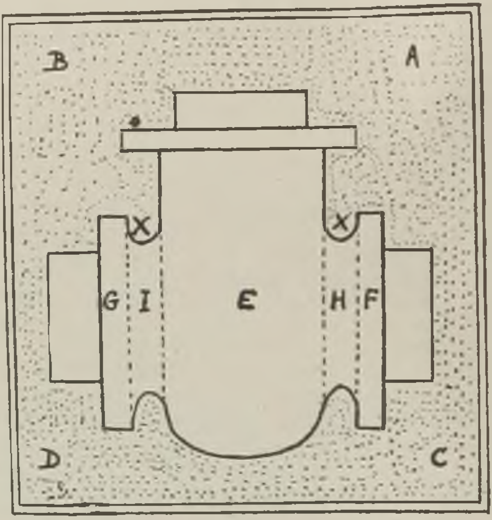


Fig. 8.—Position of Hardness Tests in Experiment in Sand Flowability.

From each of these sand mixtures half-moulds were made, giving the machine 50, 100 and 150 jolts, and hardness tests were then conducted at the positions shown in Fig. 8. In Table VII are tabulated the average hardness values obtained. These are most interesting. Considering the test using weak sand first, it will be noticed that greatest uniformity so far as mould hardness is concerned is obtained after 100 jolts.

If more or less than 100 jolts are given to the mould, this variation is greater than that obtained with 100-jolt period. In the case of the standard sand, greatest uniformity is again obtained after 100 jolts. Furthermore, by the use of the standard sand maximum, hardness values are obtained for any given jolting period, and it will be observed that the hardness of the mould face is greater than when weaker or stronger sands are used. In fact, as the sands become stronger, the hardness of the mould face becomes less, due, in all probability, to the jolt impact not being of sufficient intensity to compact the more strongly bonded sands, and this gives a very definite indication that sands having a greater green-bond strength than the standard sand shown in this table are not likely to give good results so far as uniformity of ramming is concerned.

It is considered that the hardness of the rammed face bears a definite relation to the question of "flowability" and consequent troubles of "bridging," soft spots and distorted castings. From previous observations conducted it was known that the average hardness obtained generally from satisfactory moulds was in the order of 21 m/m., and it should be noted that in these present tests the moulds made from the standard sand after 100 jolts most nearly approximate to this figure, consistent with uniformity over the mould face. Particular note should be taken of the column in Table VII, giving the variation in penetrometer values over the mould face, as this provides an excellent index for sands having "bridging" tendencies, and the higher the variation the greater the tendency for this trouble to occur.

Table VII gives an indication relative to the amount of green bond required from the sand to minimise "dropping." The final conclusions reached by this series of tests indicate that the standard sand having physical properties as shown in Table VI will give the most satisfactory results for moulds made on the Herman machine. A safe limit so far as the green compression strength is concerned would be as follows:—On A.F.A. apparatus, 5.7 to 7.0 lbs. per sq. in. at 7 per cent. moisture; on B.C.I.R.A. apparatus, 4.0 lbs. per sq. in. at 7 per cent. moisture. With sand of this strength it requires 100 jolts to effect uniform compaction. If a weaker sand is used, there will be liability for "drop-outs" to occur, and if the sand is stronger, "bridging" and variation in mould hardness will arise. "Drop-outs" due to weakly-bonded sand can be corrected within limits by a longer jolting time, but there is no correction for "bridging" if the green-bond strength is high.

Table VII.—*Mould Hardness Values obtained from Various Sands after Jolting for Various Purposes.*

SAND USED	Nº OF JOLTS GIVEN	AVERAGE PENETROMETER VALUES IN M/M AT POSITION				VARIATION IN PENETROMETER VALUES OVER MOULD FACE
		ABCD	E.	F.G.	H.I.	
WEAK	50	27	30	22	36	14
	100	24	24	22	28	6
	150	20	23	16	28	12
STANDARD	50	23	26	24	34	11
	100	19	20	17	22	5
	150	18	18	17	22	5
STRONG	50	29	29	27	40	13
	100	24	20	20	29	9
VERY STRONG	50	23	25	24	35	12
	100	23	16	19	30	14

In quoting these tests as an example of the further value of sand tests to the practical worker, it is intended mainly to illustrate test method, and due consideration must be given to one's own individual practice in the acceptance of these results. Moisture control is a very vital factor in its effect on the flowability of moulding sands, and should be carefully controlled.

At the last Annual Conference at Cardiff, in the discussion on the Report of the Sands and Refractories Sub-Committee in reference to test methods for green sand, some mention was made relative to the value of compression tests as an indication of the "lifting" properties of a sand, and here again the question of "flowability" arises.

Mr. J. Hird mentioned a case where a sand giving a higher compression reading on test did not necessarily give a better "lift" in practice. This is not by any means an isolated case, for in conducting the test the method of ramming ensures a satisfactory degree of compaction even from strongly-bonded sands, and the factor of "flowability" is not of great moment. For example, let us assume that the test-piece gives a reading of, say, 10 lbs. per sq. in. compression. In practice, however, particularly in connection with machine moulding, the factor of flowability enters, and, if strongly-bonded sands are employed, exactly the same conditions can arise, as exemplified a few moments ago in connection with the tests on the Herman jolting machine, and if compression tests be trepanned from moulds rammed up in the shop, instead of a figure of 10 lbs. being obtained, probably only 5 lbs. or less will be

TABLE VIII.—*Resistance of Rammed Sand against Dropping in Top Parts.*

SAND USED	Nº OF JOLTS GIVEN	REMARKS AS TO WHETHER MOULD DROPPED ON TURNING BOX OVER	Nº OF BLOWS STRUCK BOX TO CAUSE SAND TO DROP
WEAK	50	FILLETS AT X (SEE FIG Nº 8)	ONE
	100	AS ABOVE	TWO
	150	AS ABOVE	FIVE
STANDARD	50	FILLETS AT X (SEE FIG Nº 8)	THREE
	100	CORNER OF MOULD DROPPED	FIVE
	150	NO DROP	FOUR
STRONG	50	NO DROP	THREE
	100	NO DROP	FOUR
VERY STRONG	50	NO DROP	SIX
	100	NO DROP	NO DROP AFTER SIX BLOWS

NOTE:- AN IRON OR GAGGER IS USUALLY PLACED AT FILLET X BUT IN THESE TESTS THIS WAS OMITTED INTENTIONALLY.

evident. Accordingly, it is wise to consider the influence of " flowability " in this direction, and to allow for it.

Good Sand is Essential for Good Castings

Sand control obviously helps in the prevention of defective work, and one instance has already been given of its value in this direction in connection with the property of " flowability." Of other instances which can be cited from personal experience in green sand during the last few months, one stands out with particular prominence, and that is in connection with that defect known as a blind or dumb scab. This is illustrated in Fig. 9. It is generally believed that the cause of this defect is due to lack of permeability in the sand or contributory factors, such as hard ramming, excessive moisture, etc. In the particular example under consideration our sand tests showed very definitely that these causes were not responsible for the defect, and indicated that the cause of the trouble must be looked for elsewhere.

FIG. 9.—" BLIND " OR " DUMB " SCAB.

In the scientific researches conducted upon refractories it has been found that silica expands upon heating, and as silica constitutes the base of all moulding sands, it is obvious that this expansion is also present in this latter material. The expansion takes place quite suddenly at relatively low temperatures between 500 to 700 deg., and results in a volume change of about 1.0 per cent. It is feasible to suppose that the sudden heating of the mould arising during casting causes this expansion to take place, and in certain instances, dependent on many factors too numerous to mention in this Paper, slight buckling of the sand surface takes place. If due thought be given as to the form the sand buckle is likely to assume, due to these expansion stresses, and reproduce upon the casting surface, one is immediately struck by the marked similarity of this defect with that known as a "blind scab."

Furthermore, it is feasible to conclude that if, at the time when the sand increases in volume, a volume contraction of similar order could be brought about, or provision made for the bond between the grains to become plastic, and so allow the mould surface to yield slightly without buckling, the defect would be prevented or minimised. This line of argument is at present being closely investigated, and it was hoped that the results obtained could have been incorporated in this Paper, but unfortunately they are not yet completed. However, it has definitely been found that the addition of coal dust to green sand has a marked effect in reducing the expansion arising on heating, and it is now standard practice in the author's foundry to add excess coal dust for the prevention of blind or dumb scabs in certain castings. Incidentally, Mr. Ben Hird, who has done such excellent work in investigating the effect of coal dust on green sand, confirms this fact by his own experiences.

Up to this point it has been shown that commercial moulding-sand control has a definite value in the modern foundry in reducing the cost of production along two well-defined lines. Firstly, it effects conservation, reclamation and standardisation of existing sand supplies, and these advantages react to give the second value of increased production of good castings. The third and last advantage which suggests consideration is the value of sand control as applied to practical research and consequent future progression, and no better example can be taken than the production of a sand equally suitable for green- or dry-sand moulding purposes, and for want of a better term this can be called "green-dry-sand."

"Green-Dry-Sand"

The question of green sand *versus* dry sand is one of keen controversy between practical workers, and the result of any discussion on this matter can extend indefinitely. The reason why this state of affairs exists is probably due to the fact that in the past knowledge of the moulding sands used for the production of castings has been most vague, and any real progression in this direction must arise through the more extended application of sand tests.

The average green sand in use in British foundries to-day is far from being foolproof, and its safe application to the larger casting sizes in the past has depended undoubtedly upon the skill of the moulder making the casting. Unfortunately, as pointed out at the beginning of this Paper, modern mass-production methods do not lead to the preservation of the highly-skilled green-sand moulder, and this reaction is evident to-day by the fact that one sees fewer and fewer of the larger castings being made by this method. From the economic viewpoint the extended use of green-sand moulding has much to recommend its more widespread adoption to larger castings, and it is felt that if foundry executives had more confidence in green sand this would to a large extent make up for any effect modern conditions have played upon the work of our craftsmen. Obviously, this confidence can only be obtained by coming into closer contact with green sand and getting to know each one of its characteristics better, and these can only be shown by the use of sand-control tests.

In the author's works this problem of the production of a single sand for both green- and dry-sand moulding purposes has received considerable attention, and is considered a feasible solution to the economic production of the larger casting sizes. After all, what constitutes the difference between green sand and dry sand? A superficial analysis of this question tends to show many differences. For example, the average dry-sand mixture to-day differs from green sand inasmuch as it contains more moisture as moulded, it has a greater green-bond strength, it has a greater dried strength. It usually evolves less gas on casting, due to the absence of coal dust, but invariably is not so permeable as green sand. If these points be carefully sifted, it will be found that the only real difference so far as the practical application of the two sands are concerned hinges on the question of greater dried strength. Give green sand the dried strength of its competitor, and there will be a far better medium for the production of castings, for even if one is still dubious about making large castings from it in the green

TABLE IX.—*Showing the Development of Green Dry Sand as a Moulding Material.*

TEST	OLD GREENSAND		CONTROLLED NEW STANDARD GREEN-DRY SAND N°1	OLD DRYSAND		CONTROLLED NEW STANDARD GREEN-DRY SAND N°2
	FACING	BACKING		FACING	BACKING	
% MOISTURE	7·0	7·0	6·65	9·5	9·0	7·5
GREEN COMPRESSION A.F.A. LBS PER SQ. INCH	4·6	5·0	6·3	8·5	6·1	4·4
GREEN COMPRESSION B.C.I.R.A. LBS PER SQ. INCH	3·0	3·5	3·9	6·4	4·5	3·25
GREEN PERMEABILITY A.F.A. N°	49·1	43·4	80·5	53·0	-	119·0
DRIED COMPRESSION A.F.A. LBS PER SQ. INCH	60·8	48·7	65·6	125·1	68·1	147·2
DRIED COMPRESSION B.C.I.R.A. LBS PER SQ. INCH	21·0	15·5	25·8	112·0	34·0	149·0
DRIED TRANSVERSE LBS PER SQ. IN BROKEN OVER 4" CENTRES	-	-	-	7·02	-	7·5
DRIED PERMEABILITY A.F.A. N°	-	-	-	79·0	68·3	130·0
APPROXIMATE MIXTURE	51·1% OLD 33·1% NEW [illegible] [illegible] MILLED	OLD SAND PLUS NEW [illegible] [illegible] [illegible]	[illegible] 07% OLD 0·8% COAL DUST [illegible] MILLED	55·0% OLD [illegible] MILLED	OLD SAND ONLY [illegible]	96% OLD [illegible] PLUS 2% [illegible] MILLED
COST PER TON	9/2"	?	7"	6/3"	-	3/5"

NOTE:- GREEN DRY SAND N°1 IS JUST ABOUT AS STRONG AS OLD DRY SAND BACKING SAND AND CAN CONSEQUENTLY BE USED WITH N°2 SAND AS FACING TO REPLACE DRY SAND MIXTURES.

state, one can dry the moulds more rapidly, as it contains 50 per cent. less moisture. Such sand does not crack during drying so much as dry sand, and lends itself particularly to the production of skin-dried moulds. Less power is also required for ramming.

The easiest way to increase the dried strength of green sand is by the addition of wood extract, and the effect of this from the dry-sand view is shown in Table IX. This table gives a comparison of the average properties of green and dry sand as used in the foundries of Messrs. Glenfield & Kennedy, Limited, before the installation of commercial control methods, against that obtained to-day using our standard green-dry sand. It will be observed that the controlled sand is vastly superior to old mixtures, and it may be of interest to mention that during the summer months in some instances castings normally made in dry sand were moulded from the standard green-dry sand containing 1 to 2 per cent. wood extract, air dried for a few hours by exposure to the foundry atmosphere and cast the same day with complete success.

Since the installation of sand control, the main benefits noted are:—(1) Reduction in cost of new sand; (2) increased production of finished moulds; and (3) reduction of defective work; and these alone have afforded excellent savings to the firm and paid an excellent interest on the expense incurred by the installation of the new plant and control methods.

In conclusion, it should be pointed out that it is felt that some of the points mentioned in this Paper have not been so fully outlined as they might have been, but indulgence is asked in this matter, as, no doubt, it will be appreciated that to have corrected this omission, the Paper would have been unduly long. Furthermore, it should also be understood that personal work in this direction has not been long started, and is still yet uncompleted, and this to some extent has prevented more detail being given.

Before closing, the author desires to record his thanks to Mr. H. Gardner and the directors of Messrs. Glenfield & Kennedy, Limited, for their very active co-operation in providing the excellent facilities for sand control in our foundries, and for their permission to pass on some of these results to the industry.

DISCUSSION BY THE LANCASHIRE BRANCH

The discussion was opened by the Branch-President (Mr. A. Phillips), who said that when the Paper was published it would probably be regarded more as a work of reference than merely a Paper. Probably many would desire to receive further information concerning "Bentonite," and to know what was its composition and what it would do. Possibly some of them were fully acquainted with what it was and for what purpose it was intended, but others might not be so fully instructed. Another point of interest was what was the relative cost of Wood Extract? Apparently, these were the two chief items used in regard to the new sand in the foundry. In the Lancashire District the problem was always present to foundrymen in regard to the use of old sand.

Then, there was the question of the resistance of the rammed sand. The lecturer had stated with regard to one of his figures that 100 jolts gave the best results for test purposes. On a practical demonstration for ramming a valve body in a box, and turning the top part over, and taking the number of blows to knock it out with a piece of iron, the figures in the table shown indicated that 150 jolts gave the best results. It would be interesting to learn what number of jolts the lecturer recommended for this casting in order to ensure the best results being achieved in the foundry.

The Question of Scabbed Castings

If one had a series of scab castings and also found the castings were too rough, what method would the lecturer use to produce castings which would not sell unless they had a smooth finish? In regard to the Osborne jolt machine, for green sand the hardness figures were stated to be 4.1 to 4.5. Would the same moisture conditions prevail for jolt and hand-rammed? When an amount of sand was trepanned out, that which was hand-rammed weighed 155 grammes, whilst that from the Osborne jolt rammer weighed only 137 grammes. The table showed a harder surface when using the Osborne jolt machine, and yet there was a less weight with the trepanned section taken out. These two conditions could hardly be reconciled, probably he might have reversed the figures through taking them hurriedly down, due to the short time the slide was on the screen.

Bentonite and Colbond

Mr. Hudson stated that " Bentonite " was a colloidal clay imported principally from U.S.A. and Canada, and was, really, 100 per cent. clay. It was very much like flour, and was supposed to have been formed through extreme volcanic disturbances. It existed in a natural state and merely required grinding. It was somewhat expensive, and cost, approximately, £14 to £20 a ton. Latterly, a substitute for " Bentonite " had been introduced in this country, which was known as " Colbond." It was very similar to " Bentonite " in being 100 per cent. clay, and it was cheaper in price.

Mr. Hudson then referred to the survey of rebonding clays mentioned in his Paper, and said it should be pointed out that the test mixture used was composed of:—77 parts dried sea sand; 20 parts dried green-sand floor sand, and 3 parts rebonding clay under test. This mixture was milled for 5 min. at both 4 and 6 per cent. of moisture, and the test results obtained at these moisture contents showed " Colbond " to be 50 per cent. efficient in comparison to " Bentonite." Furthermore, the moisture content that could be safely used in the working of sand or clay gave one an indication of the likely green and dried-bond strengths available, and it would be found that the more water required the greater the amount of clay grades present. Alternatively, if a sand required less moisture, it definitely indicated a weaker sand. The question of refractoriness and longevity is not vitally important to the grey-iron founder, and these points, in the past, had received greater stress than was necessary.

Wood Extract

Continuing, Mr. Hudson said the price of " Wood Extract " varied according to quantity ordered, but a fair average price was round about £8 to £9 per ton. It was a by-product of the paper industry, and was imported mainly from Canada and Newfoundland, Norway and Sweden.

Dealing with the percentage of defective castings, the laboratory at the Glenfield Works had rather the honour of being blamed for most of the defective castings produced in the shop, and, in fact, the laboratory was responsible to the management for defective castings, because they were directly responsible for the metal and for the moulding sand. The foundry foremen have had to control method, labour, and produce the output. As far as possible all raw materials were under scientific control. Nevertheless, there were still a few jobs which ran out, or were defective, when the moulder forgot to put in the smallest core of the batch. The point has been reached when the further reduction of defective castings entails intensive supervision over that most variable element of all — the human element. The finish of the castings in the foundry at the present day was greatly superior to what it was twelve months previously.

Influence of Jolting on Sands

The point with regard to jolting was rather a hard one to answer, because jolting depended principally upon the type of sand used. The point he had endeavoured to emphasise was that the flowability in a moulding sand determined how many jolts must be given to the sand. If the sand was too strong it did not matter how long the jolt was, as the sand was never properly rammed, although the velocity of the jolt impact might be sufficient to compact it. In the case of a very weak sand, the longer the jolt the harder the mould surface became, and so compacted that probably the metal would not lie on it. To begin with, the sand had to be what was classed as a "satisfactory" sand. It must have just the correct bond and adequate permeability. With such a sand, the jolting period for normal castings from, say, 2 cwts. up to 10 cwts., at any rate, would be round about 88 to 120 jolts, 100 being a very good figure, and usually about 15 per cent. more than what the makers of the machines predicted they could do.

Skin and Permeability

A point had been raised with regard to the relation of surface finish and the prevention of scabs. When a smooth-surfaced casting was desired many problems could be discussed. To begin with, permeability by itself was of no real value, because if there was no gas generated by the mould, permeability did not matter. His own view of producing a smooth-skinned casting free from scabs would hinge particularly on obtaining a correct dried strength. Many green-sand moulds in use at the present day appeared to have a satisfactory green bond—he made the statement advisedly—and yet when the sand was dried the bond disappeared entirely. In his opinion, the dried-strength of a green-sand mould was infinitely more important than the green strength, the latter being only necessary in order to obtain the plasticity for moulding purposes. If the strength deteriorated during pouring, and every green-sand mould was for a few seconds during casting a dry-sand mould, then there would be scabbing. It might be that the sand was deficient in dry strength; on the other hand, it might be that the coal-dust percentage was so excessive that far greater gas was being generated than the natural permeability of the sand would stand.

An attempt had been made, by means of the tables, to give some indication as to the amount of gas present in the mould as well as the permeability. It was not possible to answer the Branch-President's question in a direct way, because there were so many variables to take into account. The only way probably in which a reasonable answer could be given to the question was by examining the foundry practice and probably testing the sand. If Mr. Phillips cared to avail himself of the opportunity, and send him (the lecturer) a sample of the sand, he would be pleased to test it for him. The test could then be compared with the result shown in the table, and it would be possible, perhaps, to indicate what was wrong.

With respect to the Osborne jolt machine and the hardness test, the green-sand values of 4.1 and 4.5 were not the hardness values, but the green-bond values.

Life of Modern Sand Plants

Mr. A. Sutcliffe inquired how long the sand-treating plant would last, and whether blacking was used on the mould. It would be interesting, also, to learn if the lecturer had had any experience with the use of sawdust. Three or four moulders might be engaged on the same class of job, and every one of the castings would be different, although they were all using the same kind of sand. Twenty years ago he had more loam than sand moulders. The plant described would not mix loam or clay. It was necessary for the sand to be uniform in quality. A point upon which he would like to receive information was whether Mr. Hudson had experienced any trouble with the use of water containing acid. He, the speaker, used core sand, which cost 2½d. a cwt., and this was milled in a pug mill carrying treaded and plain rollers. It seemed to him that the plant described by Mr. Hudson would not be suitable for the majority of jobbing shops, although it could be adapted for a textile machine foundry or a light-castings shop. Had Mr. Hudson experienced any trouble with regard to the coal dust carrying a high ash content?

Mr. Hudson said that the plant described in the Paper had now been installed two years, and that his firm had the reputation for making a good engineering job. He appreciated the fact that some foundry plant was not made to last any considerable length of time; therefore they designed the plant for themselves, and then got the equipment people to co-operate and make it for them. There was not a bearing on the plant that was not a roller bearing. In every instance, where sand might be able to get into the bearings, the bearings were protected in order to prevent it doing so. If Mr. Sutcliffe could spare the time to visit the foundry, he would be gladly welcomed, and he would then be able to see for himself that it was a well-designed job.

Mould Surfaces and Casting Finish

Blacking was not used on the mould surfaces except for certain castings which had to have an ornamental finish. Most of the castings were protected from corrosion in some way, such as by the use of Dr. Angus Smith's solution or by dipping them in tar, and it was debatable as to whether a smooth finish was an advantage in this direction.

The bulk of the castings in the dressing shop were, however, comparable with the finish of castings made by 95 per cent. of the jobbing foundries in the country; the only people who could probably excel them being those who made a point of getting an extraordinarily high finish, such as Harpers, of Willenhall, and some of the light-castings people.

At one time sawdust was incorporated in dry-sand mixtures, but they could never ascertain what real advantage there was in doing so. Like other additions, such as horse-dung, etc., they did not appear to affect the permeability of the sand very much.

Coal Dust and High-Ash Content

Coal dust and ash had not proved to be any source of trouble, because the firm had a definite specification for coal dust, and the suppliers had to conform to that specification. New deliveries were analysed in the laboratory, and if the ash content was too high then the suppliers had to take their coal dust back.

Why did Mr. Sutcliffe still adhere to loam moulding? Surely, making a skin-dried mould was cheaper than using loam. His firm were endeavouring to cut out loam work as much as possible. They formerly used loam in the manufacture of hydraulic cylinders and rams, for which there seemed to be now a scarcity of orders. The plant was certainly not designed to mix loam. What was now desirable was to fix a standardised green sand, which with suitable modifications could be used for making castings formerly made of loam.

The modified green sand referred to in the Paper was perfectly satisfactory. Castings had been made with it which were formerly made entirely with the old dry-sand mixture, with excellent results.

Troubles from Polluted Water

Undoubtedly water quality played an important part, particularly in the case of oil-sand cores, but apparently it did not play a very great part in regard to the ordinary sand containing clay bond. When used for mixing oil sand it was important not to use polluted canal water or anything similar to it. In Scotland there was a plentiful supply of clean fresh water, and all the moulding sand used by the firm was tempered with fairly pure water. Therefore, he had not as yet had to overcome any particular problem with regard to the use of polluted water for moulding operations.

He noted that Mr. Sutcliffe's core sand cost 2½d. a cwt., which was 4s. 2d. a ton. His own firm were to-day using core sand which cost 1s. 9d. a ton, so there was a direct saving in that respect. Tests were being undertaken at the present time with regard to the production of a semi-oil sand-core mixture for heavy castings, and it was hoped that the cost would work out at not more than 1s. per ton.

Elimination of Facing Sand and Transport

Mr. H. Sherburn considered that the Paper provided a great fund of information for those foundrymen who had been brought up in what might be termed the school of experience. The problem of sands, and moulding sands particularly, was so complex that it was necessary for the problem to be dealt with by technically-trained people as well as the practical men. It was obvious that all through the Paper the practical side of the question had not been overlooked, and doubtless the practical foundrymen with whom Mr. Hudson was associated had rendered considerable assistance.

One thing he would like to have heard something about was in regard to the cutting action of the flowing metal, particularly in the vicinity of the runners. This was a matter of great importance. Another point was, of course, that the process described by the lecturer dealt with the whole of the sand operated in the foundry. He was not dealing with a facing sand, as such, which was obviously the common practice, and the one most commonly followed at present in the absence of general mechanisation. This, in itself, created limitations, while it possibly had certain advantages.

It would be of interest to know if Mr. Hudson had considered the question of the fusibility of the different sands, which was, again, a matter of primary importance. Certain new sands had been tested recently, and it was surprising to note the difference in the fusibility of the common sands commonly in use in the Lancashire district.

Another point of moment, as far as he (the speaker) could understand, was that the use of new sand in Messers. Glenfield & Kennedy's foundry must be almost a negligible quantity. This suggested, of course, that the problem of clearing out old sand, and that of bringing new sand into the works, had been largely eliminated, and hence one of the problems of the foundry as to the movement of materials had been largely solved.

Cutting Action of Metal on Sand

Mr. Hudson replied that a little trouble had been experienced at one time with regard to the cutting action of the flowing metal. The trouble took the form of the bottom of the Runner gate washing into the casting. This was found to be entirely due to the excessive use of the swab. Most of the firm's castings were made in half-boxes, and the runner gate was usually mounted on the pattern plate. In drawing this gate pattern the workmen were apt to use a heavy swab containing a great deal of moisture, and the extra moisture naturally weakened the sand. In many cases trouble was experienced at the gates from this cause. By omitting to use the swabs on the gate pattern the cutting ceased, owing to the increased strength of the sand at that point.

The sand referred to in the Paper was regarded as being quite equal to facing sand. There were two foundries in the works—one a light foundry, handling the bulk of the production, and the other a heavy foundry, making jobs of anything from 2 tons to 60 tons in weight. The heavy foundry handled special work, and until very recently did not use the same type of sand as was used in the light foundry, namely, a cheaper sand. The cost of the facing sand used in the heavy foundry worked out at 9s. a ton. It was decided to use the light foundry mass-production sand as a facing sand in its stead. This was done within the last month or so in regard to some very heavy sluice gates, and the castings came out better than when using facing sand.

The Old and the New

The method of preparing this facing sand was that the sand was mixed on the foundry floor by the moulders and then put through an aerating machine. It was not milled. It was considered now that the green sand was actually superior to the facing sand, and the bond was greater and the permeability was better. The foreman in charge of the heavy shop was very adverse to trying it; he could not see how it could possibly be better. He now admitted it was far better than the old facing mixture.

In regard to refractoriness, or fusibility, sands varied considerably. When carbon was added to sand its refractoriness was increased. Carbon could be added in the form of coal dust, as wood extract, core oil, or as heavy mineral oil. The refractoriness was then increased enormously. Erith loam was a sand with a low index of refractoriness, and at temperatures below that of cast iron it vitrifies and tends to slag. By adding 5 per cent. of carbon in the form of coal dust to the Erith sand it will neither glaze nor melt. This was a very important point in the effect of carbon in increasing the refractoriness of a sand, and was one of the main benefits of coal dust.

The refractoriness of new sands varied, but his line of thought at present was not to use new sand! in fact, his ambition was to produce high-quality castings from scrap alone, using no sand and having no defective castings.

In further reply to the remarks of the President, he then answered, with the aid of figures on the blackboard, Mr. Phillips' question with regard to the surface hardness and the jolt test.

DISCUSSION BY THE LONDON BRANCH

The Branch-President (Mr. C. H. Kain) commented that the Paper contained a great deal of information which would make the old school of foundrymen turn in their graves, and he was certain that very few present-day foundrymen were using 99 per cent. of old sand in their facing mixtures.

The Hon. J. M. W. North said he understood that 99 per cent. of the old moulding sand was used again, so that the new additions amounted to only 1 per cent. Considerably more than 1 per cent. of moulding sand must go out of the shop on the castings, however; this was made up from the old core sand, and he asked what percentage of old core sand was added to the shop sand to maintain the constant quality of old sand in the system.

Referring to the cooling drum, he said there did not appear to be a fan or other equivalent means of cooling the sand, and he wondered what was the length of time during which the sand remained in the drum, and at what temperature it came out.

The Silting-up Problem

Mr. G. E. France said he had listened to the Paper with very mixed feelings. In the first place, he was intensely glad that at last we were getting to know something about sand control, the properties of sands and the manner in which they should be prepared; many foundrymen had been unable to complete the story by reason of lack of data, and it was pleasing to note that the need for proper research had at last been appreciated. But whilst he had been an advocate of reducing very considerably the quantity of new sand used in facing-sand mixtures, of the discontinuance of the use of facing sands as such. and the use of one moulding sand throughout the foundry, it was something of a shock to hear that for two months the author's foundry did not require any new sand. It was interesting to learn that at the end of the period of two months, under the conditions obtaining, the sand was not silting up; that experience was so unusual that Mr. France asked if the author had any confirmatory data from sources other than his own experiments. It was generally accepted that moulding sand did silt up, and he supposed the author would say that the silting up was due to the addition of the new sand itself.

The author's insistence upon the absolute necessity for magnetic separation was particularly pleasing. Although the cost of the installation was somewhat high, once the plant was installed the cost of magnetic separation was negligible—and it was a definite essential.

Mr. G. C. Pierce (Past Branch-President) asked what was the wood extract which the author added to the sand mixtures. He was not so alarmed as some people appeared to be with regard to the use of 99 per cent. of old sand. Surely those who were alarmed had lost sight of the fact that the whole of this sand was going through the plant and was being prepared. One would not like to see the moulders ramming up the whole of a mould with facing sand, and it was safe to say that about 10 per cent., or even less, of facing sand was all that was required in a mould. If one considered the figures carefully one would get somewhere near the author's figure of 99 per cent. But the problem of the silt had bothered him and he had wondered what became of it. In most foundries a proportion of the old sand was thrown away, but uses could be found for that sand, and some foundries did use it. But he was not prepared to accept that one could make much use of silt. He liked the idea of carrying on for two months without new sand, and did not wonder that feeling ran rather high; but at least that experience must nullify some of the prejudice.

Moisture Content and Mould Ramming

Mr. W. Tait said the author's reference to the flowability of the sand was particularly interesting, but he had not laid sufficient stress on the importance of moisture. It was stated that in America moulds were jolt rammed much more quickly than were moulds in this country; but it should also be pointed out that the moisture content of the American sand was very much lower than that of the sands referred to in the data sheets exhibited by Mr. Hudson. The sand used in one automobile foundry in this country had a moisture content of about 4 per cent., and it was said that the moulds were rammed much more quickly there than in most foundries in the country. The importance of the clay bond had also to be borne in mind. It was said that with a fireclay if one added four times the amount as compared with Bentonite the product was cheaper. One would have thought, however, that if an increased amount of clay were added it would be necessary to increase the moisture content, and that that would have affected the flowability of the sand. Further, one would imagine that the method of milling the sand would have to be changed. The author was passing the sand through a riddle; one assumed, therefore, that there were no lumps of new sand going into the sand mixer. It had been said that the effect of the mullers in the mill was to distribute the lumps; in large foundries in this country, however, where very large tonnages were used, good results were being obtained, although mullers were not used.

Finally, in a reference to the old pug mill referred to by the author, Mr. Tait asked if tests had been carried out to ascertain whether there was a breaking down of the sand grains in that mill.

Steel Castings Made in Silt

The Branch-President (Mr. C. H. Kain) was not quite sure whether or not the author treated the whole of his sand in the foundry; he had gathered that only a portion of it was treated, and that a considerable proportion went through the knock-out grid and passed straight back to the foundry.

Some really accurate information was required with regard to the silting up of the sand and the breaking down of the sand grains, and he would be glad if the author could give data on those matters. He personally had made steel castings in the silt taken from a dust-separating apparatus in his foundry, where considerable trouble was taken to separate the dust from the steel-foundry sand. He did not consider that the breaking of the sand grains in milling was at all serious. This matter had been raised very often in Papers dealing with oil sands, but in an ordinary mill, with a bed of sand about 1 in. thick under the rollers, it was not important, because the sand would flow.

Commenting on the author's reference to the strength of dried sand, the Branch-President asked what process was used for drying the sand specimens, what temperature was attained, and whether any moisture-exhausting apparatus was fitted to the oven. The estimation of the amount of gas evolved from the sand was most important; he asked, therefore, what apparatus was used for this purpose, how the gas evolution was measured, and whether the apparatus could be used with the other simple apparatus in the ordinary foundry.

AUTHOR'S REPLY

Sand-Cooling Methods

Mr. Hudson, replying to Mr. North, said the amount of sand lost was not great, and in Messrs. Glenfield & Kennedy's foundry 1 per cent. was the outside limit. The amount of sand in circulation was about 200 tons daily; 1 per cent. on that was 2 tons per day, and certainly not more than that amount was lost on the castings going into the dressing shop and from the waste sand being dumped. But he was not prepared to apply the figure of 1 per cent. generally; obviously, the loss would depend to a considerable extent upon the type of casting being made.

The cooling drums were not fitted with fans, but they had internal vanes which regulated the speed at which the sand came down the drums. The sand came down the drums in about 1 to 2 min., roughly, and the temperature of the sand leaving the drums was about 80 deg. Fah., *i.e.*, about blood heat. It then remained in the storage hoppers for about 2 hrs. before it was used, and during that time it cooled off to a temperature at which it could safely be used in the foundry. He had not been troubled in any way by hot sand; the plant produced cool sand without any particular precautions being taken. Here again, of course, the particular circumstances applying to individual foundries must be considered. In certain mass-production plants, where the same sand was being re-used more rapidly and more frequently, the sand would get hotter, and special provision would probably have to be made for cooling it. The production in Messrs. Glenfield & Kennedy's light foundry was roughly 40 tons of castings per day as a maximum, and about 200 tons of sand was in circulation. If, however, 100 tons of castings had to be made per day in 200 tons of sand, undoubtedly that sand would become too hot, unless equipment were installed to cool it.

Replying to Mr. France, he said that new sand additions were made only when the control tests indicated the need for such additions. At the end of the year 1933 he had totalled the number of months in which there had been no additions at all, and the number of months in that year when additions were not made was six. He drew Mr. Pierce's attention also to that point, and to the fact that the 1 per cent. addition covered a period of only six months in the year.

Silt in New Sand

With regard to silting-up, he had not obtained any confirmatory evidence other than that given in the Paper. Certainly when new sand was added the silt increased. Sieve tests, for example, showed definitely that since additions of new sand were stopped the percentage of fines or silt had been markedly reduced.

Wood extract was not very far removed from dirty water, as Mr. Pierce had suggested; it was a waste by-product of the paper industry, and the main sources of supply were Norway, Sweden, Newfoundland and Canada.

Mr. V. C. Faulkner (Past-President of the Institute) said he understood it was sulphite lyes.

Mr. Hudson agreed that it was. It had quite a strong dried bond, and was quite useful for the purpose he had indicated. Indeed, it could be used as a core oil, but its strength was not up to the usual standard for core oil.

Elimination of the Sand Bill

With regard to the control of facing sand, admittedly this sand was being used over and over again, as Mr. Pierce had indicated. But the whole point was that it was under control. In the old days the moulder took whatever facing sand he liked, and in many cases probably moulds were rammed up entirely of facing sand, or far more facing sand was used than was necessary. One great advantage of a system of control such as his was that the moulder could not use facing sand, and had to use what he was given. But the main advantage was the saving in sand costs. One was apt to be misled by the fact that the sand was used over and over again, and if he had used perhaps 98.5 instead of 99 per cent. of old sand the savings which had in fact been effected would probably not have been made. He was quite hopeful that in the very near future about 99.5 per cent. of old sand would be used in Messrs. Glenfield & Kennedy's plant; indeed, they were already using just about that percentage, because for six months of last year there were no new sand additions, and for the other six months 99 per cent. of black sand was used, so that the average for the year was about 99.5 per cent. The whole job had become very much easier for himself than it was at first. Certainly for two months the foundry foreman and the moulders were up in arms; for a time, every bad casting that was made was said to be bad by reason of bad sand, and some time had elapsed before he could convince them that it was not due to the sand at all. Then they began to take a greater interest in the matter, and more recently they did not worry very much about sand.

Commenting upon Mr. Tait's remarks, he emphasised that the sand he had described in the Paper was a natural sand, and a modification of a British sand. The sands of lower moisture content, such as those used in America and in some of the British foundries referred to, were definitely synthetic, and were usually made up from silica grains, re-bonded. They were of different type from that mentioned in the Paper and from that commonly used in this country. For the purposes of the Paper he had thought it wise to stick to the sands of this country, so that the bulk of the founders here could take advantage of the work with which he was connected.

Moisture Content and Scabbing

Admittedly, when the weaker clays were used one had to add larger quantities than was the case with the stronger clays, and the moisture content to obtain a suitable sand must be greater. But one could make of the moisture problem as big a bogey as that of the silt problem, and he was quite confident that the results obtained in Messrs. Glenfield & Kennedy's foundry, using sand containing from 6 to 7 per cent. of moisture, were as good as those obtained by the Americans and by some English automobile firms using sand containing between 4 and 4½ per cent. of moisture. One of the biggest problems on a hot summer day, even in Scotland, was the drying out of the sand, which could cause trouble. He was always averse to departing from his own practice because he felt that if the percentage of moisture were higher the sand did not dry out so readily as it did if the percentage were lower. Furthermore, the work on the expansion of sands had shown that in a green sand with a high moisture content the shrinkage arising from the removal of the water tended to balance the expansion of the sand grains, with the result that there was less scabbing. He was quite convinced that the ordinary theories put forward by the practical men as to the causes of scabbed castings did not meet the bill fully. Castings were sometimes scabbed when the sand was right and when the moulder had said that the ramming was right; there was something else we were trying to find out in order to get the whole story.

Insufficient Milling and Blown Castings

With regard to milling, Mr. Hudson pointed out that the mesh of the rotating screen was about ¼ in. The sand, when it left the screen, was not suitable for moulding, and it had to be milled. With all due respect to the paddle mixer, he still considered that it did not mix so efficiently as did a properly-designed mill, nor did it mix so quickly. At Messrs. Glenfield & Kennedy's foundry it was necessary to mix roughly 1 per cent. of new material in three minutes and to distribute the water uniformly, and he doubted that a paddle mixer would do the work in that time. Recently there had been a breakdown on one mill, so that it was out of action, as the result of inexperience; thus, the milling time had to be cut to about 1½ min., and there had been some trouble due to blown castings. It was found that the moisture was not properly distributed throughout the sand, some small patches containing 9 per cent. and others only about 3½ per cent. One could not distinguish them by the hand, but when the metal came into contact with a slightly wetter spot about the size of a shilling, a blow-hole was formed. One could not improve upon a properly-designed mill for efficient and rapid mixing. At the same time, if some simpler form of machine could be devised, it would be of advantage, because there was a good deal of wear on a mill. He made a point of fitting new scraper blades every week, and the scraper clearances were adjusted every morning, with a view to keeping the machines in good running order, but, even so, the wear was greater than one would desire.

Breaking Sand Grains in the Mill

At one time he had stated dogmatically that a mill did break down the sand grains, but he had since become less dogmatic about it, because, in the first place, a lot depended on the mill, and, secondly, it was a very moot point whether the grains did break down in a modern mill. The old mill he had described certainly would crush the sand grains, because in Scotland there was a habit of making loam from gravel. Coarse gravel river-bottom sand was crushed for about 40 minutes, and three or four shovels of ordinary boulder clay was added, and a beautiful loam was produced in that way. Very good castings, weighing up to about 50 tons, were made in it; it was most impermeable, like mud.

In reply to the Branch-President, Mr. Hudson said that all the sand at Messrs. Glenfield & Kennedy's foundry was treated. The dry-sand specimens were dried in an electric oven, having a natural-draft chimney to remove as far as possible all products from the drying. The temperature was controlled at 105 deg. C., and the drying was effected in about one hour. The oven was quite simple, and was made at the foundry from a couple of radiator elements, but it worked efficiently.

Finally, he said that in this Paper he had purposely refrained from any reference to the estimation of the gas evolved, because he had dealt with it previously. In a Paper on " Light Castings Production," which he had read in Scotland, he had described fully the two types of apparatus commonly used, and he referred the Branch-President to that Paper.

Mr. W. T. Griffiths, seconding the vote of thanks, said he was impressed with what Mr. Hudson had done that evening towards obtaining a greater " flowability " of information concerning sands. During the last ten years or more there had been a great deal of theoretical investigation of sand problems, and a whole mass of information had been collected as to what sands should or should not be; it was only by finding out what was happening in the foundries, however, that we should be able to use this valuable information. Mr. Hudson had indicated how he was applying that information by instituting proper control, and how it was even possible to make some profit out of sand control. Further, he was proving or disproving the various theories put forward, and when others followed the example of Messrs. Glenfield & Kennedy and installed accurate methods of control, the information obtained by theoretical investigations could be sifted and we should be in a better position to take advantage of it.

The vote of thanks to Mr. Hudson was accorded with acclamation.

What is Silt?

Mr. J. W. Gardom (Past Branch-President), proposing a vote of thanks to Mr. Hudson for his Paper, said he had wished that the questions of the fineness of sand and the moisture content had been dealt with more fully. Despite Mr. Hudson's final remarks, one felt that in future he would say that the most important thing was grain size. Further, it was essential, in order to ensure an even flow of sand in any mechanical system, to limit the water content and to increase the bond. The silt problem always worried foundrymen when putting in mechanical plant. The main problem was to determine what was silt. It was not necessarily fine sand; it might consist of small pieces of iron, and Mr. Hudson had definitely advocated the removal of this by magnetic separator. Again, Mr. Gardom suggested that Mr. Hudson was quite wrong in his references to the paddle mixer, and that if he had to mix 75 tons of sand per hour, the capital cost of the plant advocated in the Paper would be enormous. Finally, he suggested that most of the troubles experienced with sand used in the various types of ramming machines might be due to the percentage of air in the sand being wrong Some foundries, he believed, had already found that they must definitely aerate the sand differently for the different types of machine.

Mr. Hudson, responding, said the main difficulty so far was that there were far too few carrying on the work in the foundries. If more foundrymen and foundry executives would take up the practical study of sands we should arrive at some agreement with regard to details, such as those mentioned by Mr. Gardom, much more easily. The aim of Papers he had written was largely to interest the foundrymen in sand. If he succeeded in that he could deal more deeply with the science of sand testing; for the time being he had had to shelve these deeper studies because if he talked about them at this stage many people would not be able to appreciate what he was talking about. Moisture content and grain size were very important factors, and a considerable degree of agreement would be achieved in regard to these matters when there were a few more workers in the field. So far he did not believe there had been published in this country a Paper, dealing with sand, by a man who was directly in contact with the newer synthetic sands. His own experience of synthetic sands was more or less limited to what he had learned in America, and it would be of very great advantage to have a Paper on synthetic sands, so that foundrymen could compare notes and see how far agreement could be achieved. He suggested that on the Institute's Sand and Refractories Sub-Committee there should be someone connected directly with that part of the industry.

When he had first suggested the use of less new sand in the foundry he was told that his ideas would not work. He had decided to take nothing for granted and to work only on the facts discovered, and as a result very much greater advance had been made than was made formerly. He had not attached much value to the old ideas of the foundrymen (which in many cases were rather " fancy ") unless they were proved to be facts, and in the last year he had done more than during the nine years preceding it.

Sheffield Branch

ALLOYS IN THE IRON FOUNDRY

By J. Roxburgh (Member)

Since the days of the introduction of that misnomer "semi-steel," practically the first definite attempt to improve the properties of cast iron, efforts have been continuously devoted to that end, resulting in the development of alloy cast iron, a definite advancement and one still pregnant with distinct possibilities for the wider application of cast iron.

Undoubtedly, a great deal of literature in this connection has been published, and many results of research work carried out by investigators, both at home and abroad, have been made available to the industry; yet, very often, the practical details of the foundry practice and conditions involved have not been given the attention they rightly deserve.

It is granted that, generally speaking, it is difficult to specify an analysis for a casting to be used for a definite purpose under known conditions, but, having settled that important issue, it is entirely another matter to produce such a casting, sound, free from warp, of the right dimensions and of correct alloy content and analysis.

Sometimes there is a prevalent tendency to believe that alloys are a cure for all ills, but, personally, where possible, the author endeavours to get the most out of ordinary irons and only resorts to the use of alloys where special circumstances demand it. When all is said and done alloy irons are more expensive, and it has been found, in some cases, that a mixture of specially-selected irons and scrap has given results comparable, in so far as tensile, transverse and Brinell figures are concerned. Again, although it might disturb the scientist, the author has actually made castings to resist abrasion from a mixture of steel scrap and "burnt" iron, which, it will be agreed, is a very cheap mixture indeed. This particular instance is cited with the object of advising founders to go as far as they can with ordinary irons before incurring the expense of alloy irons. Perhaps, too, the founder might have been able to correct some fault in a certain casting by the use of alloys, but that is not to say that, if he had had the necessary fundamental knowledge, he could not have achieved the same result in some other way. It should not be thought, however, that any attempt is being made to decry the use of alloys. Far from it! There is a definite place for them in the foundry industry.

It is of paramount importance, at this stage, to emphasise the fact that it is essential for the producer to be cognisant of all the details regarding the conditions of service of a casting before any attempt is made to specify a suitable analysis or mixture. With this end in view, it is really unnecessary to mention that the closest co-operation should be maintained between customer and supplier, especially in the initial stages.

Heat-Resisting Irons

In this connection, take, for instance, the heat-resisting irons. The working temperature should be stated, whether maintained at this temperature for short periods or continuously, the atmosphere whether oxidising or reducing or whether gas-laden containing sulphur or its compounds, or whether the casting is subject to any corrosive action due to acids or liquors simultaneously. At the same time, the strength properties at normal and elevated temperatures must be given consideration, as it is known that some good heat-resisting irons lack strength, and so other types having the necessary strength must be used.

It is generally assumed that irons containing low total carbon, under most conditions, are better for heat resisting, as the graphite is in a finer form, thereby eliminating the channels, which are present in irons with large graphite flakes, along which oxidation can take place. On the other hand, however, sight must not be lost of those castings which are liable to oxidation, growth and subsequent cracking due to the drastic treatment to which they are subjected, *e.g.*, ingot moulds, which, in the majority of cases, are made with hematite containing high total carbon, low combined carbon

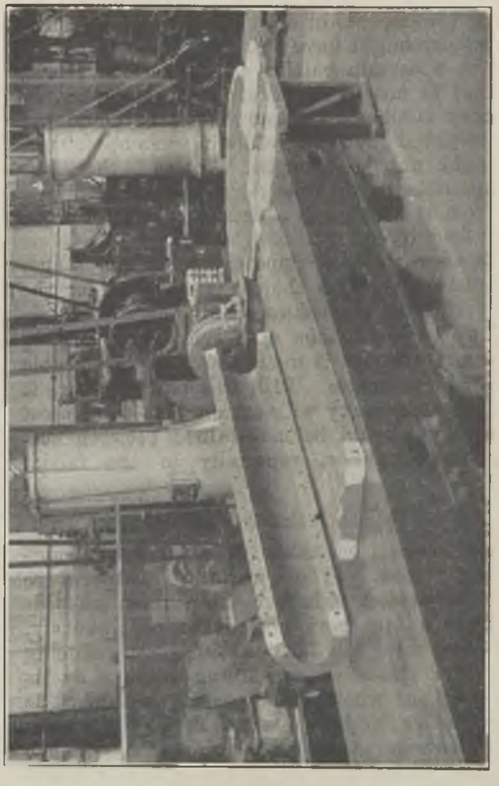


Fig. 1.—Chrome Heat-Resisting Castings to Withstand 650 deg. C., shown Machined.

and large graphite flakes. The elevated temperature of the surfaces in contact with the steel, the expansion and contraction of the mould, demand that the casting should possess, for want of a better term, that elasticity to take care of the strains. It will have been noticed that the surface of the mould after a number of casts begins to show that "crocodile" appearance. It is postulated that, with a mould containing low total carbon, it would fail prematurely due to cracking. The author once made an ingot mould, for experiment, from the air furnace with a hematite base, the resultant total carbon being 3 per cent., and found that, after only two or three casts, it was of no further use due to cracking.

Again, the author experimented on somewhat similar lines, only this time with a semi-steel mixture from the cupola, with a 12-in. dia. chill, 6 in. thick for a chilled roll, and found that after five casts, to be precise, that it had cracked beyond further utility. Sometimes, with preconceived ideas, founders are liable to a rude awakening.

The conditions of service, too, are important with regard to the wear- and abrasion-resisting castings, and often it is a question of obtaining a higher hardness value and uniformity of structure to obtain an enhanced life. Sometimes the author has found that, having prepared an iron solely to resist abrasion, only after actual service has it been discovered that corrosion also is taking place due to the presence of some liquor, and so an alteration had to be made in subsequent castings in an endeavour to counteract this.

Therefore, although perhaps it may seem unnecessary to stress the point, it is obvious that the producer should be in possession of all the facts relating to the service of the casting, before ever attempting to manufacture, or even indicate, the most suitable metal.

Having decided that for these special purposes the casting should contain a certain percentage of alloy or alloys, inquiry is made as to the form in which the various alloys are available to the foundry and as to the various methods of addition. It is well known that the alloy can be supplied as a ferro-alloy, as pure ingot, as shot or in powder form or briquettes. On the other hand, special synthetic pig-irons, to specification, can be purchased from reputable firms willing to guarantee the analysis. Knowing that, in some cases, the alloys can be obtained in any of the above forms, it is often perplexing, without previous experience, to know whether it is wisest to make ladle additions in certain cases or to add direct to the furnace available or to make use of the special pig-iron previously mentioned. Naturally, the melting point of the alloy, the temperature obtained in the ladle or furnace, the degree of accuracy of control of the metal desired, and, in these days particularly, the comparative extra cost of the alloy addition, by whatever means, are all points to be considered before arriving at any decision.

At this juncture, therefore, it would be advisable to consider the various melting units in general use to-day in conjunction with these alloy additions. The cupola suggests itself for primary consideration as probably it is the most common type of furnace used.

Introduction of Chromium

In connection with the cupola, the introduction of chromium will be considered first. It is known that this element can be added as ferrochrome, containing up to 70 to 80 per cent. Cr as desired, and from carbon-free up to 8 to 10 per cent., and again as chromium briquettes, usually containing little or no carbon. The ferro-alloy is added in lumps and, owing to the high melting point of the alloy, approximately 1,580 deg. C., which is lowered with increasing carbon, it is somewhat difficult to obtain complete liquefaction, which might lead to the occurrence of hard spots in the casting, and there is also to be taken into account the appreciable loss by oxidation. In the usual commercial grades of ferro-chrome, the chromium for the greater part is already present in the carbide form and, consequently, it is difficult to melt, and variable results are liable to be obtained. However, owing to circumstances, the jobbing founder often has to resort to this method for adding chromium, but with good cupola practice and laboratory control it is surprising how satisfactory are the results obtained.

The importance of obtaining hot metal when dealing with alloy metal must be stressed, and generally the author would make sure that the coke bed was well burnt to ensure a hot hearth, and would put extra coke in the separating charges. The resulting hot metal can then the more readily be dealt with, and especially if chill tests are taken, when the metal has to stand at least ¼ hr. and longer if the depth of chill has to be adjusted by the addition of soft metal.

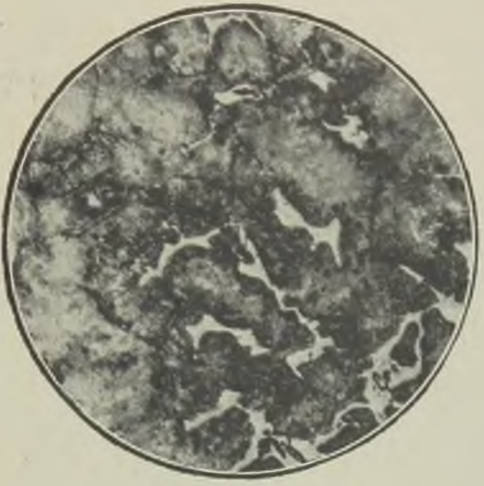


Fig. 2.—Microstructure of Metal for Castings in Fig. 1. × 100.

With chromium briquettes, containing little carbon, liquefaction takes place more readily and rapidly, owing to their lower melting point.

These briquettes yield their chromium to the molten iron without absorption of carbon and with practically no loss. Unfortunately these briquettes are expensive, but recently a firm has commenced making briquettes with 4 to 6 per cent. C at the same price as ferro-chrome. The addition of powdered ferro-chrome to the ladle should not be encouraged, although, probably, some foundries still adhere to this practice when dealing with smaller additions. The author strongly recommends those foundries not having

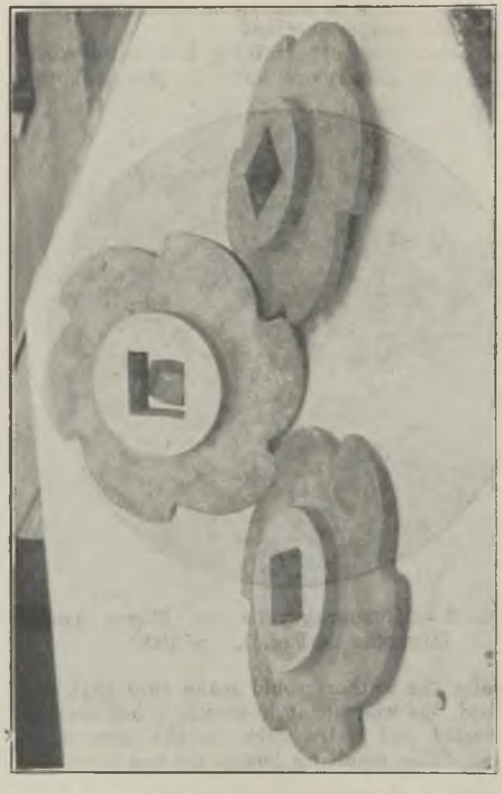


FIG. 3.—CHILLED CHROME COKE SCREEN DISCS.

the services of a chemist or laboratory to use synthetic pig-irons, which probably make the resultant iron dearer, but which, under such circumstances, would prove cheaper in the long run.

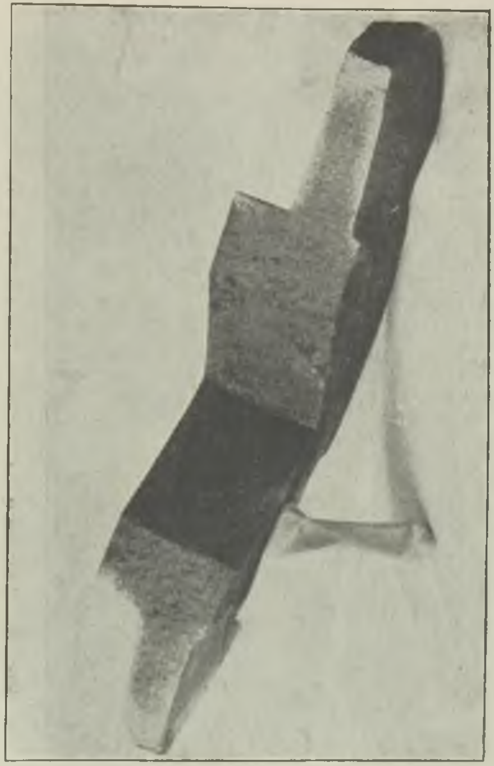


Fig. 4.—Fracture of Broken Chilled Screen Disc.

Addition of Nickel

Regarding nickel, this can be added to the cupola in the form of Ni ingot or sheet and approximately 2½ per cent. loss should be allowed for. In the main, the results obtained with sand castings are fairly reliable, although the high melting point of this element again militates against obtaining complete liquefaction and satisfactory distribution in the metal. Provided that there is sufficient metal to be run into a ladle, the "F" nickel shot can be added down the spout. This shot has a lower melting point, approximately 1,260 deg. C., and contains 92 per cent. Ni and about 6 to 8 per cent. Si. This method has given in practice fairly consistent and satisfactory results. With reference to molybdenum, this is available as ferro-molyb-

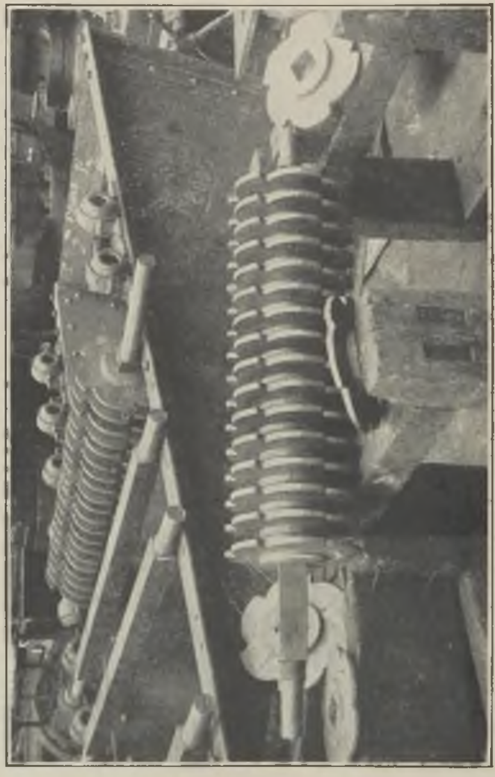


Fig. 5.—Assembly of Chilled Screen Discs on Shaft.

denum, containing 80 per cent. Mo, and no loss should be allowed on melting. The author has found from experience that it is essential to melt iron containing Mo, twice or even three

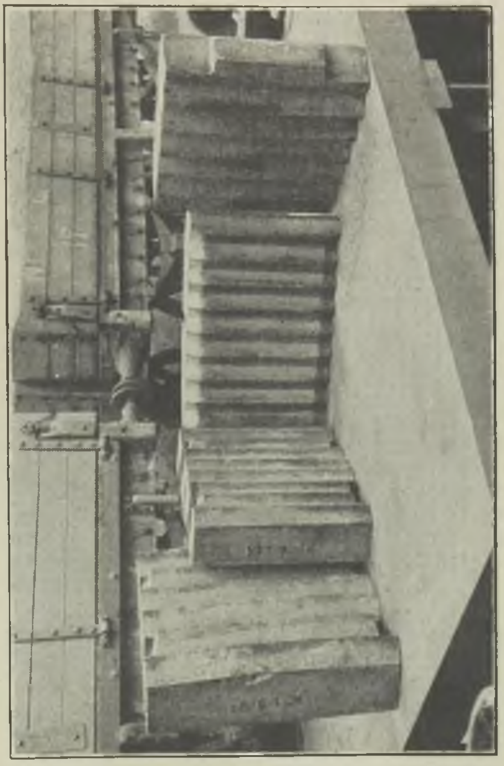


FIG. 6.—CHILLED CRUSHER JAWS IN ALLOY IRON.

times before uniformity of analysis and structure is obtained.

The author strongly advocates that before pouring alloy irons they be boiled up with a "robbler," made by fixing a piece of wood in the end of a long tube, which is simply inserted in the metal, and, by this means, a correct mixing is obtained.

Further complications arise with cupola melting, however, and the most meticulous care is required if good results are desired. Owing to the character of its work, the requirements of alloy iron in a jobbing foundry vary from day to day. Some days it might be only a case of 10 cwts. required, other days 1 or 2 tons, whilst another possibility is that of 3 or 4 tons, or even more, containing varying amounts of alloy or alloys on the same blow. All these possibilities create their own difficulties. In any case, if possible, the special iron should be put on first and charged in excess of requirements to avoid contamination of iron following. It is always possible to pour the extra down and make useful scrap, or arrange for the extra to be mixed with the iron following and put in some suitable casting. Great care, too, must be exercised with the order of charging, and the ferro-alloys should be added with the first charge so that the further charges comprising the mixture will bring down the alloy into the correct ladle. If the price obtained for the castings warrants it, it is much easier, from a control point of view, to buy special pig-irons. With two meltings, also, the metal is rendered more uniform. In this connection, where possible, it pays a founder to consider the manufacture of his own iron by either running down initially from the cupola into pigs, when probably it would be necessary to desulphurise, or, better still, from his air furnace, where no sulphur gain is registered and where he can obtain a low total carbon, to allow for the carbon pick-up on remelting in the cupola.

Air and Rotary Furnaces

In an air furnace, of course, the bath of molten metal is not in contact with the fuel and oxidation of the various elements in the iron takes place. Now, without previous experience, it is a problem to know when to add the alloy or alloys, *i.e.*, at what suitable stage of melting, and so, if we take ferro-chrome, for example, you will find that it is advisable to add this alloy to the bath a few hours before all the metal is actually in a molten condition, the time, of course, depending on the weight of alloy to be added. For instance, 2 cwts. of ferro-chrome should be added to 10 tons of metal 3 hrs. before you consider the metal will be all melted. Even in this type of furnace the temperature obtained is not really sufficiently high to ensure the best melting conditions for the complete liquefaction of the ferro-chrome, but better results are obtained in this respect than in the cupola. Ferro-molybdenum and nickel ingot should be added with the charge, and practically no loss allowed for. Fairly consistent results have been obtained with the various alloys in the air furnace up to percentages round about 1 to 1.5 per cent.

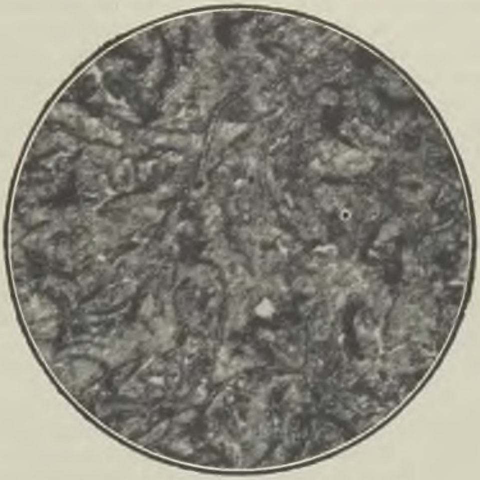


FIG. 7.—MICROSTRUCTURE OF METAL CONTAINING 50 PER CENT. HEMATITE AND ALLOY FREE. × 100.

Of course, with the advent of the rotary furnace, alloys can be dealt with still more successfully, as the temperature obtained is much higher. In the case of chromium, it can be added in the form of lump ferro-chrome, 60 to 70 per cent. Cr and 2 to 4 per cent. C, either with the cold charge or when the charge is just becoming soft. Possibly the latter is the better practice, although no appreciable difference is found in the oxidation, which, in both cases, averages 10 to 15 per cent. With 70 per cent. Cr and 6 to 8 per cent. C, the ferro-chrome could be added even ½ hr. before tapping. With regard to nickel, " F " nickel shot is favoured, put in tins containing, say, about 56 lbs. This may be added 25 minutes before tapping, when the bath is quite hot and fluid. It is a definite advantage to have a good fluid slag so that, from the physical point of view, the alloy has no trouble in getting through. Very special alloy irons, *e.g.*, Ni-Resist or Nimol or Nicrosilal are best melted in crucible furnaces, whilst oil-fired furnaces can be used for irons containing 27/30 per cent. Cr. Melting losses in various types of furnaces are shown in Table I.

Chromium Irons

When alloyed with cast iron, Cr forms hard complex carbides and helps to refine the matrix, and for these reasons renders the iron suitable for abrasion- and heat-resisting castings under certain conditions. Again, in order to resist the action of oxidising gases, containing S compounds, high contents either of Cr, Si or Al must be used in the castings. As the carbides are stable, the addition of even small quantities of Cr makes cast iron resistant to the action of heat, and consequently it retains its special qualities at high temperatures. Familiar applications are firebars, furnace parts, retorts, annealing pots, etc.

Where temperatures are maintained for long periods and growth is likely to occur, an iron with low T.C., low Si, commensurate, of course,

TABLE I.—*Typical Melting Losses and Gains in Various Melting Units.*

	T.C.	Si.	Mn.	S.	Ni.	Cr.	Mo.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Cupola	+ 5–10	− 10–15	− 25	+ 0.030	− 2½	− 25	Nil
Air furnace	− 10–15	− 25	− 25–30	+ 0.010	− 2⅓	− 20	Nil
Sesci rotary	− 5–10	− 10	− 10	+ 0.020	—	− 10–15	Nil

with the section of the casting and the Cr content, will withstand temperatures up to, say, 800 deg. C. Where Cr is alloyed by itself, machining must be considered, *i.e.*, the percentage of Cr and Si, and section of metal, should be correlated. Personal experience is that 3.1/3.2 per cent. T.C., 1.2 per cent. Si can be used, for instance, with 0.7 per cent. Cr maximum on 1-in. section and still permit of machining at 25 ft. per min. with a high-speed tool. It is remarkable the effect that coke exerts on cast iron with regard to abrasion, and so many applications of cast iron are found containing Cr in this direction, *e.g.*, coke-shute plates, liner plates for coke-oven cars, coke-screening castings, etc. Very often in coke-oven plant, too, there is the dual action of abrasion and corrosion from the tarry liquors.

With chilled surfaces Cr increases the shore hardness and therefore, unless cracking occurs prematurely, gives increased service. In the attempt to avoid cracking with chilled surfaces, it is advisable to keep the Cr content at 0.4 per cent. maximum. Cr also tends to prevent the loss of chill from the test-piece to the casting.

Chilled Cr-Alloy Rolls

Chilled Cr-alloy cast-iron rolls have now been some time in fashion, and the most common type is the Cr-Mo, where longer service is claimed and a stronger roll obtained. In the early days variable results were obtained, but some success has undoubtedly accrued since. With regard to grain rolls, containing low T.C. and cast from the air furnace, it has been customary for a long time to introduce 0.5 per cent. Cr, and doubtless the combination of the two, *i.e.*, low T.C. for strength and Cr for wear, gives a splendid roll. Nickel is often alloyed along with Cr in cast iron and gives improved strength, wearing properties and often good heat-resisting properties. The authorities generally recommend the addition of Ni of three times the Cr content. Ni-Cr alloys have a wide application for motor-car components such as cylinders and cylinder heads. Additions of nickel help to improve the quality of cast iron, by refining the grain and making unequal sections more uniform in structure. It eliminates hard spots, thereby assisting ease of machining, and by ensuring a closer-grained iron improves pressure tightness and also increases resistance to wear and temperature. Generally, the silicon is lowered when Ni is added, as Ni acts similarly to Si, only precipitating the graphite in a finer state of division. However, in an atmosphere containing S or its compounds, Ni should be avoided owing to the formation of Ni S at comparatively low temperatures. Additions of Ni up to 5 per cent. give an iron containing a pearlitic matrix, whilst between 5 and 15 per cent. it becomes mainly martensitic and great hardness is obtained. Above 15 per cent. approx. the irons are completely austenitic. The austenitic irons are practically non-magnetic, and with 10 per cent. Ni and 5 per cent. Mn the well-known Nomag is obtained, whilst Ni-Resist and Nicrosilal are other examples of austenitic irons.

Effect of Molybdenum

The addition of Mo to cast iron produces a more uniform distribution of the graphite, with consequent refinement of the structure. It also toughens the matrix and retards grain growth. It is claimed to increase the tensile, transverse and Brinell, yet not enough is known of the effect of this element on cast iron and further developments must be awaited. At any rate it is an expensive element and should only be used in very special cases. Brake drums are made in America with 0.2/0.4 per cent. Mo, whilst certain castings, with which the author has come in contact, have contained as much as 2 per cent. It is said that 0.20 per cent. Mo to an ingot mould increases the life given. Mo is now used for quite a number of chilled rolls, *e.g.*, strip and sheet rolls, and claims are made for increased service, less breakage, less frequent dressing and a better finish on the rolled products. With some rolls Ni, Cr and Mo are alloyed together.

For a long time the effect of manganese on cast iron seems to have fallen into the background, and one is apt to neglect the importance of addition of high Mn from the point of view of heat resisting and hardness. Take, for instance, ingot moulds. Some experiments conducted on small moulds indicated that between 1.5 and 2 per cent. Mn there was an optimum content, which gave the best results in service.

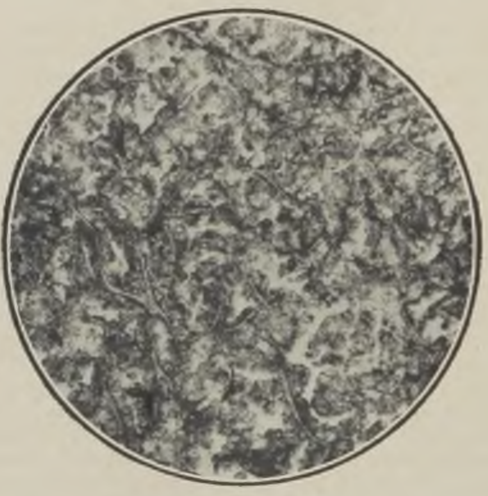


FIG. 8.—MICROSTRUCTURE OF SIMILAR METAL WITH ADDITION OF 0.3 PER CENT. CR AND 1 PER CENT. NI. × 100.

Again, with chilled safe plates, a high T.C., about 3.8 per cent., a Mn, in the region of 1.2 per cent., with low S, effectively resisted the blowpipe and drill of the burglar. Mn, again about 1 per cent., gives the founder the necessary medium whereby with a fairly low T.C. he can obtain Brinell hardnesses of the order of 200 to 220, demanded on slide faces by the machine-tool maker. It will be noticed, too, that Mn is specified about 1 per cent. in most of the well-known special irons, *e.g.*, Ni-

Resist and Nicrosilal. With sugar rolls, where a rough surface is required to grip the sugar canes, 5 to 6 per cent. Mn is incorporated to ensure a coarse grain. However, on the other hand, a high Mn chill, obtained on chilled rolls, does not give as good results as a roll containing low Mn content.

In the control of alloy irons, the chill test is invaluable in the foundry, as the depth of chill thrown on such a test indicates approximately the balance of the various constituents, and it is especially helpful in the case of castings which have to be machined, when, from experience, one can find a definite maximum chill for ease of machining.

It has been the author's endeavour to put forward a practical man's views of alloys in the iron foundry, and although theory and practice must go together to get the best results, he feels that the practical man sometimes is content to miss a splendid opportunity. A practical man with a technical knowledge has always the advantage over the purely scientific individual because, invariably, it is the practical man who must be consulted when some scientific idea is to be put to a practical test. Therefore the author strongly urges the practical man, especially with the facilities that exist to-day for learning, to acquire the technical side of his job and thereby fit himself for the highest position in the foundry, a position which he ought, by virtue of his practical experience, to hold, and if he does not, it is entirely his own fault.

Scottish Branch

GREY-IRON CASTINGS FOR LAUNDRY MACHINERY

By J. Longden (Member)

There is offered to the modern laundryman, by manufacturers of laundry machinery, a wide range of mechanical aids to his work. In consequence, there are few industries which are more highly mechanised than the laundry trade. The machines in use include, in an extensive range of designs and capacities, washing machines, hydro extractors, ironing machines and presses. Designers of these various types of machines are continually introducing improvements of one kind or another, with a view to increasing their capacity or the quality of the work done by them. The modern laundry machine is, therefore, a first-class engineering job, making a serious call upon the capabilities of those engaged in their construction. Upwards of 95 per cent. of the material built up into these machines consists of castings, in cast iron, bronzes, brasses and aluminium. The bulk of these castings, however, up to about 97 per cent., are made in grey cast iron, and it is to the making of a few representative types of these iron castings that attention is here directed.

An ironing machine may weigh anything up to 23 tons, depending upon the number of rollers, which may vary from one (in the "Decoudun" type) to eight or nine. In Fig. 1 is shown a six-roller Tullis ironing machine in service. It consists essentially of strong cast-iron cheeks, upon which are built the steam-heated beds, rollers, gearing and guards, which together do the work of ironing and drying the goods as they are passed through the machine. Fig. 2 shows a Tullis two-roller starchwork ironer.

Its constituent parts are essentially similar to that of the machine shown in Fig. 1, the difference lying mainly in the size and shape of the beds and rollers. The cheek castings present no serious difficulties and call for no comment. The problems associated with the making of cast gears and gear blanks have been discussed by the author in other Papers. The castings which present the greatest difficulty to the foundryman in these machines are the beds. These are

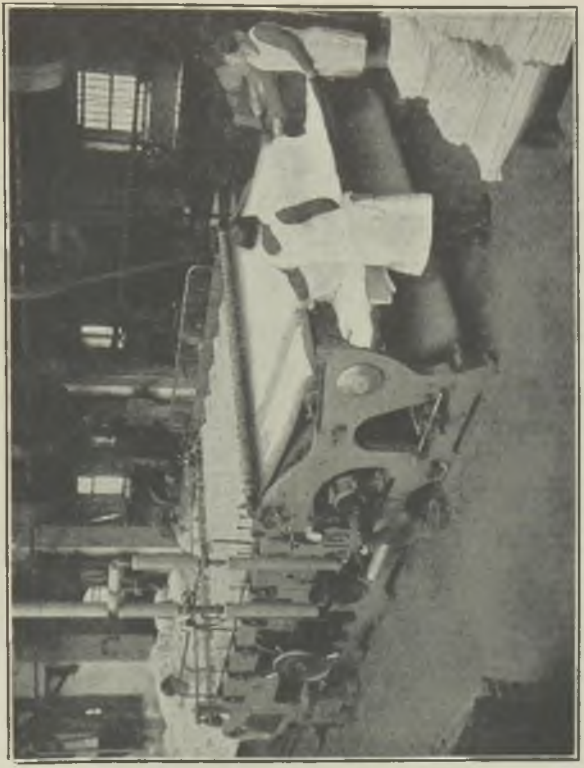


FIG. 1.—TULLIS IRONING MACHINE IN SERVICE.

made in varying sizes and shapes; the one thing common to them all being that each is a steam-tight chest, one (hollow) surface of which must be a flawless polished surface. Fig. 3 shows a 24-in. by 120 in. (Decoudun type) bed, with the polished, working face down. This bed will be used here to illustrate the general problem. Fig. 4 shows a cross-section of the bed, and a longitudinal section (smaller scale). The casting as it leaves the foundry weighs nearly 33 cwts.

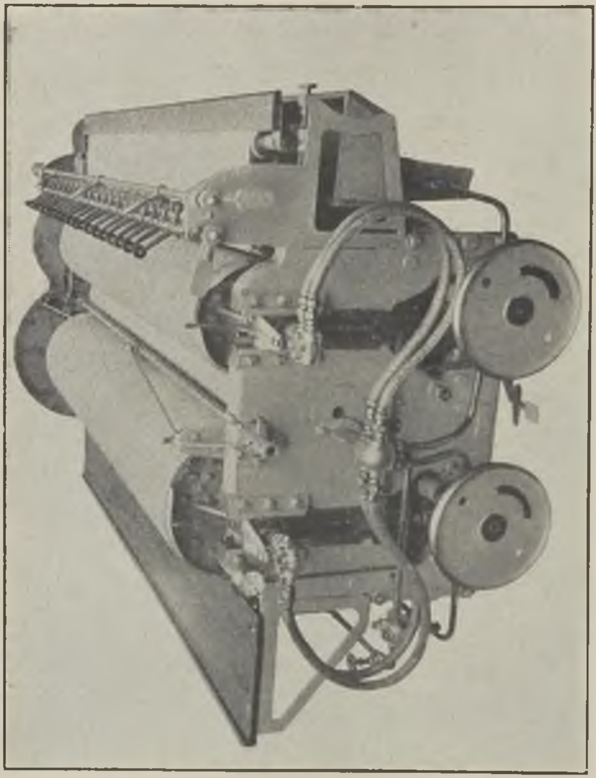


Fig. 2.—Tullis Starchwork Ironing Machine.

The operating surface of this ironer bed has a machined and highly-polished surface of nearly 32 sq. ft., which is cast down. Though the working steam pressure is only in the region of 100 lbs. per sq. in., these castings must be classed as high-duty castings. They are expected to give satisfactory service for a period of upwards of 20 years. This means that they must not distort or lose much of their mechanical strength in service. Further, these castings are subjected to repeated heatings to temperatures approaching 200 deg. C. each working day, and cooling during each night. Every article passed through the machine abstracts heat from the operating face of the casting locally. It has been estimated that some 30 per cent. of the weight of the articles, prior to passing under the rollers, is water. The sudden and repeated local application of wet cloth on the surface of the bed sets up continual stresses and strains in the casting, owing to varying contractions and expansions.

FIG. 3.—A 24 IN. × 120 IN. DECOUDUN BED.

A metal suitable for this work must have certain definite qualities. It must be of high tensile strength, highly rigid and yet capable of "breathing" without fracture. It must show the minimum growth of graphite (consequent upon the breaking-down of combined carbon) on long-continued heating and cooling to and from 200 deg. C. over long periods of time; for a reduction in the proportion of combined carbon in a casting results in a serious reduction in mechanical strength, and also in growth or distortion.

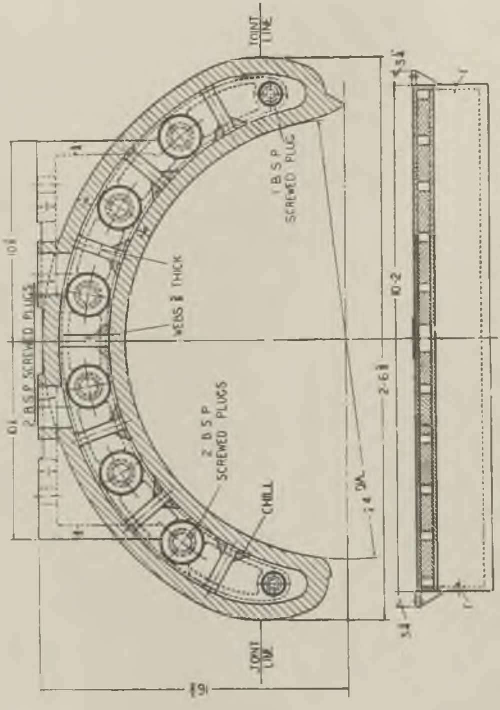


Fig. 4.—Cross Section of Decoudun-Type Bed weighing 33 cwts.

A good deal of work has been done upon this subject during the last 25 years by various investigators, but probably the most helpful in this particular connection has been that of Campion and Donaldson. In a Paper* read to the Lancashire Branch of the Institute in 1926,

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* Proceedings, I.B.F., Vol. xx, 1926-7, p. 513.

Dr. Donaldson gave the results of a very comprehensive series of experiments, and he arrived at conclusions which confirm and simplify the results of other investigators. He showed that decomposition of carbide in grey iron takes place at temperatures as low as 200 deg. C. (it certainly takes place at even lower temperatures), that the extent of the decomposition depends upon the amount of the silicon content, being more pronounced the greater the quantity, and that it also depends upon the temperature and duration of the heat-treatment. He further found that there exists a critical condition at round about 1 per cent. silicon, at which carbide decomposition is at a minimum. Any higher silicon proportion results in a more rapid decomposition. Dr. Donaldson's conclusions considerably narrow the search for a suitable grey iron for the purposes here under consideration. Irons of high silicon content are clearly quite unsuitable, even when, as in the case of the Thyssen Emmel iron, it is associated with low total-carbon. Irons of this order have a total carbon content of from 2.4 to 2.8 per cent. together with a silicon content of 2 or more per cent. In the course of the discussion following the reading of the Paper referred to above, Dr. Donaldson pointed out that he had carried out a test with an iron containing 1.78 per cent. silicon and 2.75 total carbon, and that after 200 hrs.' treatment at 550 deg. C. the carbide decomposed to the extent of 48 per cent.

In some results published by Campion and Donaldson in 1922,* an iron which had been heat-treated, containing a total carbon of 2.8, gave no more resistance to growth than irons with 3.3 per cent. The reasonable conclusion is that irons with high silicon contents, even when associated with low total carbon, must rapidly lose some of their initial strength on repeated heating and cooling, and that the rate of that loss of strength is very much greater than in the case of irons having low silicon

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* Proceedings, I.B.F., Vol. xv, 1921-22, p. 211.

content. With the loss of strength due to carbide decomposition there is always associated growth, and where that growth is uneven there follows distortion. Though the carbide decomposition in an ironer bed must be very slow, it should be remembered that, in five years' time, it will have been heated for 8 hrs. each day and cooled during the night some 1,400 times. In this connection the microphotograph shown at Fig. 5 has interest It was taken from a piece of an old ironer bed which had been in service for 28 years. From its composition, it probably had an original carbide content of about 0.5 per cent., together with a silicon content of 2.0 per cent. As will be seen, the combined carbon has almost entirely broken down, the structure consisting almost entirely of ferrite, temper carbon and graphite.

An iron in or approaching this condition has lost a good deal of its rigidity and mechanical strength and is likely to distort or fracture under comparatively light loading.

In the Paper* read by Campion and Donaldson in 1922 a good deal of light was thrown upon the influence of manganese. They proved that this element exercises a powerful influence in retarding growth on repeated heatings and coolings. But they also showed that manganese, in proportions above 1 per cent., induces an actual shrinkage in volume after a few heatings and coolings to and from 500 deg. C. Donaldson also noticed the same phenomenon in the case of chromium additions to cast iron. What influence these elements have in the case of repeated heatings and coolings to and from temperatures no higher than 200 deg. C. is at present unknown. That they will help to maintain unimpaired the mechanical strength is indubitable. On the other hand, in a case such as an ironer bed where heating (owing to service conditions) is uneven, and where an important consideration is absence of distortion, a tendency to uneven shrinkage in size might give results as

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* Proceedings, I.B.F., Vol. xv, 1921-22, p. 211.

Fig. 5.—Photomicrograph of a very old Ironer Bed taken at the Cross Section of a patch after 28 years in service. × 800 dias. The Combined Carbon is 0.14 per cent.

unsatisfactory as those due to growth. The writer therefore concludes that, in the light of present knowledge, a manganese content of about 0.8 per cent. would appear to offer the maximum advantage for work such as is here being considered, whilst additions of chromium would be of doubtful utility.

In view of these considerations, the iron used for the bed shown in Figs. 3 and 4 has a composition of the order of silicon 1.0; combined carbon 0.8; graphite carbon 2.4; manganese 0.8; phosphorus 0.3, and sulphur 0.1 per cent. Such an iron has a high resistance to carbide decomposition and a tensile strength averaging 17 tons per sq. in. cast in a test bar $1\frac{1}{8}$ in. dia. and machining down to 0.798 in. dia. The metal leaves the cupola at a temperature in the region of 1,400 deg. C., and the moulds are cast at round about 1,330 to 1,350 deg. C. The metal is made up of Scottish hematites and steel. It is highly fluid at the temperatures used, giving a close-grained and entirely satisfactory metal.

FIG. 6.—PHOTOMICROGRAPH OF IRON NOW USED FOR BED CASTINGS. × 500.

The microphotograph at Fig. 6 shows the structure of this metal taken from a test-bar cast at $1\frac{1}{8}$ in. diameter. It represents a magnification of 500 diameters. The microstructure, which is of fine pearlite and sorbite, indicates considerable strength. The tensile strength of this metal is probably equal to what can be attained in day to day workshop practice, where Thyssen Emmel iron is in regular use (one British licensee states that strength at 14-20 tons per sq. in.), and without the disadvantages resulting from high silicon contents.

In service the beds rest at each end on flanges on the cheeks, and are stressed in much the same way as is a test-bar under transverse loading. The load is not of a high order, being in the region of half a ton distributed more or less evenly, by the roller, along its length. To this must be added the gravitational pull of the bed's own weight. The loading is intermittent and repeated, and takes place when the bed is at a temperature approaching 200 deg. C. If the metal is of a quality which, being high in silicon content, is predisposed to carbide decomposition and tends to become ferritic, it will tend to extend under repeated loading on the side of the bed which is put in tension, *i.e.*, the under side. This results in a slight sag in the middle of the bed, which, though only in the region of a few thousandths of an inch, militates against maximum efficiency. This sag may become evident after 5 to 10 years' work. It is therefore quite clear that any iron which has a high silicon content, and which is, consequently, predisposed to rapid carbide decomposition, is not suitable for work of this character. The practice of the author's firm is to cast these beds in a metal which has a high degree of carbide stability, ensuring maximum strength over many years of service. This is supplemented mechanically by the provision, at the centre of each bed, of a support which is adjusted to take up the full load. Consequently the possibility of sag is reduced to the barest minimum.

The moulds for these castings are rammed up from a pattern in dry sand. The sand used has, as a base, Scottish rock sand. The moulding calls for no special mention, except that nothing less than first-class workmanship is good enough. Very careful ramming and finishing of the mould is imperative, for a mould or core scab will give an unsatisfactory casting. It is essential that the mould should be thoroughly dried, firstly because of the need for avoidance of scabs and, secondly, so that there shall be no water vapour in the mould prior to casting.

The core for a casting of this character is a serious proposition. A view of a core for a smaller bed than the one under consideration is seen hanging from the crane in Fig. 7. The construction of the core for the bed shown at Fig. 4 is similar. As will be seen, it is just a shell, 2¾ in. thickness, tapering down at the ends of the horns. Through the core, joining up the inner and outer walls, are 70 webs, varying from 6 to 9 in. long, but only a few of them are of the shorter length. These break up the continuity of the core mass. The ironwork of the core consists of light iron bridges threaded on six steel tubes. The tubes have an inside diameter of 1 in. and an outside diameter of 1½ in. These tubes are drilled along their length every six inches for venting, and serve that purpose adequately, with the aid of a series of wax vents in the region of the horns of the core. The core is made by strickle, being struck up directly upon a cast-iron plate giving the exact contour of the hollow side of the core. The sand is an oil sand, which has obvious advantages; the first being its ready venting qualities, and, secondly, ease of extraction from the casting. In castings of this character it is important that no sand should be left in them. It is not difficult to visualise the difficulty which there would be to get out of the casting a core made in ordinary core sand, and there would never, having regard to the many webs inside the casting, be any assurance that all the core had been taken out.

The sand in use is Irvine sea sand, which has proved highly satisfactory in use. The oil used is of the thin fluid type, the ratio of oil to sand being 1:20. This sand mixture, all along the extremities of the horns of the core, has an additional bond constituent of 1 per cent. of core gum. It is along this part of the core that the metal races as it fills up the mould. Where, in any core, the bond burns out too soon, the

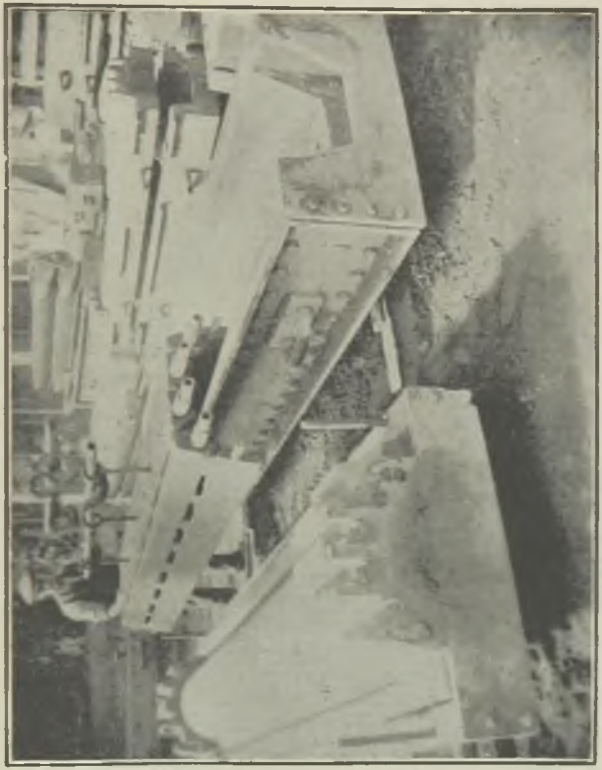


Fig. 7.—Mould and Core for an 18 in. × 120 in. Ironer Bed.

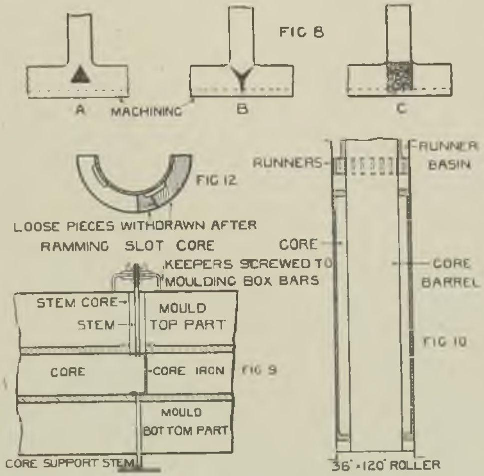
core tends to disintegrate, and sand will be found in the casting where it is not wanted. Consequently, such portions of an important core as are subjected to long continued impingement by the molten metal should have an excess, or a reserve, of binding material.

A burnt or underbaked core is useless for a job of this character. A temperature of 200 deg. C. should never be exceeded in the stove. A properly baked core is easily checked. Its finished colour should be nut-brown. The touch of a finger-nail will break the surface of a core which has been over-baked. Such a core as is now being considered should be examined all over its surface prior to blacking, for it may be burnt locally.

It has been pointed out that there are 70 webs joining the two walls of the casting. Every foundryman will at once realise that these provide at least 70 possibilities of porosity on the machined inner face of the casting. Further, apart from the question of steam-tightness, it is necessary that there should be no places showing an open structure, which would seriously diminish the capacity of the bed to give a good finish to the articles put through the machine in service. Consequently, the fillet of every web is chilled along its whole length, on both sides of the web, where it joins the working face of the casting, as is shown in Fig. 4.

Shrinkage Phenomena

A few general observations may not be out of place here. Cast iron, in common with most other metals, shrinks in volume in crystallising from the liquid to the solid. As the outer shell of metal in contact with the mould and core surfaces freezes first, the total net shrinkage usually appears in the inner portions of metal, particularly wherever there is a local increase in section, due to the joining up of walls, the presence of bosses or similar additions to bulk. The freezing shell takes the form and size of the mould, and, consequently, the shrinkage in volume due to crystallisation often results in the presence, somewhere in the heart of the casting, of a cavity or cavities. Or it may make its presence felt, in a more widely distributed form, as porosity or even structure. These forms of cavity are illustrated in Fig. 8. Of course, these cavities never appear as regular figures as shown in the sketches, but they will serve to illustrate the tendencies at work.



Figs. 8, 9, 10 and 12 show Defects and Moulding Details connected with Laundry Machinery Castings.

The sketches are intended to show three similar sections in which, depended mainly on metal composition, the same amount of cavity will be distributed in a different way. In the case of "A" the cavity lies hidden and may be quite harmless in regard to the efficiency of the casting of which it forms a part. In the case of "B" the defective nature of the cavity is a very serious matter, but local. The case of "C" is hopeless, for nothing at all can be done with a widespread spongy area. It is perhaps unwise to generalise, but there are sufficient grounds for thinking that the defect at " A " is representative of grey irons, the composition of which makes for a short freezing range (the strong irons), that at " C " of those with a long freezing range (the weak irons), while " B " represents the intermediate type.

In the case of " A," freezing probably takes place as a more or less level thrust of dendrites from the outside of the metal section to the middle, building up solid behind from the available mother liquor—for as long as the supply lasts. When that fails a fairly regularly shaped cavity will appear. In the case of " C," long pioneer dendrites grow out, with the result that a final lack of mother liquor is manifested in widely-distributed small voids or porosity, which connect one surface of the section with another. The case of " B " is again intermediate. Observation shows (and commonsense assures it) that those portions of a casting which freeze first are those which are thinnest or farthest from the runner, and those portions will always be found quite sound, as far as shrinkage cavities are concerned. The obvious inference (and observation demonstrates it) is that the thin portions make up their loss of solid volume at the expense of neighbouring heavy sections, or of sections which, for one reason or another, hold metal which is still liquid enough to flow—in accordance with the law of gravity. Now these observations are true of all grades of grey iron, even when metallic additions are made (*e.g.*, nickel) or of the low total carbon irons of the Thyssen Emmel type.

The metal compositions which have the shorter freezing range are those low in carbon, silicon, and phosphorus, but, whilst such irons will always show greater soundness (other things being equal) their solid volume will be less than their liquid volume and, in the absence of provision for a supply of new liquid to make good the loss of volume, cavity in some form will occur. A good deal of that loss, however, is made up naturally. No casting freezes instantaneously. Freezing takes place in accordance with the heat gradient set up in the mould by the path of the metal during pouring; and a good deal of the crystallisation shrinkage is made good from the runner and from heavy risers. But isolated bosses, wall junctions, and other heavy sections cannot get their quota of new liquid in this way. The " chill " can be so used as to provide a solution. It should be of such a weight as to make for solidification of the heavy portion before the surrounding thin portion.

But, it may be said, will not the heavy section then rob the thin? In such circumstances the thick portion will not rob the thin, for the thin places will have their losses made good from the runner, or other head of metal. Take a shank of iron and cast out of it (1) a 5-in. cube and (2) a plate $\frac{3}{8}$ in. thickness, both having the same cubic capacity. Assuming proper moulding conditions the plate will be found to be quite free from defects, but the cube will show cavity. Why is this? The plate will freeze quickly and the crystallisation shrinkage will be made up automatically, along the line of the heat gradient from the runner. The cube, longer in freezing, finds its supply of new liquid cut off, with consequent residual cavity.

To return now to the particular case of the ironer bed, reference to Fig. 4 shows that a chill is laid along each side of each web where it joins the operating face of the casting. There are 140 such chills in each core. In each chill a series of sprigs is cast; the sprigs being bent round the core barrels to ensure stability. Before laying in place in the core, each is wiped with sperm oil, and another wipe of sperm oil is given the chill when the core is ready to place in the mould.

There is a point of interest to note here: Observation shows that a chill which is long as compared with its cross-section, and which comes into contact with the molten metal on one of its faces, tends to camber. Trouble will arise from this where it occurs, but no trouble of this character arises even when these chills are used up to 16 in. long. The reason is that the cross-sectional area of the chill is small, being a right-angled triangle having a length of $\frac{3}{4}$ in. on each side of the right angle, less the round fillet. In such a small cross-section the heat transmission is sufficiently rapid to prevent camber of the chill.

No chaplets are used anywhere in this casting. The core is seated in six $1\frac{3}{4}$ in. round core prints at each end (these holes being later plugged). Two 2-in. holes on the back of the casting provide the remaining anchorage. This is illustrated in the sketch at Fig. 9. A hole is made in the centre of the bed mould in the drag, and before the core is lowered into the mould a pin is passed through it, resting on an iron plate on the floor. The pin is clearly seen sticking up through the drag at Fig. 7, which is a photograph of a mould and core of a smaller bed (18 in. by 120 in. of a different design). The pin stands up above the surface of the mould the exact thickness of the metal required. A bridge iron in the core carries two lugs, the bottom one of which rests on the pin, thus supporting the core. When the top part is put on, two $\frac{3}{4}$-in. screws are passed through the 2-in. holes in the top part, and screwed into the upper lugs in the core bridge.

A suitable 2-in. core is then slipped down round the screws, thus filling up the print, and ensuring that the screw is kept clear of the metal. The holes in the top part are then rammed up with sand. The screws project above the top part past the keepers shown in the sketch, and thumbscrews above the keepers take up the weight of the core, ensuring the exact thickness of the metal below the core. Also, as will be seen in the sketch, nuts on the underside of the keepers effectively hold the core in place against the displacement lift of the metal. The pin in the drag which had been supporting the core is then taken away and the hole sealed.

The moulds are cast "on the bank," at an angle to the shop floor of about 20 deg. The runners are at the top end, giving entry to the mould at the bottom of each horn.

Roller Making

Another important part of an ironing machine is the roller, of which there may be as many as eight or nine on a machine. They need to be perfectly clean and well balanced. They are made in various sizes, up to 120 in. in length, and of diameters from 9 to 48 in. Plain rollers up to 15 in. dia. are rammed up from patterns. The bigger diameter rollers are strickled up in loam. These moulds up to 36 in. dia. are made in boxes which enable the mould to be split in half, longitudinally. The joint edges of the moulding boxes are machined and the mould is struck out with a semi-circle strickle. The mould for this type of roller is always a simple cylinder, the internal flanges of the roller being swept up in the core. The cores up to 36 in. dia. are all struck up on trestles, the core barrels for the smaller diameters being of steel, and those for the larger diameters of cast iron.

This type of roller does not call for much comment. A line section view of a 36-in. roller mould and core is shown in the sketch in Fig. 10. The method of running is indicated in the sketch. The runners are all 1 in. by $\frac{1}{4}$ in. in cross-section, and the same kind of runner is used for all rollers. They are rubbed in the core at the top core-seating, and are placed at intervals of about 4 in. all round the circumference. These runners have proved highly satisfactory for all sizes of rollers. Their nearness to each other results in the metal, when rising in the mould, being kept in constant agitation at its surface, and drosses are brought up safely into the head. These rollers are machined all along their length, and most of them are required to stand up to a working pressure up to 100 lbs. of steam. The chief defect to guard against in a casting of this character is the blow hole, found on machining. The cast thickness for some of the smaller rollers is $\frac{7}{16}$ in., though the larger ones run up to 1 in. It is not an easy matter to get 10 ft. of a thin casting absolutely free from blemish on machining and test, but, with care and forethought, highly satisfactory results may be obtained. The chief conditions for success are (1) a properly-rammed and dried mould and (2) a good core, well dried but with no burnt haybands—the last two layers of hayband leaving at least an inch between each band. A further important condition is that there shall be left no wet or damp luting between the bottom end of the core and the mould. Where loam stamps are used on an important casting to seal up the flash round a cylinder core of any kind, the stamps should be thoroughly dried before the top part is put on. It is futile and stupid to depend upon the hot mould to dry a stamp. Where that is done there will be a trail of grief in the shape of a group of mysterious blowholes not far away from the region of the stamp.

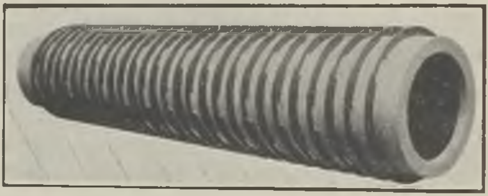


FIG. 11.—VENTILATED ROLLER CASTING, 24 IN. × 120 IN.

Another type of roller, having a little more difficulty, is shown in Fig. 11. All the general remarks above apply equally to this type of roller, which is cast on end in the same way. An important thing to control, in a casting of this character, is that after pouring it should be as free as possible to contract. This cuts out the use of gaggers in the top half of the mould, as rammed up. The mould is, of course, dried, and a double row of 6-in. sprigs is found quite sufficient to carry the outstanding sand between the gills. Soon after pouring, the box with the casting is lifted out of the pit and the bolts are taken out at the joint.

It will be noticed that each gill of this casting has four slots cast in it, their purpose being to allow of easy evacuation of water vapour, which is generated in service from the goods passing through the machine. If these holes were formed by loose dry-sand cores, the result would be a not very good job, leaving a lot of unnecessary work for the fettler to do. In the casting shown in the illustration there are 92 such slots. They are made very simply. On the pattern there are no core prints for these holes. The gills are plain flanges, and are finished in the mould as such. Two small making-up pieces are then

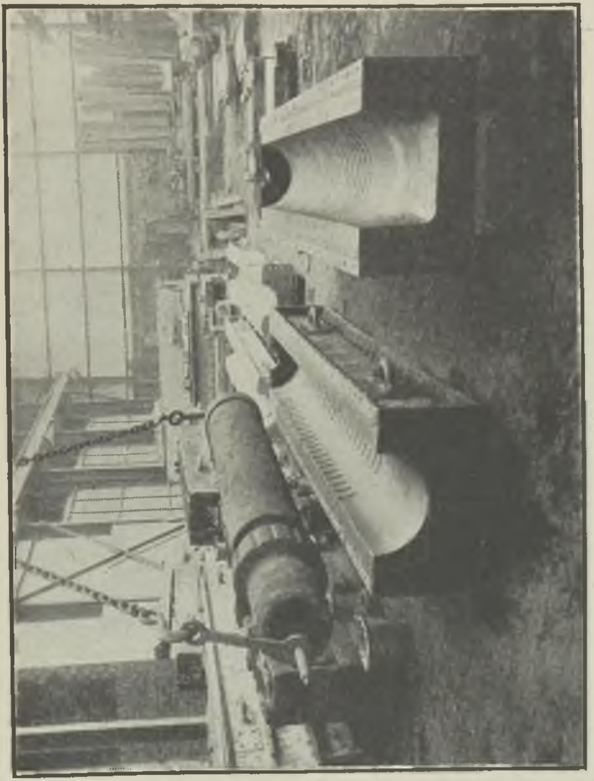


Fig. 12a.—Mould and Core for a 24 in. × 120 in. Ventilated Roller.

inserted in the gill, as shown in Fig. 12, sand is rammed into the space which is to be the slot, sprigged and vented, scraped and sleaked level and the loose pieces withdrawn. This makes a sound job, binding up the sand between the gills, from one end of the roller to the other. A view of a mould and core is shown in Fig. 12A. The right-hand half-mould is unfinished, the ventilation slots not having been rammed in.

Metal Characteristics

The metal for castings of this character need not be of a very high tensile order. Any plain cylinder, which has no attachments in the shape of brackets, etc., and which is cast on end, is likely to be perfectly sound when cast with a relatively soft iron mixture which will facilitate machining operations. For the thinner rollers a metal having a silicon content of round about 2.3 per cent. is quite satisfactory, and, in the heavier rollers, a silicon content of about 1.75 per cent.

Pneumatic Press Castings

In Fig. 13 is shown a Tullis pneumatic press. The chief material in its construction is cast iron. The machine consists of the sand, carrying the air cylinder, fulcrum arm, levers and the upper and lower "bucks." Space will permit here only to draw attention to the making of the "bucks." Fig. 14 shows a selection of a few types of these, which are of many shapes and sizes. Each of these castings is a steam-heated jacket, one face of which is machined and highly polished, and which is afterwards coated with electrolytically-deposited nickel. Each is tested by water at 240 lbs. per sq. in. and at 150 lbs. steam. The metal thickness is $\frac{3}{8}$ in. A plan and section of a "buck" is shown in Fig. 15. It will be seen that the two outer walls of the casting are joined up by 48 webs. The core for this type of casting is exceedingly delicate in its construction. The core is a plate of sand $1\frac{1}{8}$ in. thickness and 15 in. by 3 ft. 9 in. through which the 48 webs shown penetrate. This is completely enclosed in metal, except at the external holes.

A view of the mould and core is shown in Fig. 16. The moulds are made in dry sand. The core construction is on the same principle as in the case of the ironer beds. For the "buck" in the sketch, three thin cast-iron core-irons are tied to four tubes, which are kept at sufficient length to protrude at each end of the moulding box when closed. The tubes are $\frac{3}{8}$ in. inside diameter and $\frac{5}{8}$ in. outside. They are drilled for venting every 3-in. interval along their length. These, with a few loose wires, give sufficient stability to the core, which is made in oil sand. The tubes also, with a few wax vents, adequately vent it.

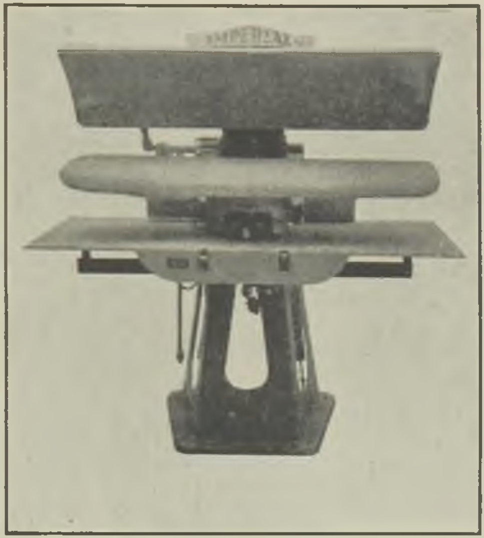


FIG. 13.—TULLIS PNEUMATIC PRESS.

A job of this character presents some difficulties. It is necessary, in order to get a spotless working face, to hang the core in the top part, as seen in Fig. 16. This is reduced to simplicity by means of end plates, which are provided with holes of slightly larger diameter than the core tubes. After the core is placed in the mould the plates are slipped over the tubes at the end of the box. One $\frac{3}{8}$-in. bolt then screws the plate to the end of the box and the core is firmly held

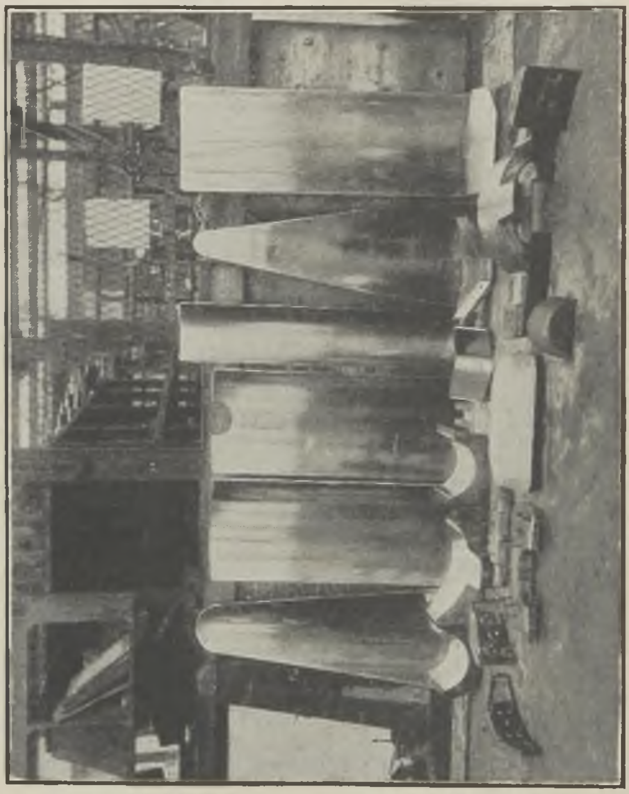


Fig. 14.—Typical "Bucks" for Pneumatic Presses.

In this job, success depends mainly upon free venting of the core. A well-baked core and mould are imperative. They are cast with metal at a temperature of about 1,320 deg. C. and,

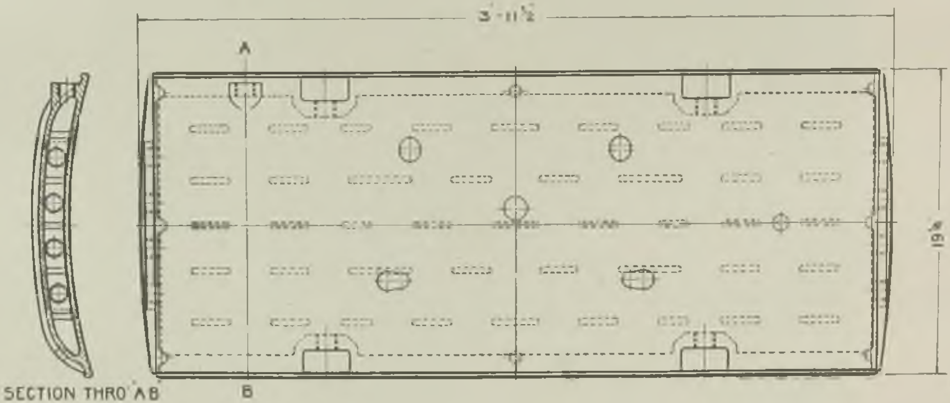


Fig. 15.—Plan and Section of a "Buck."

like the ironer beds, are cast "on the bank." There is no doubt that, in cases like this, casting on the slant is advantageous. When such a mould is cast on the flat, the metal fills the mould up to the top of the core, and then covers up the top of it in a flood, when a certain amount of bubbling will take place until such time as the head of metal is sufficient to face the newly-generated gases through the vents provided for them. In a thin casting particularly, and one which is intended to stand up

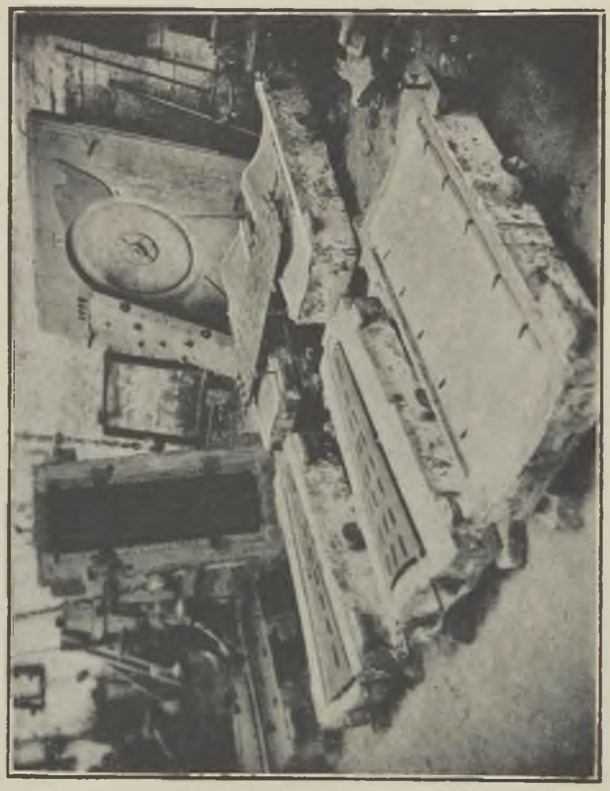


FIG. 16.—MOULDS AND CORES FOR "BUCKS."

to steam pressure, bubbling in any degree is dangerous. On the other hand, a mould cast at an angle to the horizontal fills up gradually, from the lowest part first, creeping up under and over the core. In this case the call upon the vents is more gradual, so that they are not over-taxed.

It has been pointed out that the upper "bucks" are nickel-plated. For this to be satisfactorily deposited a close-grained iron is needed. It is found that all the necessary qualities are present in an iron of the following order: C.C., 0.75; G.C., 2.4; Si, 1.5; Mn, 0.7; S, 0.08, and P, 0.4 per cent. Such an iron, cast at the temperature indicated, will give a sound casting free from defects on test and without any open-grained patches on the operating surface in the region of the webs. One of these castings was tested to destruction in the presence of an insurance inspector. It finally burst under hydraulic pressure of 1,360 lbs. per sq. in.

Washing Machinery Castings

One further example will be discussed here, and that a matter of design. In Fig. 17 is shown a Tullis washing machine. The photograph in Fig. 18 shows a number of green-sand moulds of the outside ends for this machine. In Fig. 19 is a sketch of one of the cast-iron outside ends. It is essentially a circular plate, 3 ft. 4 in. in diameter and $\frac{7}{16}$ in. thickness, carrying the rim for jointing on to the shell of the machine, two feet, and outstanding brackets for the driving gear. The sketch shows an older design of outside end which is seldom built up recently, but it will serve to illustrate a point. As originally designed, the bracket was made separately and bolted on to the outside end. But there are obvious advantages in making the bracket integral with the main casting, the chief one being that of greater stability and rigidity for the drive—usually from a neighbouring shaft. Upon the decision to cast the bracket integral with the casting, it was first designed simply as a continuous plate extended from the body of the casting, carrying the necessary bosses and stiffening ribs.

When machines with these ends were put into service conditions, some of the ends cracked as shown at the dotted line " A." This is a symptom which is evidence of a fault in design, and which in other connections is responsible for a good many failures in service of castings of many kinds throughout the engineering industry, wherever such castings are subjected to irregular heating conditions.

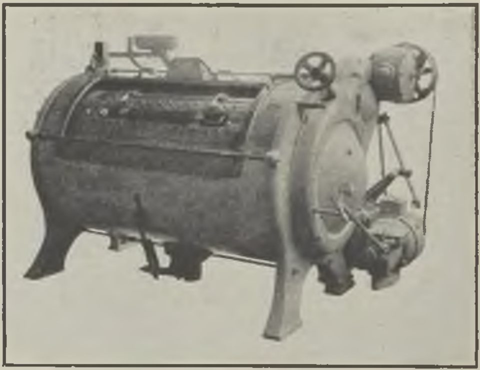


FIG. 17.—TULLIS WASHING MACHINE.

In the case under consideration the diagnosis is simple. In service, the interior of a washing machine is brought up quickly to the temperature of boiling water. There follows an equally quick expansion of the whole of the circular plate. But the outstanding bracket remains at or near room temperature, and cannot expand with the circular plate, with the result that heavy stresses are set up in the rim in the region of the bracket, and a tendency to fracture at the point indicated by the dotted line " A " in Fig. 19. The remedy proved simple. The bracket was joined up to the plate by three arms (as shown in the sketch) instead of by a

FIG. 18.—GREEN-SAND MOULDS FOR WASHING MACHINE OUTSIDE ENDS.

continuous plate. This allowed the bracket to "breathe" in line with the expansion and contraction of the centre plate. In this Paper a few foundry problems in laundry machinery have been discussed, but the list is by no means exhausted. They may, however, be sufficient to demonstrate that this branch of engineering, like every other, has its own peculiar difficulties and problems to solve and overcome.

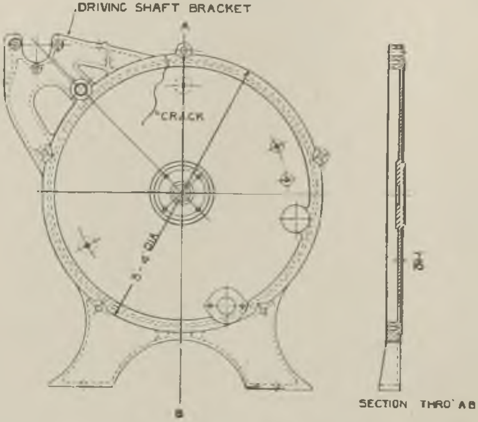


Fig. 19.—Sketch of Washing Machine Outside End.

In conclusion, the writer expresses his thanks to Messrs. D. & J. Tullis, Limited, for facilities afforded him to discuss and illustrate here some aspects of their foundry practice, and to Mr. D. R. Tullis for the microphotographs.

DISCUSSION

The Chairman said that he was sure that they were all agreed that they had listened to an extraordinarily interesting Paper from Mr. Longden; he had been very straight and practical in the descriptions of the problems which he had had to solve.

Mr. R. Ballantine said that he had listened with immense pleasure to Mr. Longden's Paper and the descriptions of the methods he used in the making of somewhat difficult castings. He had had the pleasure of seeing through Mr. Longden's foundry and had been impressed by the efficiency of the methods and the quality of the castings produced. There was a point in connection with the beds upon which he was not quite clear. Mr. Longden told them that he used chills or denseners at the bottom of the cores of the webs and he wondered why the chills were not carried right to the top, as he understood that the necessity for soundness and ability to withstand steam pressure there was equally important. Perhaps Mr. Longden would give his reasons for chilling the bottom part only. In connection with the casting with the gills, the photograph of the casting showed an alternate coring of the gills, but in the photograph showing the moulds and method of making up it appeared that the coring was in a direct line.

Mr. Longden, in reply, said that the casting of which a photograph was shown was as a matter of fact one taken some time ago, but they now made them straight as shown in the view of the mould. Mr. Ballantine's question about the chills was important. The reason they used them at the bottom of the web and not the top was the result of observation and experience. Messrs. Tullis got beds back which had been made a long time ago as scrap. On examining them carefully he had never found any defects at the top part of the web, but had often found them in the bottom. Foundrymen, when they had an item of trouble, had to resort to means of overcoming it, and it was a case of adapting the practice to eliminate the trouble. He had never seen one of these beds leak on the top part, and he thought the effect of the shrinkage was different at the top and the bottom. Mr. Longden here explained his views of the shrinkage with the aid of blackboard diagrams.

Mr. A. D. Mackenzie said that he had been particularly interested in the cylinder and the method of moulding. Mr. Longden had said that the core was made up with straw rope, and he would like to know what thickness was used and the amount of loam. He would also like to know whether any difference was made in the size of the top and bottom of the core to allow for pressure. He took it that the cores were run up on a barrel of some sort with a strickle.

Mr. Longden said that he would take a 36 in. dia. as an example, and proceeded to illustrate his remarks by blackboard sketches. He said they got as big a bar as possible that would pass through the narrow end. Such a core was bound to be built in loam, about 2½ in. thick. The straw rope was put on fairly close on the first layer, and, then depending on the type of bar used, a number of rows of hayband, quite 1-in. spaced, the idea being to build up loam behind. He did not build up the different cores with the idea of standing any conceivable hydrostatic pressure which might be exerted. He had never found the necessity for it.

Mr. A. D. Kirby said that Mr. Longden stated that he used an oil-sand mixture of 1 part binder to 20 parts of sand. That appeared to him to be a very high proportion of binder, and he would like to know whether there was any trouble from blowholes. In regard to the roller, which appeared rather thick in relation to the flange, were there any chills used in it?

Mr. Longden replied he did not use chills, as he thought where a casting was thicker than the average, if it was at the bottom of a deep casting, it was more solid than the top. Regarding oil sand in cases like the one referred to, he thought that a little excess binder was necessary. He had never had any trouble with blowholes and would never hesitate to use an excess where the burning tendency was serious.

The Chairman, speaking in regard to the long thin casting for presses which appeared full of webs, said he was not quite clear as to the method of casting. Was he right in thinking that they ran the metal to separate runners to the bottom and then allowed the metal to flow up?

Mr. Longden said that in a way the chairman was right, the metal went down the downgate and then entered by a number of separate inlets.

Mr. A. Bruce said that he had been very much interested in the Paper, which had been instructive in regard to the general making of castings. He thought that the use of denseners in the bottom part of the web of the bed helped to freeze the metal quicker and prevented the drawing from the top part. Referring to the question of the amount of binder in the sand, he thought that an excess was essential in such a case, and it would do no harm provided the core was thoroughly dried. Referring to the cylinder casting, he thought the core bars would not have a very big contraction, but Mr. Longden had stated that he sometimes had a half-inch of clearance. He would like to know what Mr. Longden put in there. Mr. Longden had said that the pressure did not alter the thickness of the core; he would like to know what thickness of loam he had on to resist the pressure.

Mr. Longden said that perhaps Mr. Bruce might be right, and there might be a certain amount of thickening of the bottom of the core. He had, however, never noticed it. What they put on was white rope, and there had never been any difficulty. When the mould was cast, the bar began to expand. The thickness of loam along the main length of the core was 2½ in.

Mr. A. Bruce mentioned some cases where he had seen evidence of strain on the building plate. He said that in regard to the core which Mr. Longden had spoken about, he thought that if they had two courses of straw rope seven-eighths or three-quarters apart, there had got to be a very good layer of loam on that bar, and they would certainly get a strain. In his own case, they had to make castings as near as possible to the size ordered, and in many cases it would be impossible to do it on such a core. When they came to a cylinder of large diameter such as 36 in. and over there would be too big a strain.

Mr. Longden replied that he really could not say the cores did not yield at the bottom, but he had no reason to suspect that they did. The pressure on the castings was the same as on a heavier casting, but probably there was a good deal in what Mr. Bruce had said. When they had a building ring on a bricked-up casting the ring began to expand when the metal filled the mould more rapidly than the brick part, and perhaps there was some pushing out of the ring.

Wales and Monmouth Branch

SOME PRACTICAL CONSIDERATIONS IN A SMALL JOBBING FOUNDRY

By B. Gale (Associate Member)

In these days of huge combines and mass-production shops, it was somewhat surprising and yet pleasing to read the leader in "The Foundry Trade Journal" of July 20, 1933, entitled "The Future of the Country Jobbing Foundry," in which it was said: "Yet, realising that the country jobbing foundry is an ideal place for youngsters to learn their trade, nobody deplores their present parlous condition more than we. . . . If the larger establishments would send them their one-off jobs, they would in the long run be helping along their industry by keeping alive these real nurseries for future craftsmen."

The article in question certainly referred to the very smallest of shops, without any means of mechanical aid to assist them in the stern fight for existence, as it referred to hand-mixed sand, boiler-tube cupola and castings made from scrap iron, and it is not proposed to deal with that class of foundry, but, nevertheless, the remarks concerning the craftsman does apply to the small foundry in general. For this Paper an attempt will be made to give an outline of some of the methods by which a small foundry concern manufactures some of the higher-grade castings.

Perhaps a brief description of the foundry will be of assistance in visualising the scene. The foundry is not connected to any engineering concern and is, therefore, dependent upon securing general casting orders, in the open market, for its trade. Imagine a small shop having six moulders, four moulding machines, two coremakers and the usual complement of fettlers, labourers, cupola-tenter, etc., open to take any class of work from one-off jobs up to 4 tons in weight and small repetition castings in any quantity, up to 3 cwts. The moulding machines are all of the hand-ram types, and that section has no power appliances, but metal, sand, castings, etc., are conveyed by monorail runways. The sand-mixing department is served by a disintegrator and a roller mill. Floor sand is prepared by a " Royer " machine, whilst melting is effected by two Whiting-type drop-bottom cupolas, of 30 in. and 18 in. internal diameters respectively. The core-making department has three stoves, coke-fired, of varying sizes, a belt-driven oil-sand mixer, and a hand-driven rotary core-machine for the production of round cores up to 2½ in. dia. The fettling department has the usual fixed emery wheels and rumbler, and electrical portable grinder and wire-brush for the larger castings.

Material Control

The control of materials affects all foundries, whether large or small, but the small foundry is very greatly handicapped for several reasons: (1) It cannot afford to employ a chemist in a laboratory of its own, and must, therefore, depend upon practical tests for some of the materials. What analysing is done has to be sent to a consulting laboratory, possibly in another town, with consequent delays; (2) it cannot afford to buy in large quantities, and is, therefore, liable to get varying qualities at each small order; and (3) it cannot afford to experiment with " sample trucks " of a material, as a truck-load may be a month's supply, and, therefore, acting on the principle of " leaving well alone," may be paying a higher price than is necessary.

Believing that metal analysis is one of the major points in material control, it is necessary to have every truck of special pig-irons sampled and analysed, in order to be able to control the mixtures for high-grade castings. In the case of pig-irons to be used for the manufacture of high-pressure castings, pig-irons are bought to analysis, and rejected if out of the specified limits. Common irons are not so seriously dealt with, only occasional analyses being taken for checking purposes. Mixtures for pressure castings are periodically analysed for checking purposes, and all castings made in these mixtures are date marked, so that, in the event of porosity troubles arising at some later date, maybe two or three months after casting, the date, mixture details, etc., can be traced to give indication of the expected analysis of the metal. An analysis of the faulty castings should give indication of error in cupola charging or of the allocation of the metal on that particular date.

Coke and Foaming Slags

Coke is a very complex material, and it has been shown from personal experience that a certain coke that will melt metal admirably in one cupola will have adverse results in another, and in the case of the small foundry this is a material where the author would advocate the policy of "leaving well alone." Cheap coke may be false economy. It is quite realised that a margin of 2s. or 3s. per ton may, in a large firm, effect a saving of some hundreds of pounds sterling per year, but to the small user this saving is not of such importance. To look at it another way, if one is melting 10 tons of iron with 1 ton of coke, and the saving in price is 2s. per ton, the price per cwt. of the molten metal is only effected by 0.12 of a penny, and so small an amount cannot be taken as an inducement to reduce casting costs. Is this small saving worth while if the small foundry is to be saddled with a month's supply of coke, which is of inferior quality? The author recently had a peculiar and somewhat costly experience with coke. For about three years the coke supply had given excellent results and trouble-free melting. It was decided to try a sample truck of another coke which had a reputation of being superior to the one in use, and on analysis and physical testing the coke appeared to be a good-quality foundry coke. As soon as the foundry commenced using the coke, troubles began. At two or three hundredweights of metal the furnace became choked up to the tuyeres with a foaming slag, and when the slag hole was opened the operators could not get rid of the boiling mass of slag in the cupola. The slag, when cold, resembled a porous, spongy mass, and a barrowful weighed only ½ cwt. Different blast pressures were tried, but with no improvement, and the management had to throw out the whole supply and get back to the previous source to overcome the trouble, and it was naturally chary on the subject of trying another coke. For a month or two all went well, and then the trouble recommenced. The suppliers of the coke closed down their ovens, and the foundry was compelled to find a new supplier. It tried several brands of coke, but could not find one to give the same clean, hot melting to which it had been accustomed. The management could not explain the trouble, and could not understand why one coke should give excellent results, whilst others, at the same iron-coke ratio, and similar melting conditions, should be contrary, and it went thoroughly into our melting conditions to ascertain whether the trouble was in our own hands, but it could not find a solution, and was compelled to seek other coke supplies. Then the management enlisted the aid of several of their foundry friends, and also put the question before chemists, but it was unable to obtain any definite conclusion. The only "tip" to overcome the trouble of the foaming slag was taken from a Paper read before the Wales and Monmouth Branch by Mr. G. Moran, and published in the Proceedings, Vol. 25, which suggested an increase in the coke-bed charge, but to keep the bed at a high level greatly reduced the iron-coke ratio and was consequently expensive, and experiments with further cokes had to be made until conditions could be got back to good melting on the usual procedure. This trouble is not now experienced with the coke in use, but it would be interesting to learn the views of others as to the cause of the foaming slag trouble. The peculiarity of the whole trouble was that it was associated with the melting of steel-mix cast irons. Any of the cokes appeared to melt straightforward common irons successfully, but as soon as steel scrap was incorporated into the charges, the trouble commenced. It is felt that the coke must be the cause of the trouble, as previously, and now the foundry has used steel scrap daily, and it has a constant supply of this material of identical analysis and quality.

Moulding Sands

Moulding sands are mixed in various strengths to suit the varying types of work, and but little difficulty in the control of this material is experienced. The foundry is fortunately placed for supplies of excellent-quality red sand in the district, and coal dusts are purchased from manufacturers of repute to the specified grades. For green-sand work, only the heavier castings have any blacking coating, it being personal experience that for green-sand castings of light and medium weight sufficient protection from sand fusion is effected by the coal dust in the sand. The continual use of sea sand for cores and moulds makes the floor sand rather poor in bond, and this is overcome by making the facing sands rather rich in new sand.

Core Sand and Core Making

Fully 90 per cent. of the cores are made in sea sand, bonded with proprietary brands of core binders. At various times the author has experimented with rock sands and river sands, but with small measure of success, as these are not generally reliable. Whilst one supply may be satisfactory, the next lot from the same source may be entirely different in composition. Seashore sand has not given any trouble and each supply can be relied upon. The binding materials, however, are an entirely different proposition, and there is probably more necessity for testing these materials than any other foundry material.

There are so many types of binder on the market, at all sorts of prices, that one must test out a binder in one's own works. Laboratory tests and figures may be quite good for a binder, but it does not follow that that particular binder is suitable to individual classes of work. It is not intended to depreciate laboratory testing. Far from it, the author is firmly convinced that the chemist is a vital necessity to the foundry industry, but he believes that there are instances where practical conditions have a large bearing on the success or failure of a material, and core binders come in that class.

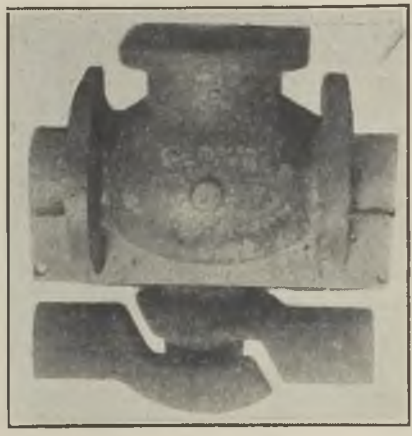


FIG. 1.—STANDARD GLOBE VALVE PATTERN AND CORE.

It is generally possible to obtain a sample of a binder for testing purposes, and personal procedure of testing is to make a comparison of the new binder with the one in use, as follows:—The new binder is measured into the mixing mill at the same proportion, by volume, of binder to sand as that in present use. It is milled for a definite time and placed on the core bench. An exactly similar batch of the present binder is also prepared. Then, a measureful of each binder is weighed and costed at its particular price per cwt. Mixing time being equal, a comparison of these figures will indicate which binder is the cheaper per cwt. of mixed sand. Should it be found necessary to mix one type of binder for a longer period than the other, time of milling must be taken into consideration. The next test is for greenbound strength by the overhanging drop test. The two or three test-bar cores are made in each type of sand and placed in the oven on the same tray. Baking time will undoubtedly vary with different types of binder, and particular notice of baking time is taken to show which is the cheaper in time, fuel consumption, etc. The baked cores are then compared for smoothness of skin. The test-cores are then subjected to a transverse test, and if one has a predetermined breaking strength, these figures will indicate whether more or less binder is needed per mixing. The cores are then tested for water absorption by placing in a jar of water and leaving for a definite time. Comparison can be made of the water absorption of the cores by the softening. The last practical test is to make two identical castings with one core in each type of sand, and these can be examined for signs of blowing, scabbing and for the manner in which the burnt sand leaves the casting during fettling. The whole series of these tests can be carried out with a sample pint of binder, in a very short time, without having to resort to the expense of laboratory testing, and will show what may be expected from a material in one's own foundry, using

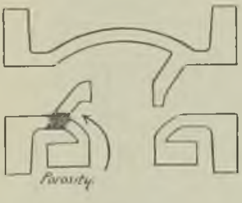


FIG. 2.—SECTION OF A STANDARD GLOBE VALVE.

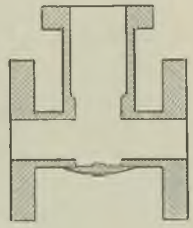


FIG. 4.—SECTION OF A WEDGE VALVE BODY.

one's own particular processes. It is doubtful whether any particular core job requires all the qualities determined by these tests, and it is, therefore, up to the foundryman to judge the binder according to the demands of the job for which the binder is required. For instance, he may not require a greenbond, or he may not be particular about water absorption.

Three Core Mixtures Used

In the author's works, every core that can possibly be made in oil sand is so made, three mixtures of sand being found suitable for any type of core encountered. Where possible, cores are made in halves, on flat plates, in a mixture of sea sand and thin oil binder. This type of core is the cheapest method, giving, when baked, a hard, strong, waterproof core, and can be mixed at 40 parts of sand to 1 of binder, and as one is able to use wet sand, the heavy cost of drying sand is avoided. This sand has little or no green bond. For cores having awkward shapes or overhanging pieces that demand the use of a greenbond sand, a treacly compound is used and dry sand is essential. A greater volume of binder must be used, as it appears that the

FIG. 3.—GLOBE VALVE WITH HEXAGON ENDS.

greater the greenbond strength with a given binder at a given proportion, the lower the baked transverse strength. This appears to be accounted for by the effect of the water. A test recently made with a binder mixed at 40 of sand to 1 of binder and dry sand gave a green drop of 1¾ in. with a transverse baked strength of a breakage at 22½ lbs. on a 1-in. square core at 6-in. centres. A similar mixture, but with 2 parts of water added, reduced the green drop to 1 in., but increased the transverse by over 50 per cent. to 37½ lbs. Now, as water alone cannot give the strength, and all water is driven off during baking, the extra strength must be obtained during the mixing, and probably the addition of water in the mixing mill emulsifies the binder and gives a more even distribution on the sand grains than when dry sand is used. Therefore, as water reduced greenbond, and greenbond is necessary, extra binder must be added to the dry sand to give the desired baked strength to the core, the mixture being 30 of sand to 1 of binder. The third sand mixture is sea sand and red sand in equal proportion and the oil binder. In this case 1 part of oil is used to 30 parts of sand, as the clay bond acts adversely on the oil binder and extra oil is

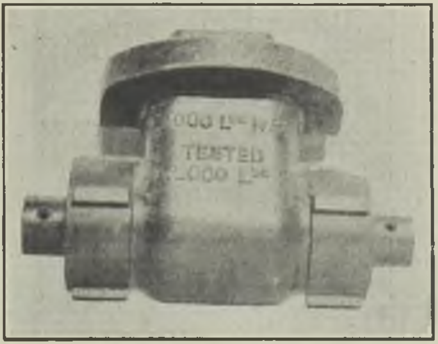


Fig. 5.—Heavy Duty Wedge-Type Valve.

necessary to give a hard core. In some districts, such as the Midlands, the cost of the extra oil is offset by the vastly cheaper price of red sand to sea sand, but in other places that would not apply. The mixture has the advantage, however, of producing a very strong greenbond without having to resort to dry sand. Whilst this sand is more open than ordinary loam core sand, it is, of course, not so porous as the all sea-sand mixtures, and venting must be employed or blowing and scabbing will probably occur.

Fig. 6.—Clack-Type Retention Valve.

The main use for this mixture is for the round cores on the rotary machine, the strong green bond allowing long lengths of core to be made without cracking and distortion, and as the machine automatically vents the cores, they are trouble-free. The cores when baked are exceptionally hard and waterproof and can be made and stocked for indefinite periods without deterioration.

Melting

The success or failure of any foundry depends upon its cupola practice, and in the small shop this section demands the most careful control, especially in times of poor trade. There is a 30-in. and 18-in. cupola, the latter being termed "an emergency cupolette." In normal times such is the case, but under the conditions of the past year or two the larger cupola has become the "emergency" one. Clients' demands must be met daily, and if one is to cast only two or three times per week much business is lost. To run the large cupola for small casts would be too costly, and the small cupola is an undoubted asset to the small foundry, it being possible economically to melt for as low as 10 cwts., and quite suitable for casts of 2 or 3 tons. It has, of course, a limited field for the size of the castings to be poured, as the well of the furnace can only hold 5 cwts. of metal, and if a half-ton casting is required to be cast hot, it is essential to use the larger cupola. A 14-cwt. balance-weight, however, has been cast out of the small cupola, but the metal was rather dull. The small cupola has been designated as unsuitable for the production of good-quality molten metal, but the author cannot agree with such statements, personal experience being that, with careful control, the reverse is the position. For instance, he uses a metal for one class of casting where a phosphorus content of 0.4 per cent. is sought. During the past year, chemists have periodically analysed this metal, and reports show the contents ranged from 0.37 to 0.43 per cent. Probably these figures prove that with careful control the small cupola can produce good-quality

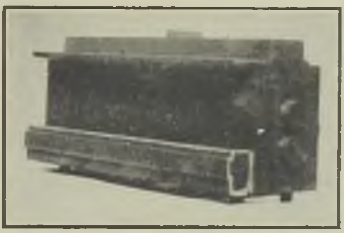


Fig. 7.—Press Tool Casting Used as Pattern.

metal of uniform analysis. All charges of metal, coke and limestone must be carefully weighed, and, with the use of a blast gauge and a timepiece, metal can be controlled to very fine limits. The cupola frequently melts five distinct classes of metal for a 30-cwt. melt, a typical day's cast being as follows: (1) Austenitic iron (nickel-copper-chrome); (2) soft iron for small machine parts, electrical work, gauge cases, etc.; (3) medium Si and low P iron for pressure valves; (4) low Si, low P cylinder iron, and (5) low Si, low C, white iron. A study of this charge sheet reveals: (1) Austenitic irons are very expensive and must be cleared before running into soft irons; (2) high Si, high P iron for light castings must be melted hot. Migration of this metal into the next charge would result in leaky valves and, conversely, miscalculation resulting into charge (3) being poured into light castings would cause waste due to castings being unmachinable; (3) for medium Si, low P, high Mn, hot metal is vital, whilst migration into charge (4) would cause leaky cylinders. Converse migration is not so serious, as the cylinder

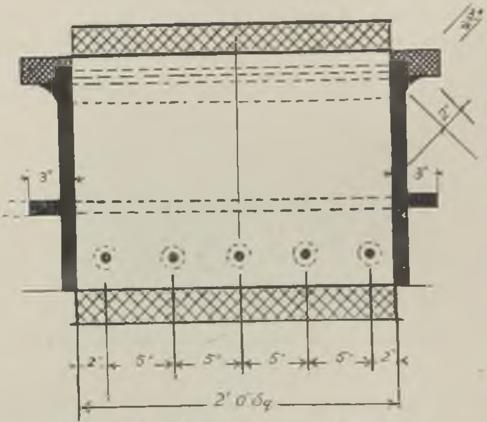


Fig. 8.—Coke Hopper Casting.

iron would make good valves, but would be rather costly; (4) for low Si, low P cylinder iron, migration to charge (5) would be disastrous, as that is a white iron, and (5) in white iron any miscalculation into charge (4) would scrap any cylinder castings.

It will be seen that difficulties must occur when casting such a varied lot in small quantities, but with care and a definite plan of procedure the difficulties can be dispersed. A good plan to prevent migration of the charges is to use a little extra coke between each class of metal, this temporarily holding up the melting and giving the cupola-tenter indication of the approach of a different class of iron. He must, of course, have a daily charge sheet, and must know the capacity of his ladles, so that as he taps off the metal he will have some knowledge of the position of his next metal. Thus, if he

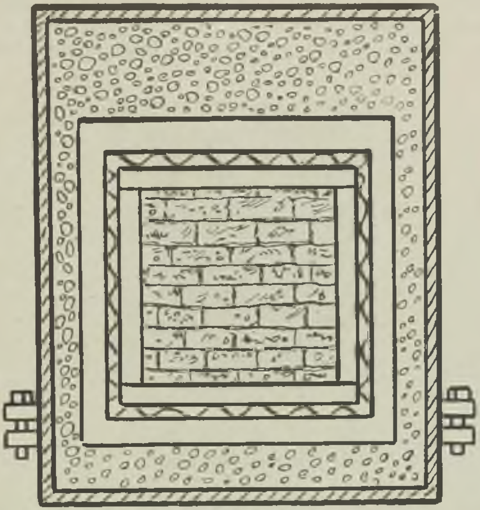


Fig. 9.—Diagrammatic Sketch of Coke Hopper Mould.

has overcharged one grade and he has no moulds into which to pour the excess, he must pour down such excess into a pig-bed. If, on the other hand, he has under-estimated the amount of a certain class of iron, he must leave the moulds uncast, and arrange another charge of metal at a later stage of the blow.

Moulding Practice

Many and varied are the types of castings made in the small jobbing foundry and many are the problems to be solved. High- and low-pressure valve castings, for oil, steam and water, are one of the foundry's regular lines, and whilst metal composition can be arranged to give rapid freezing, every type of pattern has its own particular problem. Varying metal thicknesses must be taken into consideration when setting out the job and arranging the running of the castings.

Fig. 10.—Small Steam Cylinder Pattern.

Fig. 1 shows a standard globe valve pattern and core. The main difficulty encountered is segregation between the heavy valve seating and the thin wall. To prevent segregation the metal is mixed to produce a dense grey iron of medium silicon, low phosphorus and medium total carbon. This type of metal will overcome the internal segregation, but if the composition is too low in T.C. one is liable to run into another trouble due to external shrinkage. The placing of the runner to prevent "hot spots" is of utmost importance. The most satisfactory position in this valve being in the back of the inlet flange, this being the farthest point away from the junction of the valve seating and the body. It should be noted that the cover flange on this pattern is set outside the main flanges, as this point is raised in Fig. 2, which shows the section of a similar valve, but it should be noted that the cover flange in this case is set between the main flanges.

The junction of the two flanges and the valve seating makes a natural "hot spot" that must be assisted in cooling, as the arrangement of the runner cannot avoid the trouble. The most simple manner is to insert a large-headed horseshoe nail in the joint of the core at this point. This forms a densener to eliminate porosity at this point, and the nail stem can be readily chipped out during fettling.

Fig. 3 shows the same type of valve, but with hexagon ends instead of flanges. The ends are bored and screwed fine thread, and to run in the same manner as the flanged types would be disastrous. The runner in this case must be in the cover flange, at the outlet side so that a hot spot is avoided at the valve-seat junction. Fig. 4 shows a section of wedge-valve body. The important point is the junction between the flange neck and the wedge seating. Running of these types of valves is best effected in the cover flange. Fig. 5 shows a heavy-duty wedge-type valve, tested to 2,000 lbs. per sq. in. pressure, which presents similar features to the previous types, and running should be in the cover flange. All types of valves illustrated are liable to shrinkage in the necks of the flanges. Liberal venting at these points will permit the rapid escape of the hot gases and prevent this source of trouble. Most of the valve-body castings shown are made on hand-ram moulding machines and are very simple in production. The runners are arranged by the management and are fitted on the pattern plates with the pattern. The cores made in oil sand are made in halves, on flat plates, and are placed into the moulds unjointed.

Fig. 6 shows a clack-type retention valve. This is probably the most difficult type of valve casting. Its design is particularly uneven in metal thicknesses and hot spots, and conducive to porosity troubles. Not only are there the thick and thin sections of the flanges and body walls, but heavy bosses in mould and core to carry the clack spindle. Sometimes it is aggravated by further bosses being added to carry a by-pass valve. Efforts were made to equalise cooling by the insertion of denseners in core and mould, but that was not entirely satisfactory, and metal composition appeared to be the only solution to the trouble. It will be realised, however, that for small orders, and this type is generally for only one or two castings, special metal charges could not be arranged, and the solution was found in using the same metal with a ladle addition of 1.0 per cent. nickel and 0.3 per cent. chrome.

For jobbing work large use is made of oil sand in the moulding practice. Oil-sand cores are often utilised to cut out jointing, and for small dry-sand work the author prefers an oilsand mould to ordinary dry-sand practice. Not only is it safer, but cheaper in cost of production.

Fig. 7 shows the use of an oil-sand core to aid moulding. The pattern was sent by the customer and was a replica of the casting. The face had to be perfect for press-tool work and was not to be machined. To make this face perfect in a green-sand mould would be practically impossible. The draw of the pattern would undoubtedly break away some of the sharp edges, and mending would be a long and tedious job for the moulder. To ensure a good face, a core was made from the pattern in oilsand. This was facilitated by being able to draw the pattern in the opposite direction to that employed when moulding. When baked, the core was fitted to the pattern and rammed up in the mould. The resultant castings had a clean sharp face.

Consider making the casting in green sand. The castings weighed 25 cwts. and the metal thickness was about 5 in. The mould would need to be well rammed to prevent swelling. It would require particular care in venting and mending to keep a true contour and prevent scabbing and blowing. On drawing the pattern, the oil-sand core was sufficiently hard to prevent any breakage, and mending, sprigging, venting and sleaking were entirely eliminated.

Fig. 8 shows the section of a coke hopper casting on which 50 castings were to be made. The first consideration was to make in green sand, vertically, with draw-in facings, but this was cut out on the time required to ram such a bulk of sand, and the cost of the metal pattern that would be necessary. The second idea was to make horizontally with a core for the centre, but here again the core would take up too much sand and time, and would be heavy and bulky to handle. This method is preferred to the former, as the core could be made with oil-sand walls and floor-sand centre to save the cost of the sand. The author then had the idea of making the core in four slabs to facilitate handling. He had the pattern made with core prints, as shown in Fig. 8, by the crossed section. The core slabs were made 1½ in. thick. Fig. 9 shows a diagrammatic section of the mould. The bottom slab was lowered into the print, then the two side slabs. The centre was then filled up with bricks and floor sand at the top slab placed in position. In this manner one moulder made, cored, and cast three moulds per 8½-hr. day, and the core-making time for the three moulds was 3 hr.

Fig. 10 shows a small-size steam cylinder pattern. These cylinders appear to be quite simple dry-sand practice, but a closer examination shows many hot spots, and metal thicknesses in the smaller sizes will vary from ½ to 2 in. The first attempts at this class of work were rather disastrous, the main troubles being porosity and dirty bores. A slight alteration to metal analysis, and the use of the horse-nail denseners successfully eliminated the porosity troubles, but the pin-holes in the bore persisted. This trouble did not entirely scrap the castings, as it was possible, in some cases, to cut away the holes during boring, but this entailed extra machine-shop practice, and had to be perfected.

Various methods of running were employed, and the moulds cast at a very high temperature,

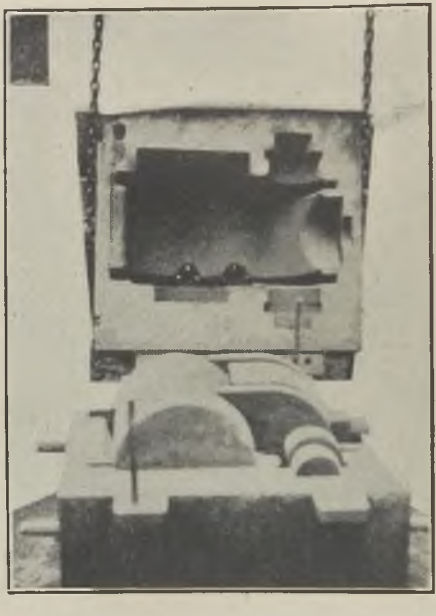


Fig. 11.—Mould from Oil Sand ready for Closing.

reaching to above 1,400 deg. C. Opinions of various experts were sought, but they could not for some time overcome the trouble. They were of the opinion that the trouble was mainly gases that were trapped under the large bore core, and it was decided to experiment with oil-sand moulds instead of the usual dry-sand practice, with a view to more quickly releasing the gases.

Fig. 11 shows a cored oil-sand mould ready for closing. The first mould was not entirely successful, but was a decided improvement, so it was tried again with a little more provision for the escape of the gases by placing large vents through the top mould over each core print, and a perfect cylinder was made, and seven others, of varying sizes, were equally successful.

The trouble had now been conquered as to porosity, machining, etc., but the management was not satisfied with the general appearance of the castings, the oil sand giving a rather rough skin, and causing "ratching" in the corners. Various coatings of plumbagoes and blackings were tried, but the nice clean skin that is associated with the dry-sand moulds could not be obtained. It should be noted that in the dry-sand moulds the wet blacking was applied before stoving, and blacking could soak into the mould and penetrate to a good depth without having any ill-effect on the moulds, but with oil sand this could not be done. The moulds were made in a bonded oil sand, and therefore the addition of a wet blacking would cause the

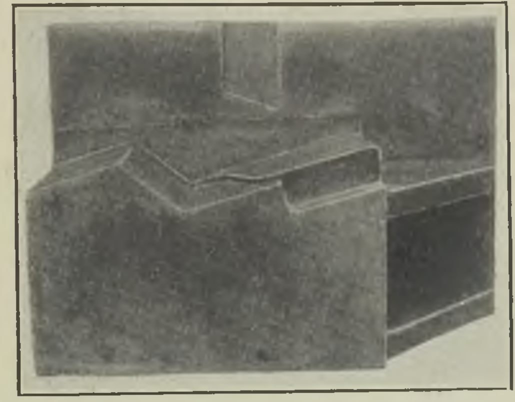


Fig. 12.—Oil-Box Pattern.

collapse of the mould, as the sand would lose its bond. They were therefore blacked after baking, whilst hot, and the sand being waterproof, the mould was only coated with the blacking. The management was compelled to look elsewhere for a solution of the trouble, and it tried an addition of red sand to the sea sand, and whilst this effected the desired improvement to general appearance, it fell back to the previous trouble, as the red sand reduced the permeability of the mould. The only alternative appeared to be to cast at a lower temperature. Now, all this time, the foundry had been working on the assumption that a cylinder casting could not be poured too hot, and the aim had been to pour at a very high temperature. It was decided to try melting at the same high temperature, but pouring when the temperature had dropped to about 1,350 deg. C., and this measure produced a good casting in all respects. This practice has been successfully continued, and not only has it eliminated sources of waster castings, but the production costs of the oil-sand moulds are lower than the dry-sand moulds. Moulding is considerably easier, the mould can be looked upon as an ordinary sea-sand core dried in a box, and sprigs and irons can be largely dispensed with on account of the plasticity of the sand in the green state and the hardness of the mould in the baked

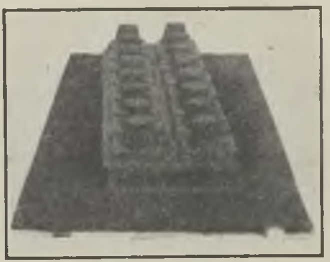


Fig. 13.—Core for Fire Escape Landing Plate.

state. Venting can be treated far less seriously than in a loam mould, on account of the greater permeability of the mould. No lifters or gaggers are required in the top mould, but to allow the top part to be clearly lifted, the pattern must be lifted with the top box, being secured by screws and fishplates. When assembling, the cores can be gently rubbed into the prints, ensuring a perfect fit without either crushes or flashes, a point that is of utmost importance, as all cores must be supported by the prints without chaplets.

FIG. 14.—HYDRAULIC RAM 12 FT. LONG.

Fig. 12 shows an oil-box pattern. This is a particularly difficult design, as the metal thickness of the box is $\frac{5}{16}$ in., and the heavy section shown $2\frac{1}{2}$ in. by 2 in. This section is machined, drilled, tapped, etc., to form oil valves and the slightest porosity causes a scrap casting. To use an iron similar to the cylinder metal or the valve metal is out of the question, as the thin section of the box would be too hard for machining, so the cooling must be assisted by the use of heavy cast-iron denseners in the core for the full length of the heavy section. This is cast in the bottom of the mould, the cores being suspended to the top box. Another difficulty to be encountered is cracking, due to contraction between the heavy section in the bottom and the light flange in the top, and to facilitate the rapid collapse of the mould at this point, the middle part of the mould is made in oil sand and the top and bottom in loam.

Fig. 13 shows a core for a fire-escape landing plate. One often encounters landing plates of varying shapes and sizes, and pattern costs would be far too heavy for a one-off job. At one time a standard-size plate 3 ft. square was used, and all castings had to be made from that pattern by stopping off or moving the pattern along, as the case may be. Now a mould is made of the plate size by strips and strickle and a flat top part, and the void is filled up with sections of the core shown. This is a very simple method, the cores being produced very quickly by boy labour, and the same principle can be employed on many types of gratings, etc.

Fig. 14 shows a pattern of a hydraulic ram, 12 ft. long, that had to be made. This is another instance of the varied type of work encountered in the small foundry, and incidentally is one of the very few types of castings made where the loam core is used. The core in this instance was 12 ft. 6 in. long by 1½-in. dia., and was spun in loam on a ⅞-in. barrel.

In conclusion, the author would like to record his grateful thanks to his principal, Mr. Edward Stevenson, for his permission to use his works and practice for this Paper.

Birmingham, Coventry & West Midlands Branch

THE FETTLING SHOP AND EFFICIENCY

By W. G. Morgan (Associate Member)

Efficiency has been defined as "the controlled application of progress to achieve better results." This is a concise statement and it impresses a factor which is extremely important, yet too often neglected, when new methods or machines are introduced. This factor is control, and at the outset it should be emphasised that if any alterations to existing conditions are to be completely effective, this is the keynote. Men must be trained to new circumstances and this training must not finish by producing simply operators, it is equally essential to infuse the spirit of co-operation in the scheme.

The degree of accuracy needed in the fettling shop depends, of course, on the class of work handled, and, consequently, the equipment necessary to achieve economical working varies accordingly.

The finish of a casting is highly important to the Sales Department, and no matter how good the general shape and skin of a casting, poor fettling will spoil the appearance. Small castings usually call for more work and greater care because of their intricacy, and as the greater number of these have to undergo many subsequent machining operations, a knowledge of certain important points is required or there will be inevitable trouble in the machine shop. Particular instances will readily occur to all of you where fettlers blend out a cross jointed casting or overfettle a part used for a spotting face in a jig, and many another. Smoothing the face of a rough casting, due to a burnt mould or poor sand, is a point which calls for a certain artistic skill if the result is to be acceptable.

Appearance demands consideration and should not be left to the machine-shop fitter.

The size of the foundry, of course, determines the extent of the equipment that can be economically used, but here it should be pointed out that it often pays to modify or instal new plant to increase the handling capacity and reduce costs even in small jobbing shops.

The wide variety and types of equipment available necessitates a careful consideration, before making any addition to existing conditions, and whilst some new ideas or machines may be mentioned, it is wished to suggest means, which may be of benefit to some if not all, of making fettling shops capable of handling their work more efficiently.

Whatever mechanical equipment is used, it should be borne in mind that the atmosphere and handling are more severe here than in any other part of the works and maintenance supervision must be keen and adequate. This is not only necessary from a safety point of view, but also from an efficiency and cost standpoint.

Pneumatic Tools

The extensive use of pneumatic power, through the wide range of portable tools available, has certainly provided a quicker and more efficient way of performing certain operations. Inattention to high-pressure air lines, however, is often one of the largest sources of loss due to leaks, etc. All pipes and connections, taps and hose should have a weekly inspection. It will save a considerable waste, due to carelessness, if all taps are of the spring-loaded plunger type and no open-end pipes allowed for blowing off. Moisture eliminators and filters reduce the wear on compressors and tools, besides helping to maintain pressure. The efficiency of all pneumatic machines is greatly reduced if the air pressure is allowed to fall below the minimum advised by the makers, so that ample compressor capacity is essential where the consumption fluctuates frequently.

An automatic electrical device, operated by the air pressure, will enable power to be conserved by ensuring that the compressor works only when the consumption reduces the pressure to a minimum and cuts out again when a maximum is reached. The use of pneumatic hammers is well established on suitable work. Regular lubrication and the replacement of hexagon sockets when worn to reduce chisel breakage are important points.

Obviously the best steel should be procured for chisels, and the correct heat-treatment, carried out under pyrometric control, insisted upon when tempering and hardening. Where necessary, it facilitates working if special benches or trestles are provided, and operators should be supplied with a full range of chisels.

Pneumatic portable grinders of the rotor type are to be preferred to piston type or electrical, on account of their weight and size. They can be of considerable value on many types of work, but it is desirable that they are cleaned and lubricated every day, and that the correct wheel be used. It should be possible to obtain 100 hrs. wear from 6-in. by 1-in. wheel and 150 hrs. from a 6-in. by 1½-in. wheel. Shaped wheels can also be used with advantage. To eliminate undue wear on the driving portion, through sand and grit entering these parts, it is useful to insist on hose pipes being blown out before connecting to the grinder.

Grinding Wheels

The choice of grinding wheel for floor grinders will depend, of course, on the type of work handled and machine used. The majority of machines taking wheels from 16 in. dia. up to 36 in. dia. give a wheel periphery speed of approximately 5,000 ft. per min., whilst the latest high-speed machines work up to 9,000 ft. per min. The speed is important, and at least two spindle speeds should be provided and used. The importance of this will be apparent if we consider a particular case. A 30-in. dia. wheel to run at 5,000 surface ft. per min. must have a spindle speed of 637 r.p.m. When this wheel has worn down to 20 in. dia., if the same spindle speed is maintained, the surface speed will only be 3,335 ft. per min., or 29 per cent. reduction. Cutting tests on this example show that it takes about 25 per cent. greater time to remove the same amount of metal at the slower speed, so that the necessity of maintaining correct speeds is obvious. It is equally important, of course, to use the correct type of wheel. The demands of different work are so numerous that it is advisable to consult a specialist. New wheels are so frequently being developed that it is very desirable to keep in touch with manufacturers. Undue wear on wheels is usually caused by loose bearings, particularly in the lighter types of machines.

Core Removal and Rough Cleaning

Methods of removing cores and rough cleaning vary with the type of casting and general conditions. Hand picking and tumbling are still the most general and cheapest in many instances. In this case, facilities for loading and handling castings should be provided to reduce congestion and multi-handling. Perforated steel trestle boxes into which castings are loaded from the foundry and in which they can be conveyed to the tumbling barrels, etc., are very convenient for small or medium size work. When the layout and type of work permits, gravity or power conveyors are an asset in making a smooth and speedy flow of work. It is advisable to consult specialists when considering the installation of this apparatus, but, speaking generally, the gravity type can be usefully applied to many plants, especially those handling a large number of castings of suitable size up to 200 lbs. in weight.

Design of tumbling barrels are numerous, but provided they are of steel construction with adequate access and dust tight there is little to criticise. It should be noted, however, that if the rollers are allowed to wear badly, apart from noise, the driving power is greatly increased. Tests show that as much as 80 per cent. increase soon results from this cause.

Dust exhaust systems are recommended and insisted upon in some cases by the Factory Act, but often leave much to be desired especially when starting up. Observation will show that men slow down very considerably in a heavily dust-laden atmosphere, apart from the general bad effect on their health. The cyclone method of exhaust and dust collection is undoubtedly better than the pit type.

Sandblasting

Shot-blast equipment provides a finish unobtainable by other methods and is essential for some classes of work. Whether the suction or pressure system is utilised the essential points to watch are the proper working of the blasting apparatus and the replacement of parts as they become worn. Regular and complete inspection, by a person conversant with the constructional details and working, will ensure that the full capacity is maintained. It is not uncommon to see shot-blast apparatus, probably because of its large bulk, located so that multi-handling is inevitable; a rearrangement so that work can be fed straight to the chippers and grinders is nearly always possible and will obviously result in speeding production. However, it is often the case in old foundries that custom blinds those in charge to the aspect of rearrangement.

Special applications of the rotary-table type machine and continuous flow through rooms are numerous and very interesting. The important point to note, however, is that in nearly all cases standard equipment is used and efficiency obtained by the manner in which it is operated to deal with each particular class of work. A turntable in the floor or mounted on the carriage in shot-blast rooms will facilitate the operator on large work.

A New Machine

A recent introduction in shot cleaning dispenses with compressed air and utilises centrifugal force to apply the steel shot at high pressure. This machine, which is called the "Wheelabrator," is claimed to reduce cleaning costs as compared with pneumatic equipment.

High-Pressure Water

Another principle for cleaning is the use of a high-pressure water jet, but whilst this is claimed to be highly efficient, in that it will completely remove all cores from intricate castings and produce a good finish, the provision of the necessary water supply and filter beds are only applicable and justified in special circumstances. It must be admitted, however, that, as this machine is practically automatic—*i.e.*, a number of water jets play on a revolving-carrier table, the cleaning time saved is from 70 to 90 per cent. of other methods and all dust is eliminated—it is a most interesting proposition.

The provision of special equipment to deal with particular work through shape, size or quantity is a matter which is the project of individual firms. Much time is devoted to evolving the best means of producing a mould or core, but the question of fettling is usually left to existing equipment and labour. This is a case when it is felt that a curse and a threat are not the only means of completing a programme and at the same time saving money. Having considered some of the available equipment for fettling castings, the query arises, what advantage will a firm achieve by installing new machines or rearranging existing plant?

Labour Considerations

It has been the experience of many that the introduction of the pneumatic hammers, for instance, has resulted in much opposition from men who have been used to hand hammers and chisels. Yet this opposition is changed, in a short time, to a feeling of complete dependence on these tools, especially if a skilled operator is brought in.

Resentment at changes in the normal working conditions is a factor which needs tactful handling, and if the men are to adapt themselves to changed conditions they must be brought to the machine and not *vice versa*. In other words, the men must be trained to use new equipment to the fullest advantage and realise the savings to themselves. Only partial success can result if the men are left to develop solely their own methods. The feeling of potential price-cutting is always predominant, and whether this factor enters the scheme or not there should always be an attempt to stabilise the wages in facilitating working conditions.

The necessary care in handling machinery and tools should not be minimised in this department where abuse is so easily possible. If a better idea of tidiness is instilled and equipment cleaned, say once a week, it is surprising what a considerable outlook is created. A definite improvement is possible either through increased production for a given space or in cost per ton by the introduction of any new plant providing it is judiciously selected, placed in its proper relation to the rest of the plant and efficiently operated.

The importance of considering in this department the plant and its production as a whole should be stressed. If existing conditions are not working in the most economical manner the position is simplified. The best grinding wheels, the best steel and its proper forgings, the maintenance of all equipment in good condition and keener supervision will save hundreds of pounds to many foundries.

There is a constant need for reviewing all existing practice, for its state of efficiency and in the light of the capacity of new methods and machines. Obsolete plant cannot be expected to give the best results, however well cared for, but it is surprising how many otherwise well-equipped foundries expect machines in their fettling shops to last for ever.

Safety Considerations

Safety is a factor everybody is taking more seriously lately. There are inherent dangers which exist in any fettling department, but with care these can be minimised. The bursting of grinding wheels is not frequent, fortunately, but with the introduction of high-speed machines giving a surface speed of 9,000 ft. per min., the fitting of wheels is an important task which should be given to a responsible man.

Regulations regarding chains, grinding wheels, dust catchers and guards are covered by Home Office regulations, but attention should be drawn to the research on the effect of dust on the respiratory system, given before the American Foundrymen's Association by Dr. E. G. Meiter. The salient point is that dust particles larger than 0.00004 in. do not penetrate the lungs, and are therefore not dangerous from a silicosis point of view. They are caught by membranes provided by nature in the nasal and other respiratory passages, and are eventually ejected by coughing and sneezing.

It is suggested that the brushing down of walls, cranes and machinery on which the very fine dust collects due to its longer suspension in the atmosphere would be done frequently and by persons with respirators. A fine-water spray should be used in conjunction with the brushing, although cleaning completely by water jet is advocated when possible, especially for walls. Obviously the ideal method would be vacuum cleaning, but as yet the necessary equipment does not appear to have been developed. It is a point not generally appreciated, yet the irritating effect of this form of dust is well known. Milk and oatmeal water with the addition of certain salts are effective palliatives.

Another interesting experiment can be made by providing all benches, trestles, etc., of a suitable height to avoid undue back bending. This has the additional benefit of reducing eye strain. In connection with vision, the intensity of lighting both natural and artificial is inversely proportional to the denseness of a dust-laden atmosphere. As much as 40 per cent. reduction in light intensity is frequently experienced, due to excessive dust. If the fettlers will fully appreciate this point the trouble can be greatly reduced. With the personnel kept at a minimum, the observing of safety precautions is essential in the drive for efficiency. Carelessness is the usual cause, and a severe attitude is the best deterrent.

Finally, it is suggested that the following circumstances exist and are responsible for the uneconomic conditions found in many foundries to-day:—(1) Cut selling prices restrict development; (2) lack of trade and money have created either a cynical or an apathetic attitude, and (3) personnel training has been neglected and many equipment suppliers fail to appreciate that a machine is not the only thing to sell; in other words, their experience should enable them to suggest potential schemes for improvement. The one factor that can effectively overcome all this is efficiency. Efficiency as an ideal and efficiency in every detail of practise.

In conclusion, the author wishes to express his very best thanks to the following for help and loan of slides:—Messrs. Alfred Herbert, Limited; J. W. Jackman & Company, Limited; Tilghman's Sand Blast Company, Limited; R. J. Richardson & Sons, Limited; Bagshawe & Company, Limited; Sir W. G. Armstrong, Whitworth (Engineers), Limited.

DISCUSSION

Mr. J. W. Gardom, in proposing a vote of thanks to the lecturer, emphasised the importance of the fettling shop, which he said could be a guide to the efficiency of the foundry. Mr. Morgan had stated that a grinding wheel was 25 per cent. less efficient when not running at the correct speed, but he did not appear to suggest the use of two spindle speeds. With regard to shot-blast equipment, a description had been given of a quantity of apparatus. He (Mr. Gardom) understood that in the Midlands equipment had been fitted which would sandblast both sides of a casting at the same time, cutting the cost by half. At the present time grinding wheels were so safe that the possibility of breakage might be almost disregarded. Where wheels were broken, however, it was frequently due to carelessness, not only in fitting, but in the rests placed against the grinding wheel. He did not believe in having a fixed rest up against the wheel if that could be avoided.

Mr. G. R. Shotton, in seconding, said the possibility of improving efficiency by mechanisation depended to a large extent on the class and variety of work being handled. For instance, a foundry working on a very small class of work, which was consistent, could very easily be mechanised, whereas when a foundry was producing a big variety of sizes and weights there were difficulties in the path of mechanisation. The question of the efficiency of the fettling shop was always a sore one from the point of view of costing. It was extremely difficult to arrive definitely at the dressing cost of a particular line of castings. He was afraid that most foundries put on a lump sum for dressing, or at the best simply judged the dressing cost on the same lines as the moulding cost. There was undoubtedly a big field for improved costing, but it was doubtful if the majority of foundries considered it worth while.

The vote of thanks was heartily endorsed by the meeting.

The Pattern and Fettling Costs

The Chairman (Mr. E. J. Lewis) asked whether the tumbling shot barrel was effective in cleaning work with intricate cores, or whether that was a separate operation.

Mr. J. A. Lacey suggested that more work was often thrown on the fettling shop than it should normally undertake. They wanted to relieve their castings of superfluous metal. Were they satisfied that they had attacked the problem of the fettling shop purely from the fettling point of view? Was not the pattern shop responsible for much more fettling than should be necessary? In producing the materials in the works with which he was associated the question of cost was the first and last to which attention was devoted. It was useless to look at the balance-sheet at the end of the year to see whether they were making a profit or loss. That must be discovered while production is going on. Hitherto founding had been regarded as the Cinderella of engineering, rather than the basic trade upon which the rest had been superimposed. Much subsequent cost could be eliminated if the foundry product was turned out correctly at the inception.

Piece-Work Fettling

Mr. A. J. Shore mentioned that at the works with which he was connected they had put the fettling shop on a job work basis, every article being separately timed. They made a very large variety of castings, weighing from 5 tons down to about an ounce, and thousands were turned out every week. Their experience was that by definitely timing the jobs they greatly increased their production through the shop and cut down the number of operators. At one time they had 90 men in the shop; to-day they had somewhere about 35.

Pneumatic Chisels

Mr. H. G. Greenhouse, referring to pneumatic chisels operating on cast iron, said his experience was that a man who was used to a hammer and chisel would travel faster than the operator of a pneumatic chisel, while he got a smoother finish and better cut.

Mr. G. M. Callaghan said he agreed with the last speaker to a certain extent. He imagined that pneumatic slippers would be more efficient in cutting off large risers, but he had not seen them cutting the flash from the edge of a casting. In that case there was not so much resistance, while the thickness was constantly varying, and he wondered how the operators got on.

Electric Files

The Chairman (Mr. Lewis) said he was particularly interested in the dressing of small castings, and he would like to know whether Mr. Morgan had had any experience with electric files. They had had a demonstration at his (the Chairman's) works, and he was not altogether satisfied. He was referring to a rotating file for finishing intricate work. It seemed to him that the life of the files must be short and the expense rather heavy.

In the course of further discussion, the opinion was expressed that one pneumatic chipper would beat any two men with hammer and chisel.

AUTHOR'S REPLY

Mr. Morgan, discussing some of the points raised, said small cores could be very effectively cleaned in a shot-blast tumbling barrel. About 70 or 80 lbs. of the castings were put into a barrel about 18 in. in diameter, and about 18 in. long, and in fifteen minutes they had perfectly clean castings. If they were dealing with curved cores he imagined the job could be done satisfactorily, provided they gave it a little longer time. They had cleaned manifolds for four-cylinder engines by shot-blast tumbling methods, but in that case they first of all knocked the core out, because it was too large to put in. He had not actually seen a rotating file, but he imagined that if it wore out quickly either a flexible shaft or small electric grinder, using a wheel down to as small as one inch diameter, might be an effective substitute. He agreed as to the value of variable gears for grinders, but many foundries had single speed machines and managements did not feel disposed to introduce variable gears. His experience was that with two spindle speeds they obtained quite efficient cutting even when the grinding wheel was worn down almost to the bottom.

Multiple Sandblast

He had not actually seen the simultaneous sandblasting of both sides of a casting, but he understood that there was a very interesting installation whereby four men stood, two on each side of the room, each equipped with a jet. They played, one on the side, one on the top, one on the opposite side, and one on the bottom of the casting. By that means cylinder blocks were very quickly cleaned, and were traversed through the room from hooks running from the roof. The sandblasting of two sides of a casting was difficult unless there was special equipment for automatically turning the casting or providing suspension, so that the casting could be revolved quickly and easily by the operator.

Grinding Machine Rests

As to rests for grinding machines, he thought a fixed rest was best, for the reason that they had something which was never likely to move unless the nuts slackened off. If they had a maintenance service sufficient to deal with all the requirements of the foundry it would be possible to adjust the rests every day. He did not think there were many foundries where adjustments would be necessary more than once a day.

Piece Work in Jobbing Shops

In reply to Mr. Shore, he might mention that at the works with which he (Mr. Morgan) was connected they paid a price per ton of castings, bulking everything in. They produced about 3,000 different types of castings a week and not more than a dozen or two of each. It would represent an enormous amount of work for them to fix piece-work prices. In his opinion, where jobbing foundries turned out such a large variety of castings it was a much simpler and cheaper system to adopt a bulk price rather than to pay individual piece-work prices. Where, however, they were producing large quantities of a few items, he agreed that the fixing of piece-work prices was a relatively easy method and by far the most satisfactory. It had been suggested that the pattern-making department could cause a great deal of trouble to the fettler. Much might be done by seeing that the patterns were correct. If a fettler had to contend with a really badly shaped casting, he had to be a genius to produce a good casting. He did not think the fettling shop should be called upon to rectify troubles in the foundry. The fettlers' job was to take off the flash and runners and risers, and clean the casting. If there were other troubles they should be rectified by the moulders and core makers.

Superiority of Pneumatic Hammers

With regard to chisels and pneumatic hammers, it took him six years to introduce pneumatic hammers into their fettling shop. He thought they tried everything under the sun, and no chipping hammer competed at all successfully with hand methods until he managed to find an expert operator. He brought him in, and in four months they had every man in the shop working a pneumatic hammer and definitely preferring it to the old hand method. If the chipping done by a pneumatic hammer was inferior to that of hand chipping they would reject it. He assured them, however, that they got superior results from pneumatic hammers. They chipped castings from 20 lbs. up to 5 tons in weight. Where large runners and risers were concerned they did not use pneumatic hammers, preferring a sledge hammer and a large chisel, held by means of a clamp. He did not consider that a pneumatic hammer was an effective tool for fetching off big risers. In the case of non-ferrous metals they were faced with a different problem. There was constant resistance to the chisel, as against the intermittent resistance of cast iron, and from what he had seen the pneumatic hammer should score every time, even on small work, over hand methods on non-ferrous work, provided they used suitable benches, or clamps, or jigs, to hold the castings.

Mechanisation and Efficiency

Mr. Morgan added that mechanisation was not necessarily efficiency. Efficiency depended upon the manner in which equipment was operated. The only way to discover what equipment could be used efficiently on the class of of work being produced was to visit other foundries and see what they were doing. Very few foundries operated equipment just as they bought it. Most of them improved on it, not because the equipment was poor, but because it was not exactly suited to their particular work. If people would visualise efficiency from the point of view of getting the best out of what they had got, and not necessarily from the point of view of putting in new equipment, or only installing it if it was necessary, he thought fettling shop efficiency would be achieved.

Lancashire Branch

SOME ASPECTS OF NON-FERROUS FOUNDING

By A. Logan (Member)

Introduction

In these days when reams of technical literature flood the country, and scores of lectures are given before technical societies each session, it becomes increasingly difficult to say or write anything original or novel upon such a general subject as "non-ferrous foundry work." Yet, when one comes to consider the matter, it will be realised that the problems of the present are just exactly the problems of the past, although perhaps intensified. Intensified, that is, by the more rapid rate of life in general; by the higher output expected; by the more stringent economic conditions, and by the greater physical demands of modern engineering. If ever there was a time when science (using the term in its broadest sense) has got to pull its weight, it is the present. Every advantage must be taken of the most economical methods of production. Unnecessary handling of materials must be eliminated. Wasters must be cut down to the lowest possible, and so one could go on. It means, in short, that every foundry operation must be carefully scrutinised, studied and overhauled.

Special Conditions

The question of sound buying of raw materials is one which is vital in non-ferrous foundry work, for a brass foundry can sink or swim entirely on the result of its buying of metals alone, apart from any question of technical efficiency or inefficiency; but as such buying is seldom entirely in the hands of the practical foundryman, it is not proposed to deal with this particular point. The question of the most economical method of production is a big subject, and it is impossible to deal with it satisfactorily on general lines. It is essentially a thing which must be studied in the individual foundry, with a full knowledge of the type of work to be produced. It is seldom in non-ferrous work that one finds sufficient off any one pattern to justify the type of mechanised foundry which is becoming more general in the ferrous world. At the same time, a greater selection and variety of moulding machines and appliances appears on the market each year, and amongst the number available, it should not be very difficult to find a type which will be a paying proposition for small numbers off, or even for sheer jobbing work.

Core-Blowing Machines

Within the last year or so, a new type of machine has appeared—the core-blowing machine—for the rapid production of cores which are blown by means of compressed air. This machine is revolutionary in repetition foundries, and is gradually being applied to jobbing work also. It has great possibilities. With the question of machine adoption is also bound up the question of unnecessary handling of materials. With rapid methods of production, the question of sand control comes to the fore. Personally, the author is strongly of the opinion that the future will see the universal adoption of a unified system of sand control. This is a natural development, whether a foundry is on repetition work or not. In the foundry of the future, the whole of the moulds will be knocked out over a knock-out grating, whence the sand will be conveyed to a central cleaning and preparation plant, there to be cleaned, renewed, and made up to a definite standard, and then issued for use as required. The physical properties of the issued sand will be known and under control; and there will then be one less variable for the foundryman to contend with.

Waster Elimination

"Wasters must be eliminated" is a statement which it is easier to make than to remedy, for, after all, are not nine-tenths of the foundryman's working hours occupied by this particular problem? The problems of the present were also the problems of the past. Nowhere more than in foundrywork is it realised that knowledge is not accumulative. If each generation could start where the last left off, then foundry problems would probably all have been solved by now; but, unfortunately, it is not so. The same mistakes constantly recur. The problems which one foundry met and overcame in the past will be met and tussled with by another, and will probably even recur later in the same foundry.

Foundrymen, and the casting of metals, is, after all, the practical application of certain definite physical and chemical principles—and it all depends upon how closely the practical operations follow the theoretically-correct principles, as to how good or bad the finished result will be. It follows from this, therefore, that it should be the aim of the foundryman to acquire some knowledge of the first principles involved, and then, when trouble arises, he is in a sound position to tackle it logically. This all seems a little platitudinous; but having for twenty years viewed foundry problems from the calm detachment of the laboratory; and now, being actively concerned and directly responsible for foundry production, the truth of this statement is brought home to the author more and more every day.

Casting Temperature

The author has on many occasions advocated control of casting temperature and outlined the reasons and stated the benefits to be obtained. It is only within the last year, however, that a policy of complete control has been put into operation which involves the recording of the complete temperature and history of every crucible of metal melted. This necessitates, in the first place, consecutively numbering each casting with a cast-on serial number, where there is more than one off the pattern. Complete records are then kept which show the make-up of the charge, the time in the fire from charging to pouring, the temperature of pouring and exactly what castings are poured, with the sequence in which they are poured if more than one mould is cast from one crucible.

This is necessary in order to arrive at an approximate pouring temperature for the subsequent casting or castings. It will be obvious that a crucible, when once lifted from the furnace, commences to cool fairly rapidly. If the typical cooling curves for the various-sized crucibles in use are known, the approximate temperature at any time after the original temperature has been taken can be fairly accurately obtained. The converse holds also, although not to such a great degree, perhaps, as the state of the furnace will obviously affect the rise; but by taking a temperature bearing as the crucible is being superheated, to its pouring temperature, it is possible to predict the time when the crucible will have reached the required temperature and be ready to be withdrawn for casting. The method actually adopted is to take an initial temperature usually when within about 50 deg. C. of the required temperature, then the time the crucible will reach the required temperature can be estimated to within a minute or so. A check temperature is then taken at the estimated time, and this is rarely found to be far out. The advantage of this system is that there is no possibility of overheating or " stewing " of the charge. Furthermore, the exact time the metal will be ready is known in advance, and arrangements to deal with it can also be made in advance. This means that the crane is on the spot waiting to draw the crucible at the right moment, and the previously-warned moulder is ready to skim and cast as soon as the pot is withdrawn.

Sound Castings

The question of sound castings is very much bound up with melting practice and temperature control, and inattention to this point will inevitably mean a heavy bill for " wasters " if the melting is uncontrolled or left to the judgment of even the most perfect of melters or furnacemen. The fact is not sufficiently realised, and it is impossible to over-emphasise the point, that there is no such thing as being able to judge the correct casting temperature of even any one alloy from day to day; much less can it be done where a number of different compositions are in use. Human judgment cannot be relied upon to give the same temperature day after day. It would seem unnecessary, and in fact almost childish, to reiterate this elementary statement, which has been made scores of times, yet how many foundries completely or systematically exercise temperature control? Dozens of instances could be given where the furnaceman has been asked to indicate when, in his judgment, the metal had reached the correct casting temperature. In the case of one alloy alone, Admiralty gunmetal, during a period of nine months, the outside limits found in this way when checked by pyrometer were 1,080 to 1,300 deg. C.—giving the almost incredible range of 220 deg. C.; and this by an experienced man definitely aiming at a certain temperature, with one alloy.

The correct casting temperature of phosphor-bronze is notoriously difficult to judge by eye, and the usual "rule-of-thumb" method is to draw the crucible at an obviously too high temperature, and allow to stand and cool whilst various "knowing" moulders observe and commune together, the while one of their number gently and gracefully draws a skimmer across the top surface. One hesitates to think what the percentage of wasters can be under these conditions.

If the matter is carefully considered, it will be appreciated that the only logical thing to do is to control the temperature by pyrometer entirely, and give the operator in charge of the instrument the full authority and complete control of the casting temperature of every mould poured. In the small foundry, this would naturally be carried out by the foreman; but in large foundries, the amount of work involved necessitates the services of a special man. His duties would include the fixing in advance of the casting temperature for every mould made, the responsibility for seeing that the crucible was drawn immediately the temperature was reached, which would give the correct casting temperature, and the recording of the complete particulars of every mould poured.

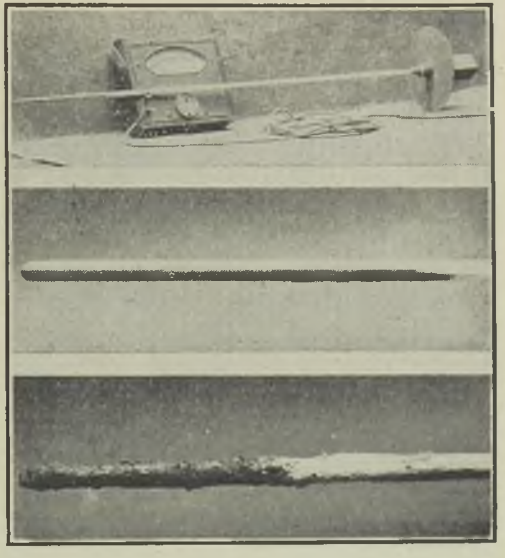
Economy Realised

It might be argued that the retention of an operator to control casting temperatures which were previously judged by the furnaceman or moulder is uneconomical and unnecessary expense. On the contrary, it has been found to be excellent economy—the reduction of wasters and better castings generally far outweighing the cast of the service. It will further be appreciated that it is desirable to remove the whole question of temperature into the hands of a person who has no axe to grind other than the production of the most nearly perfect casting. The furnaceman may be rushed—therefore, the urge is to get the crucible out before its correct casting temperature is reached. This frequently happens, and personal experience has shown that errors on the low side are more common, and just as harmful, as errors on the high side. At the same time, errors on the high side do occur. The furnaceman may be occupied with some job which distracts his attention or the moulder may not have the mould ready. Under this system of control, these difficulties are eliminated.

One of the greatest difficulties in the past which discouraged any attempt at systematic temperature control, was the very practical difficulty of getting a pyrometer which would be sensitive enough to give a reasonably rapid reading, and yet substantial enough to withstand the frequent immersions. A practical pyrometer has been evolved by the laboratory which meets the conditions very well, and details of its construction are given in case they may be of interest to others.

Type of Pyrometer Recommended

Fig. 1 shows the complete pyrometer and indicator. The length of the tube portion is 4 ft. 6 in., and this is necessary to reach to the metal level in the furnace without discomfort to the person using it, and also to keep the cold junction at a low temperature. The tube consists of fused silica and is ½ in. dia. with 2½-mm. thick walls. It is closed at one end. The thermocouple itself consists of two wires of 0.016 in. dia., one of pure platinum and the other of platinum-rhodium. These wires which originally are 6 ft. long, are fused together at one end and the free ends are coiled on drums in



Figs. 1 to 3.—Fig. 1 (Top) Complete Pyrometer and Indicator; Fig. 2 (Middle) Sheath prepared for Immersion, and Fig. 3 (Bottom) Sheath after 160 Immersions.

the cold junction box. One wire is encased in a thin fused silica capilliary tube, inside the main tube. From the junction box, the leads go away to the indicator, which is of the dead-beat type.

If one takes a bare silica tube such as described, and immerses it a time or two in a pot of liquid bronze, it will not be long before the end disappears, as the attack is fairly rapid. Under these conditions, perhaps six or eight immersions might be obtained before the sheath finally gave up the ghost and presented one with a crucible of bronze containing small amounts of the rare elements, platinum and rhodium. As the platinum wires cost 1s. 6d. an inch, and the silica sheaths cost 13s. each, this is not to be recommended. Actually, the life of a sheath in the foundry averages approximately 160 odd immersions, and the way this is obtained is to give it a $\frac{3}{32}$-in. coating of plumbago and china

Fig. 4.—Structure of Sound Material.

clay (Fig. 2). After every four or five immersions the remnant of coating is scraped off, and another coating applied. The object is to prevent molten metal ever coming into contact with the sheath.

A year's experience has shown this arrangement to be perfectly practical—the sheaths averaging, as stated, over 160 immersions (Fig. 3). At intervals, it is necessary to anneal the platinum wires, and when the two or three inches at the hot junction begin to discolour with constant use, they are clipped off, and a new junction fused together. The amount that was cut off is now fed forward from the spare on the drums in the cold junction box. It is just as well, of course, to have a complete spare couple and sheath ready to connect up at a moment's notice. The actual running costs for sheaths works out at approximately 1d. per immersion.

Fig. 5.—Structure of Unsound Material.

Casting Temperature

With regard to actual casting temperature, this has been dealt with by many others, as well as by the author, on numerous occasions, so that it is not proposed to add much more on this point. Obviously, there is a range of casting temperature for every alloy, and within this range there will be a correct casting temperature for any individual casting which will give the maximum degree of soundness. In this connection, it should be remembered that there is no such thing as a perfectly sound casting. Perfectly sound, in this case, being taken to mean a casting in which every cubic inch is the maximum density of which the alloy is capable. This is regulated largely by uniformity or otherwise of section, mass, casting temperature, rate of cooling, freedom from dissolved gases, oxides, etc. Of these, casting temperature is the only factor which is under immediate direct control, and it follows that the casting will approach the maximum best possible, just in so far as it approximates to the correct casting temperature —whatever that may be for the particular alloy and object being cast. The terms " just right," " hot," or " dull," which are common foundry parlance, are absolutely valueless. What may be regarded as " hot " by one man may be " just right " to another, and both may give opposite versions later the same day; and, in any case, be 50 deg. or more from the truth. The only sensible action, therefore, is to eliminate the human element altogether; find out by experience what the normal casting range for a particular alloy really is, then put the whole onus of pre-judging the required casting temperature of every casting on to one man, whose responsibility it will then be to see that the casting *is* cast at the required temperature.

An alloy such as Admiralty gunmetal requires to be superheated about 200 deg. C.—that is to say, the normal casting temperature is round about 1,180 deg. C. There is a normal casting range of 30 deg. either side of this—say, from

1,150 to 1,210 deg. C.; yet it is still possible to pour castings as low as 1,060 deg. C. (but not sound). This fact makes it obvious that without proper temperature control the majority of castings will have a tendency to err on the too-low side rather than on the too-high, for the dangers of casting too high are known and exaggerated, and the outward signs, such as greater amount of fume and greater liveliness, are readily recognisable; whilst there are no such obvious pointers to indicate the low side of the correct casting temperature. This is further proved by the furnaceman's errors, which are more often on the low side. The time factor is against it to commence with. Every second the crucible stands, it is cooling. The skimming may be protracted; there may be a slight delay for someone or something; or where there is small work being cast, an urge to cast just another mould if there is metal left over.

The practical effect of this is rather contradictory. If the castings be not subjected to pressure tests, then probably the deleterious effect may not be very noticeable to the casual observer. In fact, the castings may appear quite sound with a greater freedom from " piping." If subject to pressure tests, however, the greater microscopic porosity will definitely be shown up in a high percentage of failures. Where a casting is poured below its correct casting temperature, the metal does not remain liquid long enough to " feed " satisfactorily. This is due to the casting setting as a whole almost immediately the mould is filled, caused by the insufficient amount of superheat being lost by the metal on its travel through the mould.

The correct casting temperature ensures sufficient superheat, so that a more progressive solidification takes place. The first metal running through the mould undoubtedly gives up a considerable proportion of its superheat to the walls of the mould; the portion of the casting farthest away from the runner is therefore the coolest, and solidification commences there. There will then be a temperature gradient throughout the mould, from the point furthest away from the runner, to the last metal poured into the head.

If sufficient superheat has been given, there will then always be sufficient hot " live " metal adjacent to the portion undergoing solidification to follow up and " feed." It only remains, then, to ensure that the runner and head is ample, and that the ingate is large enough to remain liquid and allow the last portion of the casting to feed from the runner; otherwise, when the gate is cut off, a " pipe " running into the casting will be disclosed.

Cold-Cast Castings

Castings poured too cold do not exhibit " piping " at the gate. The unsoundness is mainly distributed throughout the casting. Machining an outside face may reveal nothing, but a pressure test will probably show it up. A section of such a casting, when subjected to a " deep etch," will clearly reveal its porosity to the naked eye, whilst it is equally obvious if a section is examined under the microscope. Strong, sound, dense gunmetal, correctly cast, and fairly rapidly cooled, exhibits a definite dendritic structure.

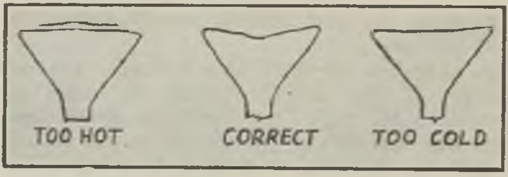


Fig. 6.—Types of Runner Heads associated with Casting Temperature.

Fig. 4 represents the structure of sound material of 21 tons per sq. in. and 40 per cent. elongation. Weak, low-density gunmetal, seen under the microscope, looks weak, having none of the strong interlocking dendritic arrangement. This type of structure, as shown in

Fig. 5, is usually accompanied by actual voids or cavities—giving porosity under test, and being of low specific gravity, the example shown having a specific gravity of only 8.2. Some years ago, in a similar Paper, the author published a diagram indicating the type of runner head usually associated with the three phases—cast "too hot," "normal" and "too cold." Fig. 6 illustrates this diagram.

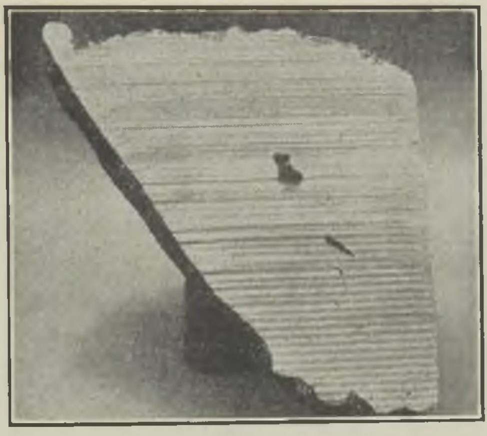


FIG. 7.—SECTION OF RUNNER HEAD SHOWING DEFECT.

Gas Evolution

In this connection it should be noted that the material poured too hot does not always indicate itself as shown in this way. The qualification is needed that, when this type of head is found, it indicates that the metal has, in addition, been damaged during melting by the absorption of excessive oxides and gas. This phenomenon can be observed, apart from any temperature effect, in a casting poured from correctly-melted metal which has been poured into a ladle with a damp lining. The steam evolved is split up into hydrogen and oxygen; the oxygen causes severe oxidation, and the hydrogen apparently dissolves. On solidification this is released, and the effect on the casting can be imagined. This type of head, therefore, is really evidence of the gas evolution which takes place at the moment of solidification. Instead of a normal shrinkage due to feeding, there is an expansion due to the gas evolution. An example of such a runner head is shown in Fig. 7. This was from a large valve, which required about 800 lbs. of metal to cast. Two 400-lb. crucibles were correctly melted and withdrawn from the furnace at a temperature just sufficiently high enough to give the required casting temperature after transferring to a ½-ton ladle. Unfortunately, the ladle was not perfectly dry, and a wild ebullition took place. After a few moments this ceased, but the damage was already done. After standing a few moments on the completion of pouring the mould, the runner head suddenly

FIG. 8.—ON DEEP ETCHING THE SERIOUS CHARACTER OF THE DEFECT SHOWN IN FIG. 7 IS REVEALED.

commenced to rise. Fig. 7 shows a section cut through this head. Apart from the actual gas bubbles, the rest of the material appears to the eye, to be fairly sound. It is only when it is subjected to a deep etch, however, that the full extent of the unsoundness is revealed. This is shown in Fig. 8.

A considerable spongy, gassy, area is seen in the centre, and above this is an actual gas bubble. It will be noticed that the chilling of the metal on the top of the head has restricted the escape of gas, and caused the gas to push its way through the pasty solidifying metal out to the corners and sides. The gas evolution increasing as the solidification proceeds, has caused a gas pressure to be built up, and this literally blows the head up. It should be noted that with this type of head is almost invariably associated the appearance of beads of " tin sweat " (this being the delta or tin-rich constituent).

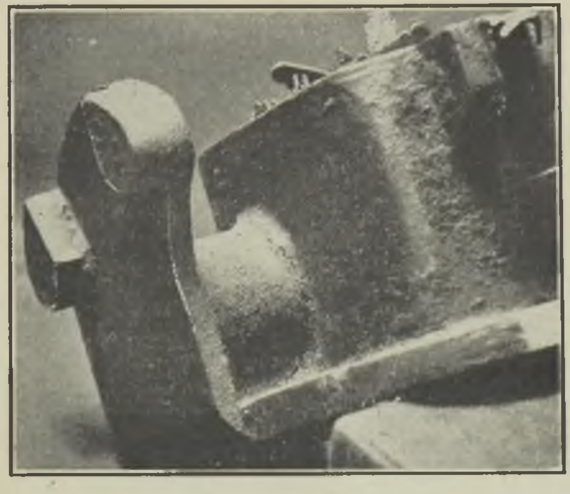


FIG. 9.—SHOWING TEAR BETWEEN SECTIONS.

This, being the last constituent to solidify, accumulates at the centre of the section; but the gas pressure appears to force it up and out, and, travelling by way of the gas fissures, is found round the outside rim of the head. An actual specimen cut from this head had only a specific gravity of 7.8. Admittedly the head is the worst part of the casting, but it is obvious that no casting attached to such a head could possibly be expected to stand much in the way of a pressure test. The unsoundness is distributed throughout all sections, and although on machining it may not appear very "loose" or porous, yet a section "deep etched," or examined under the microscope, will immediately indicate the reason for failure. As stated, this particular illustration was the result of a damp ladle, but the same effect results when metal is melted under bad conditions, giving rise to oxidation and excessive gas absorption.

Fig. 10.—Half Worm-Wheel Casting.

Foundry Faults

One of the greatest difficulties the foundryman encounters is that of bad design. Almost everyone who presents a Paper on foundry work mentions this point, yet the position seems to get no better—rather the reverse, for modern conditions, with the demand for weight reduction, seems to aggravate matters. It is common practice now to have branch or " T " pieces with a flange of 1 in. thick attached to bodies with sections only $\frac{3}{16}$ in. to $\frac{1}{4}$ in. Solid bosses of 2 in. dia. on sections $\frac{3}{8}$ in. thick are also frequently encountered. Such an example is shown in Fig. 9. This illustrates the tear which occurs if the heavy boss is not efficiently chilled. Usually, on investigation, it will be found that such a boss requires to be bored out for some fitting. The obvious thing, of course, is to have it cored out, but where this is definitely ruled out, then the only practical remedy is to use a fairly heavy internal chill. Fig. 10 illustrates a casting forming a half wormwheel, where there are two heavy-section rims connected by a light section. The heavy sections are 3 in. thick and are connected by a section $\frac{3}{4}$ in. thick. It is easy to see that trouble can be anticipated with such

FIG. 11.—THE CONNECTING RIB BETWEEN TWO HEAVY SECTIONS IS TORN.

a casting. Fig. 11 shows how the connecting rib between the two heavy sections has torn. Correct casting temperature can do much to minimise difficulties of this kind.

The valve lid shown in Fig. 12 is a common type of casting, yet it presents difficulties—especially if, as is usually the case, the flange is thickened up out of proportion to the remainder of the casting. Fig. 13 shows where trouble is experienced. Another type of defect which is due to the mould is shown in Fig. 14. This occurs with green-sand work, and takes the form of small holes which look almost exactly like the wormholes one finds in old wood. These usually extend, as shown in Fig. 15, parallel to the body, and run through the fillet into the flange. They are usually found on the underside of the casting—the bottom half of the mould—but very occasionally they may occur in the top half. It will be noticed from Fig. 15 that the normal skin of the casting is disturbed at this point, and shows bright metal with a sort of

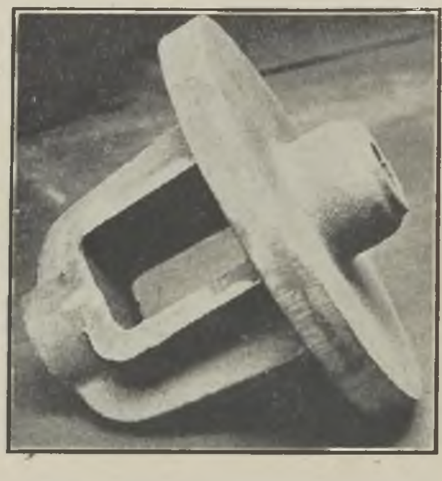


Fig. 12.—Valve-Lid Casting.

flow-line effect. This gives the clue to the trouble, for the cause is excessive dampness of the sand at his point, either through using a low-permeability sand or a sand too wet; or, again, it may be due to the excessive use of the swab. Whatever the cause, the result is an intense evolution of gas over this small area, and as the evolution is greater than the permeability of the sand can cope with, a gas pressure is built up which takes the line of least resistance—which is through the still-liquid metal of the flange. At the moment of solidification the gas which is still passing is trapped, and the holes found afterwards are the result.

FIG. 13.—SHOWS WHERE DEFECT WAS FOUND.

When the core is responsible for excessive gas generation—greater than the vents can cope with—which may easily occur in a very thin oil-sand core which is insufficiently baked—the effect is as shown in Fig. 16. This represents a bulkhead piece. As soon as the flange was machined, the large cavity was disclosed in the top half of the end flange. Fig. 17 shows the top half of the casting after sawing through on the plane of the mould joint. The core in this case was 9 in. long and only $\frac{1}{2}$ in. diameter, and it is apparent that the small vent being unable to carry off the rush of gas, and a pressure consequently developing, this has released itself by bubbling through the still-liquid metal of the flange, where it was eventually trapped on solidification.

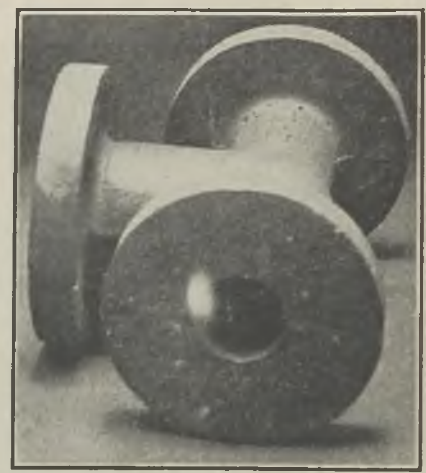


Fig. 14.—Shows Wormhole Type of Defect.

Consideration of "Burning On"

For some reason the term "burning on," by which is meant the welding or repairing of a casting by the application of molten metal of the same composition, is only spoken of in foundries with bated breath and in hushed whispers. There seems to be some stigma attaching to the process which renders it necessary to refer to it covertly and only after glancing around to make sure that no one is overhearing. The origin of this attitude probably dates back to the dim and distant past when the process was resorted to by some unscrupulous persons to enable castings to be accepted which might otherwise be rejected, this being accomplished by carefully "burning on" previously-prepared special test-bars. Everyone has heard stories of this kind, and such stories, whether substantiated or not, appear to have brought the process of "burning on" into disrepute. However, in these enlightened times it is not necessary for anyone to resort to such malpractices to meet

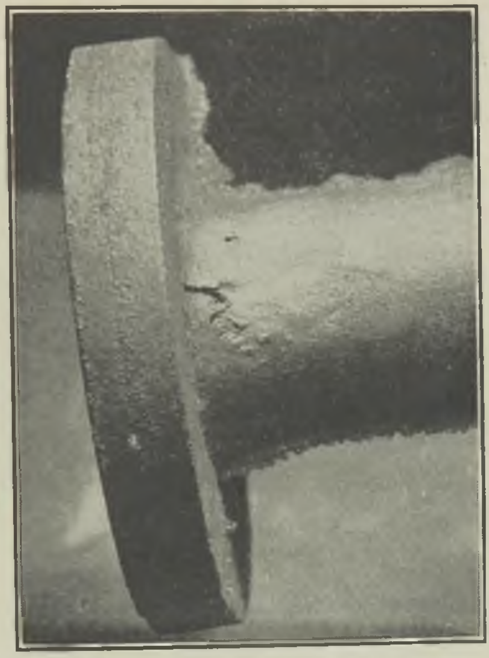


Fig. 15.—Defect extending through Fillet into Flange.

even the most stringent specification. It is time, therefore, to rid ourselves of all prejudice in the matter, and examine the process and results. If the results indicate that it is possible to make a repair which is as sound and strong as the rest of the casting, and without any detriment to the future life and working of the casting, then it is time to accept the process as a definite foundry operation, and allow its use where necessary. After all, there are many quite legitimate occasions where it may be used with practical and economic advantage, and it is desirable to clear it of the suspicion and distrust which surround it.

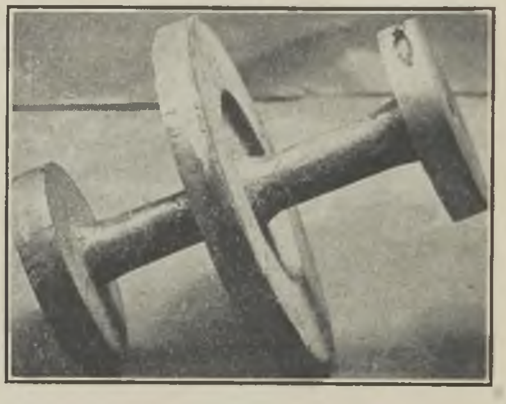


FIG. 16.—A "CORE BLOW" HAS CAUSED THIS DEFECT.

It should be realised that it is possible to make a "burn" which is a perfect weld, and which is virtually one and the same with the metal of the casting. This point can easily be proved by taking sets of duplicate gunmetal test-bars. One of the pair can be machined and tested "as-cast." The other can be cut in two equal portions and then "burned" together again. If correctly "burned," it will be found to give almost equally good test results, compared with the original bar. Usually the Brinell hardness is increased at the area where the "burn" has been carried out.

		Original bars.	After cutting and rejoining.
Tensile	..	19.4 tons per sq. in.	18.4 tons per sq. in.
Elong.	..	24 per cent.	15 per cent.
Brinell	..	85	95

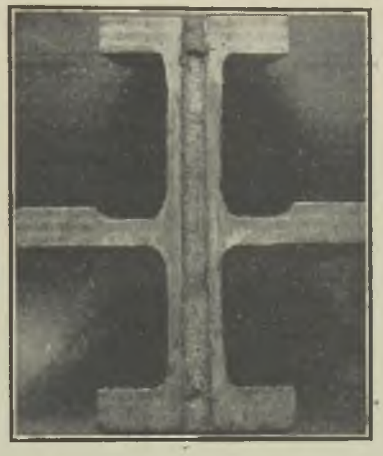


Fig. 17.—Shows Top Half of Casting after Sawing through the Plane of Mould Joint.

At the same time, it must be admitted that under bad conditions, and with careless manipulation, unreliable results may be obtained, so that in every case, where the "burning up" of an important casting is contemplated, the purchaser or user is entitled to know and accord his sanction beforehand.

It must be admitted that the "burning" together of a simple sectioned test-bar does not give results which can be interpreted as being representative of what may occur in a casting.

Where a casting is complicated or of unequal section, definite stresses will be set up when "burning" is attempted. The sudden heating up of local areas with the corresponding sudden expansion, which is resisted by adjacent non-expanded cold areas, may result in a stress of sufficient magnitude to cause a crack. Then, indeed, the case is hopeless. The remedy—or, rather, the way to circumvent this happening—is to preheat the whole costing. There is a limit to what can be done in the way of preheating, especially if the casting is of considerable mass; so that the majority of castings start with a severe handicap in this respect. At the conclusion of the "burning-on" process, the casting is usually covered up with sand and left to cool out undisturbed. If, when the casting is disinterred, the "burn" appears to be a proper weld, and is sound, and the casting is still all in one piece, the foundryman usually calls it a good day's work, and is satisfied. But this, it should be pointed out, is being just a little optimistic. How does the foundryman know that, although the casting is still in one piece, it may yet be in such a state of internal stress that it is almost cracking? How can he be certain, for instance, that on putting it into service the extra working

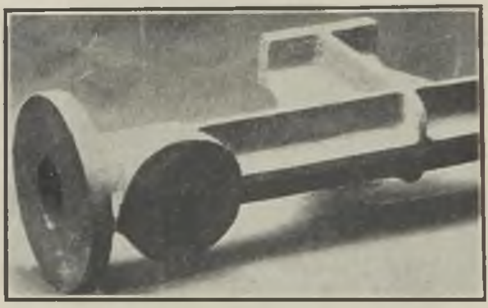


FIG. 18.—AN EXPERIMENTALLY-BURNED CASTING.

stresses, especially where accompanied by heat, may just be sufficient to carry it over the borderline and cause the casting to break down? It is certain that quite a number of cases of breakdown of this kind have occurred when castings which have been "burned" have been put into service. The breakdown may not occur immediately, but may only take place after a period of service.

It has been admitted that it is seldom possible to heat the casting sufficiently before "burning," to ensure reasonable freedom from stress on the completion of the process; but there is nothing to prevent the casting being annealed afterwards to remove any residual stress. Annealing at a temperature of 700 to 750 deg. C. for a short period, followed by a reasonably slow cooling, should be all that is sufficient to give a casting (providing the "burning on" has been done correctly, and it is a sound weld) which is as good as a sound original casting. If this practice

Fig. 19.—Casting after being Burned-on.

became universal, there would then be no more prejudice against the process of "burning on."

It should be remembered that any non-ferrous casting which has been "burned up" has, to the eye of the metallurgist, the word "burn" written upon it until the day it ceases to be a casting. In other words, once a casting has been "burned up," the evidence is there for all time. Even annealing, whilst it removes the internal stress, and changes the inner micro-structure of the crystal, does not cause a recrystallisation, and the new crystal arrangement caused by the burning process remains. Fig. 18 illustrates an experimentally-burned casting, whilst Fig. 19 shows a section of a casting which was repaired by the burning-up process for experimental purposes. Fig. 20 shows a macro-etching of a slice cut from the casting. The casting successfully withstood the normal pressure test, but was cut

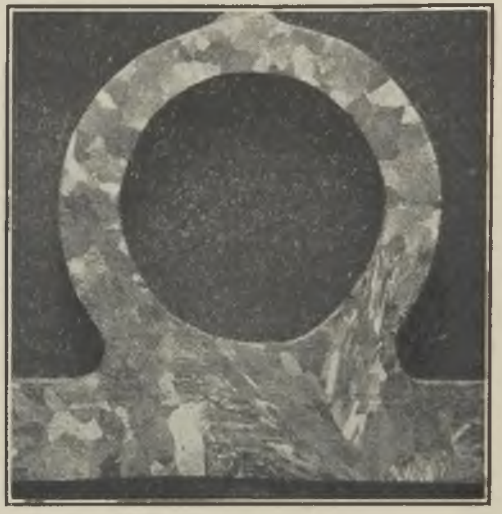


Fig. 20.—Macro-Etching from the Repaired Casting.

up for examination. The perfect junction of the added metal with the material of the original casting is shown in the photo-micrograph (Fig. 21). As far as actual physical strength is concerned, it can be accepted that, where the burning has been carefully done, the welded portion will have equal, if not greater, strength compared with other parts of the same casting, and assuming the casting has been suitably annealed, no fear as to its future need be entertained.

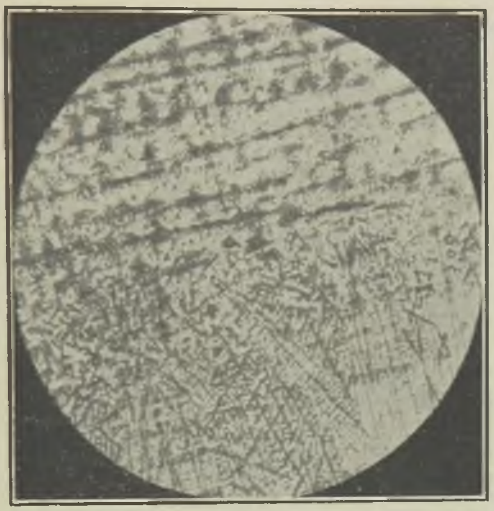


Fig. 21.—A Perfect Weld effected by Burning-on.

Necessity for Standardisation

If one considers the four metals—copper, tin, lead and zinc—and remembers that it will be possible to alloy them (with the exception of lead) in proportions ranging from 1 to 99.9 per cent., it will be appreciated that the number of possible combinations is tremendous. This does seem to have been realised by the chief engineers, designers, consultants, etc., of all the firms who buy non-ferrous castings; and a perusal of representative specifications shows an amazing collection of alloys (literally running into hundreds), many of which vary only by half-percents. To the average non-ferrous foundry, this may not be a serious matter, as, if the foundry is only making for its own particular engineering department, it may only be called upon to cast one or two alloys which have been adopted and more or less standardised by the particular firm. Where, however, the foundry is producing castings to outside orders for a number of firms which each specify the particular alloys which they require (and not only specify, but see that they get them), then the number of slightly varying compositions in use at the same time, with the necessity for careful control and segregation of the various mixtures and returns, involves a considerable amount of extra work and expense. The ridiculous and uneconomic aspect of the question is fully appreciated when it is realised that the various compositions are all for the same or similar purposes, and it does not take long for the non-ferrous founder to realise that some standardisation is urgently required. Leaving out of the question the range of light alloys and special compositions for specialised services, non-ferrous castings are used by the designer for general constructional purposes where strength and pressure tightness without brittleness is desirable. These conditions are met by alloys of the gunmetal-bronze class—alloys of copper, tin and zinc, with possibly some lead. Where a constructional part is also called upon to possess wear resistance, something in the phosphor-bronze range is indicated. It is no secret that the Non-Ferrous Sub-Committee of the Technical Committee of the Institute of British Foundrymen have under consideration the preparation of a range of standard gunmetals and a range of standard phosphor-bronzes. If these are eventually approved and accepted by the B.S.I.

and adopted by industry generally, it is considered that the majority of the weird assortment of alloys in private specifications could be abolished, with very great saving and benefit all round. This, when it materialises, will be a very big achievement with far-reaching practical results, and is deserving of all the consideration and support it can get.

Sand Control

Sand and sand control has been briefly referred to earlier. One of the great difficulties in the past has been the lack of suitable apparatus for sand testing. Anyone who wished to investigate sands had first to more or less devise some form of apparatus. The result was that it was very difficult to compare one set of published results with any other set of results.

The Sands Sub-Committee of the Technical Committee have spent a considerable amount of time getting together a suitable set of standard sand-testing apparatus, and this is now available. This is a very practical and quite robust apparatus, and a laboratory is not essential for its use. It is suggested that every progressive foundry should have a set of this apparatus and carefully check the properties of the sand in use for each purpose. Systematic use over a period of normal good working would yield a set of figures which could be taken as a basis. Any departure from these figures will then indicate some irregularity which should be accounted for. In this way it should be possible to cut out guesswork and work to standard conditions; in addition, it will probably be found that the use of the apparatus will indicate ways in which a saving can be made.

DISCUSSION

The **Branch-President** (Mr. A. Phillips) referred to the question of burning-on, which was a practice which has sometimes to be resorted to in foundry work, and suggested that it was a suitable subject to be taken up by the Non-Ferrous Technical Committee with the large national buying authorities possessing inspection departments. It could be proved that burning-on was a satisfactory foundry method, worthy of acceptance. There was ample evidence that non-ferrous practice was more difficult to control than ferrous, and that when trouble occurred there was often considerable doubt as to the best way of overcoming it. The technical Press contained a formidable list of de-oxidising and de-gasifying agents, and the reader was uncertain what course to adopt. Such a list might contain phosphorus, silicon, copper, boron, soda ash, sal ammoniac, zinc, chloride, charcoal, glass, boron-carbide, etc. Could Mr. Logan outline what fluxes he used in his practice, because it was obvious that he had initiated good methods in his foundry, judging by the slides shown. What elements could be added to gun-metal and the brasses in order to render the metal more fluid or to have more life just before pouring? A further point was whether the lecturer considered that phosphorus increased the temperature of brasses in gun-metal when it was added just prior to pouring.

Sometimes metal was left in the furnaces, and became soaked, and absorbed various oxides such as copper oxides, tin and zinc oxides. Was there any way in which these could be recognised easily? If they were present, then they had to be eliminated. Another point he would like to put forward for consideration was in connection with Admiralty gun-metal, 88 : 10 : 2. Though it was deemed there had been a correct melting control associated with a correct pouring temperature at about 1,160 deg. C., it was sometimes found that there was a very porous structure. It would be interesting to learn how this could be avoided, and also what precautions must be taken to avoid this.

A further interesting point was with regard to the addition of lead to brasses and gun-metal. Did Mr. Logan consider that the addition of lead, apart from its cheapness, had any advantages in the case of gun-metal or the brasses?

It would be useful, also to have information as to how to prevent segregation of the lead in very high-leaded bronze, such as 20 per cent. leaded bronze. Did Mr. Logan add iron pyrites or anything similar? De-gasifying and de-oxidising copper was sometimes a cause of trouble in copper castings, though, apparently, some people were able to make them easily. What did Mr. Logan consider was the best method of ascertaining the correct amount of silicon to add to copper to de-oxidise it and obviate the usual cauliflower top? A point which had been mentioned by the lecturer was the standardisation of alloys.

One firm, which at one time had 36 different types of non-ferrous alloys, after reviewing them with the various engineers, was able to reduce them to 14 and produce all the castings that were necessary. With regard to pouring temperature, he suggested that it would be good practice for anyone who had a pyrometer to stamp the correct pouring temperature on the board, if it were a board pattern, or on the pattern itself, for the information of the moulder. It was essential in aluminium foundry practice to have pyrometer control, and he would like to be informed as to the make of the particular pyrometer shown upon the screen; also, if there was any time lag, which was detrimental sometimes in foundry practice when using a pyrometer with a covered sheath.

Mr. Logan stated that he purposely raised the question of burning-on because it had now reached a stage when it should be either approved or else finally discarded. It should no longer be regarded as being in any way a discreditable method. His own view was that it was a reliable process when correctly carried out with the necessary precautions. The casting should then be quite successful in actual use. The suggestion made by the Branch-President was an excellent one, namely, that the Non-Ferrous Technical Committee should place the subject on their agenda and definitely examine the process, subsequently issuing a report of their conclusions.

The question of fluxes was, of course, a point which was usually raised in a discussion relating to non-ferrous founding. His own experience was that the less one had to do with proprietary fluxes, and, indeed, the less one had to do with fluxes at all, the better. It was usually found that the flux question, like the patent medicine question, was based on fallacies. There were very many fluxes on the market in the form of proprietary compositions, and the wonderful claims which were put forward in respect to many of them could not be maintained. Personally, the only material of this kind he used was charcoal. Provided there was correct melting practice, then charcoal was the only covering necessary. Very often brassfounders experienced entirely unnecessary troubles simply through bad melting practice and incorrect or no control of casting temperature. Providing the metal was reasonably treated and raised to its correct temperature as rapidly as possible, and that it had an efficient covering of charcoal, then, in his opinion, the less one had to do with fluxes the better.

The question of the addition of other elements, of course, was quite a legitimate one. In the case of Admiralty gun-metal and other bronzes, phosphor-copper or phosphor-tin could be added as a very definite asset, and were the only additions he would make to an alloy of the bronze class. They were only made in small amounts, so that probably there was actually no phosphorus remaining in the casting at all. One did not want any phosphorus left in the finished casting, because otherwise one would finish up with a phosphor-bronze casting of gun-metal.

There was no increase of temperature with a phosphorus addition, and he thought that the impression that there was a temperature gain arose from the greater fluidity obtained when phosphorus was added. There was a certain deoxidising effect which rendered the material more fluid. This appeared to increase the temperature, but such was not the case.

A point had been raised as to how to deoxidise metal. The runner head which had been shown on the screen was oxidised metal, though there were many stages not so apparent, from correctly melted gun-metal to one which was hopelessly oxidised. There were many degrees of oxidation, and usually the oxidised material caused porosity. It could be easily recognised by means of the microscope, but it would be very difficult, probably not even possible, to recognise an oxidised metal by merely looking at it with the unaided eye. When a section was etched and examined microscopically, the effect was immediately apparent. It was not an easy matter to get rid of oxidation, and, in his opinion, all proprietary fluxes were practically useless from that point of view. Probably the only thing to do was to use up the oxidised material in small amounts.

The addition of lead to a bronze was definitely advantageous in cases where pressure tightness was desirable. A straight Admiralty gun-metal or straight bronze without lead was notoriously difficult to get sound. An addition of 1 per cent. lead was extremely helpful, and would make a material difference in the pressure tightness of a casting. Bearing bronzes containing 20 per cent. lead were never free from segregation unless nickel was added. By the addition of nickel, which had a much higher melting point, there was a considerable increase in the rate of solidification; in other words, the material solidified before the lead had a chance to segregate.

He had not had considerable experience with regard to cupro-silicon; that is, with pure copper castings where only silicon would be allowed. For turbine work there was an alloy which was really a low-tin bronze containing 98 per cent. copper and 2 per cent. tin with a phosphorus addition. This could be cast successfully, and was virtually a copper casting. He had had very little experience of pure copper castings as such, except that cupro-silicon could be added, and that boron-copper was quite a good addition.

He was very glad to have the Branch-President's confirmation of the necessity for standardisation, which was a consummation long overdue.

The reduction of 36 alloys down to 14 had been mentioned. If a system of standardisation was adopted it might be possible to reduce, say, the 36 alloys down to six or eight, and everything could be done that had been done previously with the 36. One had only to produce such a variety of alloys of that kind to realise the difficulties of checking the composition and the returns of heads, runners and borings, to realise what an unnecessary expense was involved.

The suggestion that the correct casting temperature might be put on the pattern was a very good one. He was, personally, trying to evolve a system whereby all such features were marked on the pattern; namely, the finished weight, the weight of the article as-cast, the correct method of gating, and the casting temperature. The next time the same pattern came to the foundry to be cast all the necessary particulars would be seen at a glance. It would be realised that a pattern successfully cast six months previously might return again to the foundry, and, due to changes in personnel, a different set of moulders might have to deal with it and find out what were the correct conditions for that particular pattern. Once a pattern had been correctly cast, then all details of that kind should be put upon the pattern so that there should be no question about the right method of dealing with it in future.

The pyrometer shown on the screen was in a sense "home made." It was evolved in the laboratory to meet the conditions of the foundry. For a long time the foundry could not put any continuous system of temperature control into operation because of the difficulty of finding a pyrometer which would do the job satisfactorily. The instrument which had been shown was definitely practical and could be put into use for long periods without trouble. The average number of immersions per sheath was 165, including breakages from all causes, and in some cases they obtained as many as 260 immersions. There was not a great time lag. The silica sheath was 2½ mm. thick. The plumbago coating did not give a very great lag, so that it was quite a practical operation to insert it in every crucible and take the temperature. The method was that the furnace man indicated when he thought the temperature was within about 50 deg. of the correct point. The time taken to bring the pot to the required temperature was known; so there was no question of the time lag affecting the metal or letting the metal get too hot.

Mr. J. A. Reynolds (Prescot) suggested that a system which he saw described some years ago for recording the various factors for the control of the casting process would probably be better than the attempt to mark the pattern. If the pattern was a small one it would be exceedingly difficult to make it into a catalogue. It would be difficult to show, on a pattern, the type of runner. It might be possible to indicate its position, but be difficult to show whether it was horngate or flatgate or was given a check in the down gate, or even indicate the height. The system he referred to was used in connection with aluminium castings. A card index was used and in some instances a little sketch was included showing the history of the casting, and sometimes even a history of one or two unsuccessful attempts.

With regard to the question of oxidation, the fact should not be lost sight of that metal could also fail by being melted in a too strongly reducing atmosphere, particularly when oil firing was used.

In many instances engineers, in their specifications and contracts, recognised burning-on, but stipulated that special permission must be obtained in all cases.

Mr. Logan, in reply, said, where oil firing was in operation, it was a very definite practical point that castings could fail by being melted in a too strongly reducing atmosphere. The trouble was largely due to the solution of hydrogen in the metal, with, possibly, carbon monoxide also. The effect would be, generally speaking, to produce a gassy metal which would show unsoundness due to gas bubbles occurring at the moment of solidification similar to the trouble experienced when metal was poured into a damp ladle.

Mr. Reynolds inquired what was the best method for removing large risers from non-ferrous castings. He believed chippers were being used for aluminium, but he had not seen them advocated for non-ferrous metals generally. Was it better to use a band saw or a hack saw?

Mr. Logan said some castings were too big to put under a band saw, while in other cases a runner would be more easily removed if simply nicked through and broken off. It was rather a slow operation to use a band saw under some circumstances, and he was under the impression that the greater proportion of the work done in the foundry with which he was connected were nicked and then broken off with a sledge hammer. This did not, perhaps, seem particularly scientific, but it was rapid and cheap. A git-cutting machine was also used.

Mr. J. Jackson said that he had experienced trouble with a casting which was in the shape of an ordinary dumb-bell used for physical-culture purposes. The casting was about 5 in. long, 2½ in. dia., and reduced in the centre like a dumb-bell. The casting worked in a lignum-vita step in water, and after two years' service, owing to excessive wear on the particular metal used, another metal was substituted, which certainly stood up to wear remarkably well. The metal now being used was 84 copper, 3 lead, 8 tin and 5 per cent. zinc. The castings originally made were cast in the horizontal position. For facility and cheapness of machining it was found better to cast as a solid block vertically, running from the bottom, then cutting out the neck. Excellent castings were obtained in that manner. With the metal now used it was possible to cast horizontally and get a perfect casting, but it had not been found possible to get a perfect casting vertically as there were small indents.

Mr. Logan replied that without knowing further details and cutting sections and examining specimens under the microscope he could not hope to throw much light upon the particular point. He suggested that if Mr. Jackson made his casting in the vertical position, with an extra head which could be cut off, he might get rid of the sponginess in the centre.

Mr. Jackson said he cast some stocks 30 in. long, and cut the top part away, but the trouble was still apparent. When cast horizontally the percentage of wasters over many thousands was something like $1\frac{1}{2}$ per cent., covering the whole foundry and moulders' faults. In the other case it was no better than 50 per cent. at present. The cost of machining was exactly half when reducing from the stock. They were continuing the casting horizontally, but because they had cast all the others vertically and saved so much in machining, he wanted to continue with that saving.

Mr. A. Sutcliffe asked whether Mr. Logan thought non-ferrous castings could be made successfully by using a small cupola operated at a very low blast pressure. Many brass moulders disliked oil-sand cores on account of the metal eating into them. He would be pleased to learn if a suitable mixture could be suggested.

Mr. Logan said that successful moulding depended upon the correct utilisation of scientific principles. If the moulder did not get correct results, it would be because he was not using correct principles. Therefore, by producing a sound casting was applying correct principles whether he was aware of it or not.

Cupola melting for non-ferrous work might be possible. He had heard of cupolas being used for copper melting and copper production. He would like to have a chance of investigating the matter further if possible.

When he first adopted oil-sand cores in the foundry he was met with the suggestion that they would not be satisfactory, though personally he thought they should be. When he came to investigate the matter he found that where trouble had been experienced in respect of oil-sand cores in non-ferrous work it had been invariably due to the fact that too coarse a sea sand had been used. His present practice was to use a fairly fine sea sand without any further additions other than the core compound. He could not remember having had any trouble with badly-shaped cores or metal eating in. With sections of 3 or 4 inches thick, surrounding an oil-sand core there was a roughness on the inside due to the excessive heat having burned out the bond, but when it was trimmed off it was unimportant. The sea sand that he used was the Seaton Carew blown sand.

Mr. Sutcliffe inquired what difference there would be by using half Mansfield and half sea sand.

Mr. Logan thought that probably some of the inherent benefits of the oil-sand core would be lost; there would be a closing up of the core. There would probably be trouble due to impermeability. By using fine sea sand, free from any loam addition, the porosity was retained. If the core boxes were lightly rammed there was not likely to be any trouble.

Mr. J. S. G. Primrose (Manchester) said there was definitely a great advantage in the use of lead in resisting the effect of steam in lowering the strength of gun-metal.

At the conclusion of the proceedings the Branch-President, Mr. A. Phillips, drew the attention of the members to the service which was given by the various technical sub-committees by supplying confidential answers to any problems posed. The committees included many men of high eminence in the various phases of castings manufacture.

Vote of Thanks

Mr. W. Norman Cook, Senior Vice-President of the Branch, proposed that a very hearty vote of thanks be accorded to Mr. Logan for his extremely interesting communication, saying that it was only occasionally that the subject of non-ferrous founding was discussed by the members of the Branch. He agreed with most of the statements contained in the Paper, and particularly so with regard to the troubles experienced by small foundries in respect to non-ferrous founding.

Mr. W. H. Meadowcroft (Burnley) seconded the vote of thanks, remarking that Mr. Logan had been very courageous in talking about wasters and in placing foundry people all upon one level.

The vote of thanks was carried unanimously by acclamation.

Mr. Logan, in responding to the vote of thanks, was of opinion that to thank the lecturer before the conclusion of the discussion was somewhat in the nature of counting one's chickens before they were hatched. Very often the discussion was the most valuable part of the proceedings.

London Branch

POROSITY IN NON-FERROUS METAL CASTINGS

By G. L. Bailey, M.Sc. (Member)

The object of this lecture, which is an extremely wide one, is to review in general terms the three main causes of porosity in castings, namely (1) shrinkage; (2) the evolution of dissolved gases, and (3) the entrapping of gases. To review so wide a field in general terms inevitably involves covering a certain amount of ground which is very elementary, and for this indulgence is asked.

Shrinkage

When a metal is cast there are changes in volume between the casting temperature and atmospheric temperature, which changes usually occur in three definite stages, and are nearly always contractions. There is in general a contraction in the liquid metal as it cools to the freezing point, a contraction in volume on solidification, and a further contraction in the solid, between the freezing point and atmospheric temperature.

As a typical example of contraction in a pure metal, liquid aluminium between 900 deg. C. and 657 deg. C. contracts 3 per cent. in volume. At 657 deg. C. there is a volume contraction of 6.5 per cent. on solidification, and on further cooling to atmospheric temperatures there is a steady contraction in volume in the solid, amounting to about 5.5 per cent.

Table I gives numerical values, relating to a number of different metals and alloys, for the contraction in volume of the liquid on cooling from 100 deg. above the melting point to the melting point, the contraction in volume on solidification and the contraction in volume of the solid on cooling from the melting point to atmospheric temperature.

Patternmakers' shrinkage, or the allowance for contraction in practice, is concerned almost entirely with the contraction in the metal after it has solidified. There is a linear contraction of from 1 to 2 per cent. in the common metals, but in ordinary foundry practice patternmakers' shrinkage is dependent on quite a number of other factors, and whilst 1 per cent. is a fairly average figure, the patternmakers' shrinkage cannot be calculated from the actual change in volume or in length of the metal under perfectly uniform conditions. One reason for this is that in some types of casting a part of the cast metal is solid before the mould is full; such factors make it unsatisfactory to apply a constant value for patternmakers' shrinkage to castings of any one alloy of any size or shape.

TABLE I.—*Volume Changes in Metals and Alloys on Cooling.*

	Contraction in volume of liquid on cooling through 100 deg. C. down to the melting point.	Contraction in volume on solidification.	Contraction in volume of solid on cooling from melting point to atmospheric temperature.
	Per cent.	Per cent.	Per cent.
Tin	1.07	2.9	1.4
Lead ..	1.0	3.1	3.0
Zinc ..	1.4	3.8	4.5
Aluminium ..	1.35	6.5	5.5
Red brass, 85/5/5/5	1.0	5.0	5.2
Copper ..	1.9	4.1	6.4

The figures for change in volume given in Table I are typical of general non-ferrous casting alloys, but it cannot be said that all metals behave similarly. Some metals expand on solidification; bismuth is the classical example. In grey-cast irons also there is an expansion on solidification, but there other volume changes occur such as that accompanying the separation of graphite.

Contraction in volume on solidification is the factor responsible for internal shrinkage porosity. Its first and most obvious effect is in " piping "; the free liquid metal surface contracts, the metal sinks in the " pipe " and further liquid is added to maintain the head. Under ideal conditions the added liquid metal should completely feed the contraction; but in all types of casting there is at some stage solidification of metal at one point across the section of the casting, forming a " bridge," which interferes with the feeding of the remaining material.

The avoidance of contraction due to solidification shrinkage and to shrinkage of the liquid metal is, particularly in the case of pure metals and those alloys which solidify at one constant temperature, largely a matter of design. Fig. 1 illustrates contraction and feeding in different types of ingot. Two extreme cases are shown, illustrating the effects that are liable to occur in attempting to feed solidification shrinkage. In ingot " A " there is a large feeder head with a narrow section where the feeder head joins the casting and an increase in the section of the casting below the junction. Such a casting will inevitably contain a contraction cavity due to solidification occurring across the narrow section before the lower part is solid. However big the feeder head, if the connecting portion solidifies first the contraction cannot be fed. Ingot " B " shows the other extreme, the ideal condition in which the casting is so shaped that solidification occurs progressively from the bottom upwards. Then, by means of a comparatively small feeding head, the shrinkage in the top part of the casting, which will be the last part to solidify, can be fed adequately and a completely sound casting results.

The cases illustrated in Fig. 1 are very simple, but they enable the whole question of the feeding of shrinkage in castings of different types in a metal or alloy solidifying at a constant temperature to be explained. One could enumerate a large number of instances of castings containing a change in section from large to small, where the effect illustrated in Fig. 1*a*, is occurring. Feeding of shrinkage of the larger section through the small section, cannot be expected. The time has passed when foundrymen deliberately put a constriction at the base of the runner so that it would be easy to knock off the head, but such cases of bad design have been known to occur.

FIG. 1.—CONTRACTION AND FEEDING IN DIFFERENT TYPES OF INGOT.

These remarks about the feeding of contraction apply to a certain extent to alloys as well as to pure metals. But there is a variable factor in certain alloys, which is of importance in this connection, namely, the temperature range of freezing. A pure metal solidifies at a constant temperature, but alloys very often solidify over a range of temperature.

A copper-tin alloy containing 10 per cent. tin, for instance, begins to solidify at 1,000 deg. C., and solidification under equilibrium conditions is not complete until the temperature has fallen to about 850 deg. C.; in practice, owing to the fact that the alloy is not in equilibrium, it is not completely solid until the temperature is down to about 800 deg. So long a freezing range has a very marked effect on the distribution in a casting of porosity due to shrinkage.

In alloys possessing a freezing range changes in volume on cooling are similar to those occurring in a pure metal. The actual contraction on solidification, however, is spread over an interval of temperature. In the case of the aluminium-copper alloy containing 7 per cent. copper, there is a contraction in volume of 7½ per cent. on solidification, occurring over a range of temperature of from about 640 to 540 deg. In considering the effect of this, one has to remember the method of solidification of an alloy of this type.

Case of Cast Iron

Fig. 2 represents a diagrammatic illustration of solidification in cast iron. The fact that the metal is cast iron is of no special significance; the principle is typical of the solidification of all metals. When a liquid metal begins to crystallise, the individual crystals grow first in skeleton form ("dendrites"). Branches are thrown off from the original axis and leave interstices, which gradually fill up as solidification is completed. A network of dendrites is thus formed with interdendritic spaces which are gradually filling up. The lowest-melting-point material is between the arms of the dendrites of purer metal which first separate, and final solidification occurs in a large number of small areas throughout the mass. Such an effect is clearly seen in cast bronzes, where the copper-rich arms of the dendrites which are first formed and the interdendritic tin-rich material are clearly visible in the microstructure.

In the case of a pure metal (which solidifies in the same way although at one temperature, the temperature gradient in the casting needs to be only very slight to cause complete solidification to occur in a very small zone in the casting. The wall of the casting may be completely solid, the centre completely liquid, and, if there is anything of a temperature gradient, the actual transition zone may be very small indeed. If solidification be very slow, then the temperature gradient becomes very flat, and even with a pure metal quite a large area of the casting may be in the intermediate, pasty zone, partly liquid and partly solid. But such conditions of absolutely flat temperature gradient are not frequently obtained in castings. With an alloy, however, which solidifies over a range of temperature, such as 90:10 tin-bronze, solidification commences at 1.000 deg. C., and it is not complete under ordinary casting conditions until a temperature of 800 deg. C. is reached. In other words, unless there is a very steep temperature gradient indeed, a large area of the casting contains primary dendrites with interdendritic liquid.

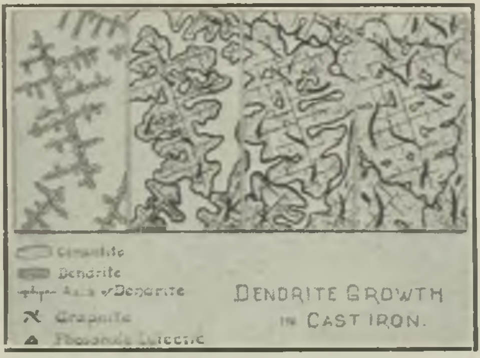


FIG. 2.—DENDRITE GROWTH IN CAST IRON (ALLEN).

Intergranular Porosity

Fig. 3 shows the dendritic structure in a cast brass, and it can readily be imagined that in the solidification of a mass of metal in this way where a large bulk is at any one time in the "pasty" condition, it is inevitable that there should be a fine type of inter-crystalline shrinkage cavity distributed throughout the mass after solidification. As the metal lower down in the casting solidifies, hot liquid from the top cannot percolate through the mass of pasty material to

FIG. 3.—DENDRITIC STRUCTURE IN CAST BRASS.

feed the shrinkage at the bottom. In general, therefore, where there is a mass of pasty metal solidifying comparatively slowly, *i.e.*, without any very steep temperature gradient, there will be distributed more or less evenly throughout the whole mass a very fine type of shrinkage cavity.

This fine inter-crystalline porosity, such as is obtained for instance in tin bronzes, is not easily visible to the naked eye and very often what appears to be a perfectly sound fracture contains in fact a considerable amount of porosity, causing a low density, leakage under hydraulic test, discoloured fracture and mechanical weakness.

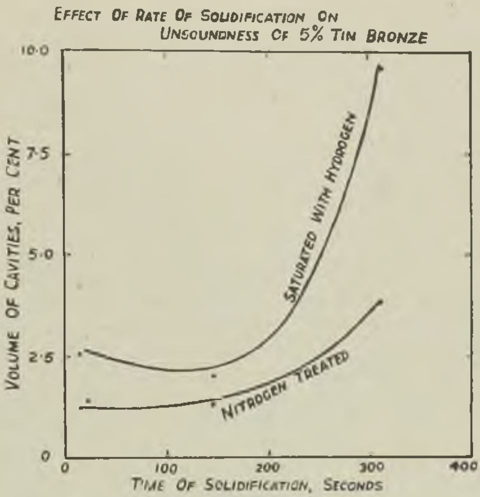


FIG. 4.—EFFECT OF RATE OF SOLIDIFICATION ON UNSOUNDNESS OF 5 PER CENT. TIN BRONZE.

The more uniform the temperature throughout the casting during solidification (*i.e.*, the slower the rate of cooling), the larger the zone of pasty material and, within limits, the more serious the porosity. In chill castings, where there is a steep temperature gradient during solidification, the liquid and solid metal are separated by a comparatively small zone of pasty material, and much sounder metal results. In the centre of a chill-cast bar, however, where the crystals growing from the two sides meet, there is the same difficulty with regard to feeding in that the liquid metal from the top cannot feed the shrinkage down the central column when once the bridging by the primary crystals occurs.

In order to keep the rate of solidification as rapid as possible the casting temperature should not be unnecessarily high. Provided the metal can be cast without entrapping air, causing cold shuts, etc., the lower the casting temperature the better the casting from the point of view of shrinkage alone.

The effect of rate of solidification on the unsoundness of 1½-in. diameter bars of 5 per cent. tin bronze (an alloy with a fairly wide freezing range) is shown in Fig. 4. The lower curve relates to metal treated with nitrogen in order to eliminate effects due to dissolved gases, and the unsoundness in these bars can be considered to be due only to shrinkage. In such cases the slower the rate of solidification the greater the unsoundness. Even with the quickest rate of cooling employed, *i.e.*, casting in a 1-in. thick solid copper mould, there was still considerable porosity, equivalent by density determination to 1¼ per cent. of the volume of the bar. With a material having no freezing range—for instance, 60:40 brass—the bar would under these conditions have been almost entirely sound.

Piping

The effect of shrinkage is most obvious in the actual piping, and the effect of casting temperature on piping is interesting. Fig. 5 shows the depth of piping in a series of phosphor-bronze bars cast in dry-sand moulds at different temperatures, within the range from 1,200 deg. to about 1,025 deg. The bar cast at the lowest temperature showed little piping, and had a high density. As the casting temperature was increased, the depth of pipe increased, reaching a maximum in the bar cast at 1,150 deg.; at casting temperatures above 1,150 deg. the depth of pipe again decreased, being similar in the bar cast at 1,200 deg. C to that poured at 1,025 deg. C. The extra liquid shrinkage in the high-temperature bar has been neutralised by the evolution of gases during solidification, the result being a similar pipe but much increased internal unsoundness.

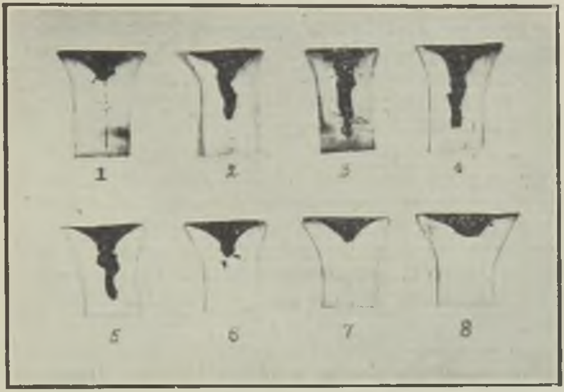


Fig. 5. — Longitudinal Sections through Runners of Phosphor-Bronze Bars cast at Decreasing Temperatures from 1,200 deg. C. to 1,025 deg. C.

Dissolved Gases

Certain gases are soluble to some extent in nearly all liquid metals. Taking metals and alloys as a whole, hydrogen is probably the most readily soluble gas. Excepting cases such as the solubility of hydrogen in palladium, where the solid metal absorbs enormous volumes of hydrogen at quite low temperature and gives them off as the temperature is raised, the solubility of hydrogen in solid metals is small. At the melting point there is a considerable increase in solubility, and as the temperature of the liquid metal is raised there is in most cases a further steady increase of gas solubility.

Copper, for instance, at 1,500 deg., dissolves over 1 milligramme of hydrogen per 100 grammes (a large volume, although a small weight). As the temperature falls to the melting point, the solubility of hydrogen slowly decreases. At the melting point there is a sudden drop of solubility, and then further cooling in the solid brings about a continuous slight fall. It is the sudden change in solubility at the melting point, causing gas to be given off during solidification, that gives rise to the porosity due to dissolved gases. In nickel the effect is more marked, and the decrease in the solubility of hydrogen at the melting point much larger.

In practice there are two important factors affecting the behaviour of dissolved gases. One is the increase generally in solubility of a gas in a liquid metal with increase of temperature; the other is that the solubility of a gas in a liquid metal is proportional to the square root of the pressure of that gas in contact with the metal surface.

While there may be a considerable drop in the solubility of the gas on solidification, the degree to which the gas is evolved depends on the rate of cooling. As in alloys, different structures are obtainable, depending on the rate of cooling, so there are different states of equilibrium with regard to the evolution of dissolved gases on solidification. If solidification is very slow, the gas may be evolved completely. On the other hand, in a chill-cast metal, the gas may be retained in solution in the solid metal, producing no effect on the soundness of the casting.

Referring again to Fig. 5, the general effect of saturating 5 per cent. tin-bronze with hydrogen was, in this case, to double the porosity where the rate of cooling was rapid, and to treble or quadruple it at the slow rate of cooling occurring in a dry-sand mould. (The intermediate drop in unsoundness was due to other factors which need not be dealt with here.) With still slower rates of solidification, the gas is enabled to escape, and, if continued, the curve would later fall again. Fig. 6 shows the effect of rate of cooling on the amount of gas evolved in a series of small bars of cast copper. In each case the copper was saturated with hydrogen, and the rate of cooling decreased in successive bars from the top downwards. If the bar cooled very quickly, the hydrogen was retained in solution in the copper. As the rate of cooling decreased, the hydrogen unsoundness increased, but here again the very slow rate at which the hydrogen would escape, leaving a sounder ingot, was not reached.

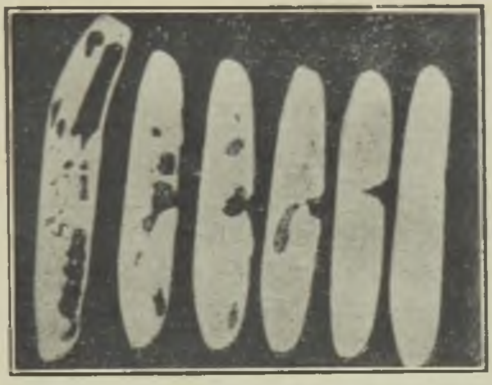


FIG. 6.—EFFECT OF RATE OF COOLING ON THE SOUNDNESS OF COPPER SATURATED WITH HYDROGEN (ALLEN).

Length of Freezing Range and Gas Content

In the case of alloys with a freezing range the gas has greater difficulty in escaping. Assuming, of course, that the pipe is still open, any gas given off in the centre of a vertical column of liquid in a casting can escape; gas will be entrapped only where a bridge is formed. But in an alloy with a freezing range where there is a large mass of pasty metal, as solidification proceeds, the gas is concentrated in the interdendritic liquid which is the last material to solidify. When the final solidification occurs, therefore, there is a considerable increase of gas evolution and the gas that is evolved in between the partially solid crystals cannot escape. In extreme cases, such as that of phosphor-bronze, where the freezing range is even longer than in an ordinary bronze, gas may be evolved at a temperature of, say, 700 deg., when there is still, throughout a large area of the casting, liquid metal between the primary solid crystals. Such gas evolution inside the casting may actually force out the liquid metal through any channels that are still open to the surface, a phenomenon known as "tin sweat." Wherever tin sweat appears, it is due to internal gas evolution forc-

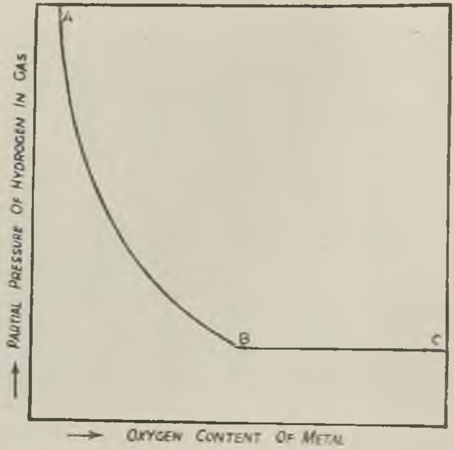


Fig. 7.—Typical Curve showing Equilibrium Relations between Hydrogen and Oxygen in the Molten Copper (Allen and Hewitt).

ing out of the casting the tin-rich liquid which is the last of the material to solidify.

So far consideration has been given only to a single gas which dissolves in the metal and is evolved on solidification. But there are other causes of gas porosity, such as reaction between two soluble materials producing an insoluble compound on solidification. In the case of copper, hydrogen and oxygen are both soluble in the liquid and on solidification of copper containing both these gases in solution steam is formed, which is insoluble and forms gas holes.

The amount of hydrogen and oxygen that can exist together in solution in molten copper is balanced; the one bears a direct ratio to the other. Actual curves for the equilibrium between hydrogen and oxygen have been worked out by Allen and are of the type shown in Fig. 7. If the oxygen content of molten copper is low, then the hydrogen content in equilibrium with it will be high, and conversely. This means that in a gassy copper containing a large volume of hydrogen, severe oxidation followed by removal of excess oxygen will give metal much freer from gas.

How Gases Originate

Soluble gases find their way into the metal from a number of sources. They may be present in the raw materials; hydrogen, for instance, is present in large quantities in cathode copper in which it is retained during the actual electrolysis. Secondly, some gases present in the furnace atmosphere such as hydrogen and sulphur dioxide will dissolve in the molten metal if they are permitted to come into contact. Thirdly, there may be gases in the furnace atmosphere which will react with the molten metal liberating hydrogen. Chief in importance in this category is steam, which will react with many molten metals forming an oxide film, which may dissolve or be slagged off, and hydrogen which goes into solution. Reaction of the molten metal with steam is a very common and prevalent source of hydrogen pick-up.

Table II.—*Effect of Steam in Furnace Atmosphere on Soundness of Aluminium-Alloy Castings.*

Ingot no.	Material.	Treatment of Molten Metal.	Density.	Appearance.
5	U. "3L11" ..	None. Standard test casting	2.771	Moderate.
6	,, ..	Atmosphere of steam for 1 hr.	2.728	Very bad.
7	,, ..	Brisk stream of steam bubbled in for 1 hr. ..	2.221	,,
8	,, ..	Brisk stream of steam bubbled in for 3 min. ..	2.690	,,
12	Virgin aluminium ingot	None. Standard test casting	2.673	Practically sound.
13	,, ,,	Brisk stream of steam bubbled in for 3 min. ..	2.469	Very bad.
14	"2L5"	None. Standard test casting	2.934	Moderate.
15	,, ...	Brisk stream of steam bubbled in for 3 min. ..	2.788	Very bad.

(Hanson and Slater, J. Inst. Metals, 1931, vol. 46)

Table II taken from the results obtained by Prof. Hanson and Dr. Slater during their research for the British Non-Ferrous Metals Research Association, gives some figures for the density of aluminium and aluminium-alloy castings which have been treated with steam when in the furnace, and illustrates the very serious deterioration of the metal melted under these conditions.

A.—Virgin Aluminium (O.P.). Not exposed.

B.—O.P. Exposed outdoors for 2 months.

FIG. 8.—EFFECT OF EXPOSURE TO CORROSIVE CONDITIONS ON SOUNDNESS OF ALUMINIUM SUBSEQUENTLY CAST (HANSON AND SLATER).

Hydrogen can also be absorbed by solid aluminium before melting. Prof. Hanson and Dr. Slater have shown that if aluminium is exposed to corrosive conditions, hydrogen is actually dissolved in the solid metal during corrosion. This does not mean that a piece of sound aluminium exposed to corrosive conditions becomes unsound, but that hydrogen is dissolved in the solid metal and causes pin-holing on subsequent re-melting and re-casting. In the experiments referred to, a stock of virgin aluminium of uniform composition, from the same bulk supply, was obtained. Some of this was immediately re-melted and re-cast; the casting showed only slight pin-holing (see Fig. 8A). A further quantity of the original material was exposed out of doors for two months and became badly corroded; when re-melted and re-cast the resulting casting was very unsound (Fig. 8B). The effect persists if the corrosion product is removed before re-melting. How far this reaction occurs with other metals is not known, but zinc appears to behave similarly.

Removal of Dissolved Gases

Passing to the removal of dissolved gases, oxidation of copper containing hydrogen has already been referred to. The same applies to a certain extent to tin bronzes from which by suitable oxidation a certain amount of hydrogen can be removed. Another method, more generally applicable though used with varying degrees of success, is very slow solidification in the furnace. It has already been mentioned that slow solidification allows dissolved gases to escape from the metal completely. If a metal is therefore allowed to solidify in the furnace and is then rapidly re-melted and re-cast it will have given up much of its dissolved gas. There are practical difficulties in this, in that it is an expensive matter to solidify a 600-lb. pot of aluminium in the furnace and re-melt and re-cast it. But the principle is interesting and important.

Another suitable method is vacuum melting. Fig. 9 shows some results obtained in Germany by Rohn, who has melted large charges of a nickel-chromium alloy (3,500 kg.) *in vacuo*, and has removed large volumes of gas during the actual melting period in a vacuum furnace.

A promising method of eliminating dissolved gases, and one which has been applied in a variety of ways, is treatment with some inert gas, such as nitrogen, chlorine, titanium tetrachloride, etc. It has been mentioned that the solubility of a gas in a metal is proportional to the square root of the gas pressure. If, therefore, gases containing hydrogen are swept off from the surface of a melt of metal which contains this gas in solution, hydrogen will pass out of the metal in an attempt to establish equilibrium. The continuous removal of, or the lowering of the pressure of, the soluble gas on the surface of the metal brings out the gas from solution. Archbutt has done this by bubbling nitrogen through aluminium; Prytherch has done it with nitrogen in copper, and Hanson and Slater have used nitrogen and chlorine in aluminium.

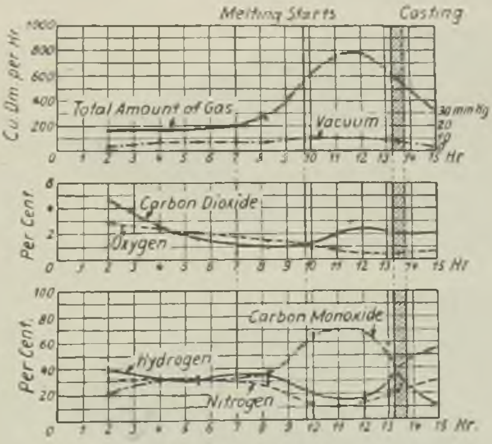


Fig. 9.—Removal of Gases from 3,500-kg. Charges of Nickel-Chromium Alloy by Vacuum Melting (Rohn).

Fig. 10 shows the improvement effected in 3L11 alloy by treatment with mixtures of nitrogen and chlorine, or with chlorine. In the same way, Rosenhain, Grogan and Schofield have

A.—"3L11." Not treated.

B.—"3L11." Dry nitrogen. 20 min. at 700 deg. C.

C.—"3L11" Chlorine. 20 min. at 630 deg. C.—640 deg. C.

D.—"3L11." Chlorine and nitrogen. 20 min. at 700 deg. C.

Reduced approximately 50 per cent. in reproduction.

FIG. 10.—IMPROVEMENT IN SOUNDNESS OF 3L11 ALLOY BY TREATMENT WITH INSOLUBLE GASES.

treated aluminium alloys with titanium tetrachloride; the bubbling of titanium tetrachloride through the material in a similar way permits the gases in solution to escape more readily.

Apart from these methods of gas removal, much can be done to prevent gas porosity in aluminium, by avoiding the use of corroded aluminium and by avoiding water vapour in the furnace atmosphere—*e.g.*, from damp coke, fluxes giving off water, damp refractories, etc.—and by avoiding a hydrogen-containing atmosphere. It has been the custom to melt in a reducing atmosphere to avoid oxidation, but with many types of metal it is now recognised that it is far less harmful to melt in an oxidising atmosphere. Phosphor bronze is far more liable to "tin sweat" if melted in a reducing than in an oxidising atmosphere.

The importance of avoiding the use of damp refractories has been shown by Zeerlederan, Hanson and Slater. Four castings were made in new crucibles using the same ingot. All except the one which was dried for 16 hours at red heat showed imperfection. It is very difficult to dry refractories completely. Heating to 500 or 600 deg. in the furnace before putting in the charge is not sufficient and several charges are necessary before the refractory is really dry.

Entrapped Gases

There is little to add about the third cause of porosity, *i.e.*, entrapped gas, the causes of which are fairly obvious. They include bad design, bad venting, the injection of gases with the stream, etc.—and there is little that one can usefully say on the subject, beyond the general statement that too low a casting temperature must be avoided if entrapped gases are to be avoided. Gases are always injected with the stream of metal during casting, and cannot be avoided by ordinary top-pouring methods in which the stream carries down gases from the atmosphere, whatever that may be. The temperature must be sufficiently high to enable such large bubbles of gas to escape before the material solidifies.

An attempt has been made to review the main causes of porosity in non-ferrous metal castings from a general point of view, and the application of this general knowledge can only be left to particular cases to the individual foundrymen directly concerned.

Scottish Branch (Falkirk Section)

LIGHT CASTINGS FOR ENAMELLING

By H. B. McNair (Associate Member)

In dealing with the subject of light castings for enamelling, it is not intended, in this Paper, to develop the metallurgical aspect too greatly, but to treat the problem as it applies to the practical foundryman. In so far as the latter is concerned, he is required to produce castings which will at least have the following properties:—Freedom from distortion or breakage during the enamelling process, and freedom from surface defects or inclusions likely to interfere with the application of the enamel or the properties of the finished product.

The first of these properties, *i.e.*, the ability of the material to withstand physical changes during enamelling, is partly a question of design and partly one of strength of material. It is not intended to discuss the design of castings for this purpose, as the subject merits a fuller treatment than can be attempted here, but to confine the issue to those factors under the control of the cupola and the moulding shop. When the surface of a casting, from a green-sand mould, is sandblasted previous to enamelling, a number of small holes and dark-coloured patches may be laid open, usually in the vicinity of runners and gates. These inclusions can often be scraped out, leaving rough depressions in the surface, which must be filled in with some compound before the enamel can be applied. In addition to this, the casting may fracture during the annealing or subsequent treatment, although analysis, design and other factors may appear quite normal.

In tracing the probable cause of these defects, it is found that when molten metal enters a mould, impurities from at least three distinct sources immediately begin to accumulate. Firstly, the heat and flow of the iron cause a certain amount of erosion of the mould, and the dirt so formed will naturally rise to the upper surface of the metal, accumulate and form a dirty patch on the surface. Secondly, the metal generates steam from the moisture in the facing sand, resulting in a surface oxidation accompanied by a liberation of hydrogen, the latter escaping through the vents of the mould along with the other gaseous products. If such oxidation does take place to any marked degree, the result will be a scale similar to that formed on wrought iron in a smith shop. The third source of trouble is associated with the metal itself, and may be caused by impurities in the materials charged, oxidation during melting with the formation of complex oxides, and by slag mechanically retained by the metal. These three, then, are the main sources of trouble, and no matter how careful the moulder may be, dirt will always accumulate from them more or less.

Cupola Control and Materials Used

In making a selection of raw materials for the cupola melt, reliance is usually placed upon analyses either determined in the laboratory or taken in good faith from the suppliers. In the case of pig-iron, apart from the constituents already mentioned, there are impurities present to a greater or less degree which may detrimentally affect the resultant casting. These are generally in the form of complex oxides, and can be recognised under the microscope at low magnification. The practical foundryman will agree that there are such irons, sound as regards analysis, that are mechanically weak and brittle, and are to be regarded with suspicion. This weakness is undoubtedly due to the impurities mentioned, and will be found difficult to eradicate, the usual method being to "dilute" the impurities by the addition of a pig-iron of superior quality.

The ordinary method of cupola fluxing by calcium carbonate (limestone) or calcium fluoride (flux) has little or no effect on the removal of such impurities, and a deoxidiser must be employed either in the cupola itself or in the bogies. There are a number of such deoxidisers on the market, such as ferro-manganese, carbon-free manganese, ferro-titanium, ferro-chrome, etc. Reduction by manganese or its alloys with iron is the most popular method, however, and a certain amount of success can be expected if the procedure is carried out correctly. The best results will usually be obtained by additions of carbon-free manganese in briquette form to the bogie, as the affinity of manganese for oxygen and sulphur is so great that cupola additions are apt to result in a heavy loss of the manganese before the latter can effect any deoxidation of the metal. Definite improvement can be obtained, however, by additions to the metal in the bogie, and if properly carried out, improved physical properties will result. When using manganese in this form, it is generally claimed that, as only 0.20 per cent. to 0.40 per cent. manganese is required to deoxidise the metal, any excess manganese will pass into the metal, and have a refining action upon it. These claims appear to be borne out in practice to a certain extent, the tensile and transverse strengths being increased by amounts up to about 10 per cent. When ferro-manganese or spiegeleisen is used, however, there is a danger of the manganese being totally taken up by the iron with very little scavenging or reduction of the oxides. The manganese here is in the form of a double carbide of iron and manganese, and before the manganese is free to effect any reduction this double carbide must be broken down. The breakdown takes place comparatively slowly, and only at fairly high temperatures, so that unless these factors are in its favour, most of the manganese will find its way into the metal without any reaction upon the oxides, and will probably result in a loss of fluidity and chilled castings. Briefly, then, the mechanical strength can be definitely improved by deoxidation, but preferably by free manganese addition to the bogie. The dangers of using dirty, rusty, or very light scrap in the cupola need hardly be stressed here, as this point has been laboured repeatedly in technical journals. Such practice will usually produce an iron mechanically weak, for the reasons already stated, and deoxidation by some method must be resorted to.

A further source of oxide inclusion in the metal is in the blast condition. It is indisputable that a low blast pressure, in conjunction with the proper volume of air, which is more important, will give good results, but it is often impossible—especially when fan speed, blast main size and tuyere areas are fixed—to deliver the necessary weight of air per minute to give the hottest and most efficient melting. If an increase in fan speed is possible and is attempted in an effort to increase the melting rate and metal temperature, then in all probability oxidation of the metal will occur. Again, a dense coke or one with a poor combustibility will tend to give a slower combustion, and therefore a lower melting rate, and it follows, if the combustion is slower than usual, and if the same volume of air is passing through the cupola, there must be an excess of air or oxygen over the required amount, and this will readily cause oxidation of the metal. If, therefore, fast and efficient melting conditions are desired, the combustibility of the coke should be as high as possible, and if in addition oxidation is to be avoided, the air condition, both volume and pressure, should be adjusted accordingly.

Cupola Cokes

Generally, in foundry practice, the question of ash and sulphur contents of coke is a secondary consideration, more attention being paid to calorific value and combustibility, *i.e.*, the possible melting rate attainable. But actually the ash, and therefore the sulphur content, of the coke is extremely important in view of the possible sulphur pick-up. It has been shown by experiment that practically all the sulphur originally present in the charged metal is retained in the re-melted iron, while from 30 per cent. to 50· per cent. of the sulphur in the coke is picked up by the charge. The amount of sulphur picked up appears to depend on at least three factors, namely, (1) the percentage of sulphur already present in the metal; (2) the percentage of sulphur in the coke; and (3) the temperature of the molten metal, and slag. The first two factors are closely related, so that there is no advantage in starting off with a low-sulphur charge if the coke has a high sulphur content, as the resultant melt will probably be high in sulphur. Very little of a definite nature has been done on the cupola in the examination of the sulphur pick-up with variations in ash and sulphur contents in the coke, but some work has been done on their effects on blast-furnace working, and an examination of the results might be interesting. In a published report by C. S. Gill, he gives a comparison between ash content of the coke charged and the average sulphur in the resultant pig-iron. Unfortunately, the sulphur contents of the cokes are not included, but it is assumed they were proportional to the ash contents. He took hourly analyses of coke and pig-iron over a period of 29 hours, and his results graphed are shown in Fig. 1.

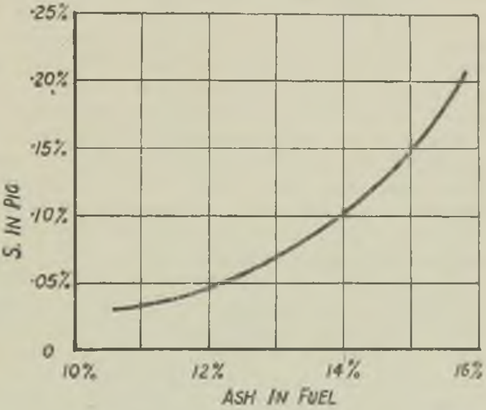


FIG. 1.—SULPHUR INCREASE IN PIG-IRON RELATED TO ASH IN COKE.

Personal observations on the cupola tend to show that the "pick-up" in the melt rises very sharply when the ash and the sulphur in the coke rise comparatively slightly. The third factor, *i.e.*, the metal temperature, has a definite bearing on the sulphur content of the melt by virtue of the increase in solubility in the iron of the metallic sulphides, with increase in temperature.

Limestone Fluxing

In turning to the question of elimination of sulphur from the melt, there are two methods open to the foundryman. The first method is limestone fluxing. The addition of limestone to the cupola charge by about 25 per cent. of the coke weight will result in a lime content in the slag of about 30 per cent., at which point the maximum amount of desulphurisation is supposed to have been reached, the slag containing about 0.8 per cent. sulphur. The addition of fluorspar (calcium fluoride) will produce a more fluid slag, but the reduction of sulphur is affected very little. It is regarded as certain, however, that a fluid lime slag is a better desulphurising agent than a viscous one. These two conditions will probably arise in the shallow well and in the deep-well cupolas. In the latter, where the slag is considerably below the fusion zone, its temperature falls, and it becomes viscous and loses its desulphurising properties. As mentioned previously, it is only the sulphur in the coke which is affected, the limestone addition appearing to have no effect on the sulphur in the charged metal.

The second method of desulphurisation entails the use of high-manganese pig in the charge or the use of free manganese or manganese alloys, as mentioned previously, for the reduction of oxides. In this case, however, it is best that the reactions take place in the cupola, as they depend on the well-known law that "the ratio of the FeS : MnS in the slag to the FeS : MnS in the metal is a constant." Therefore, if the sulphur in the metal tends to rise, part of it will pass into the slag to maintain the constant, *provided* the slag is reasonably rich in MnO and FeO. This is probably what occurs, especially when free Mn is added to the charge, as, allowing for the maximum of 0.40 per cent. Mn required for deoxidation, the excess of Mn added does not seem to reappear wholly in the metal, but is probably oxidised and enters the slag either as MnS or MnO. Over a considerable number of tests the highest percentage of Mn recovered was approximately only 10 per cent. of that added in the free state to the charge. The cost of this method is a little high, and the results are apt to vary considerably, part of the desulphurising effect being probably negatived by a further " pick-up " due to superheated metal. This will tend to occur during the first hour of the melt, when conditions are in favour of hot and fast melting, resulting in an increased solubility of sulphides in both slag and metal. The graph (Fig. 2) shows the solubility of K (Mn × S) against temperature.

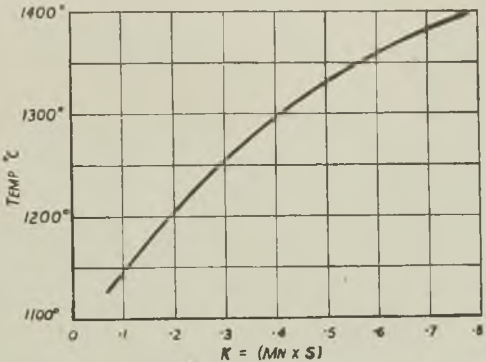


FIG. 2.—SHOWING INFLUENCE OF TEMPERATURE ON SULPHUR-MANGANESE CONTENT.

The graph will explain many of the casting losses due to dirty surfaces, and holes lying just under the skin. Examination of many of these defective castings has shown the sulphur concentration at the surface to be often as high as three times the sulphur in the casting (the lower part), and in nearly every case the metal had been tapped very hot and had been drawn some considerable distance away, the drop in temperature due to the time factor allowing the sulphide to be thrown out of solution, causing segregation. In a Paper* on "The Elimination of Sulphur from Iron," mention is made of this decrease in solubility, with decrease in temperature, as a means of sulphur reduction, but it can only apply when the metal is in contact with slag and when the fall in temperature will not affect the fluidity of the metal. In steelmaking it is claimed that by this method, if the manganese content and the temperature are correct, 75 per cent. of the total sulphur can be removed.

Soda Ash Treatment

Of late, there has been an increasing tendency amongst ironfounders towards the use of soda-ash for desulphurisation of the melt, usually in the bogies. The reactions can be set down simply as a decomposition of the sodium carbonate into sodium-oxide and carbon dioxide. The former unites with the slag particles and iron oxide and sulphide inclusions, forming a very mobile slag of low density which rises through the metal, and acting as a cleanser, absorbs some of the sulphur present. The carbonic-acid gas, bubbling up through the metal, will assist in the liberation of occluded gases and impurities of low density, which may be mechanically trapped in the metal. It is claimed that, by the addition of from ½ per cent. to 1 per cent. of soda-ash, up to 50 per cent. of the sulphur present can be removed from the metal. It is essential, however, that clean bogies be used, *i.e.*, bogies free from cupola slag, as the presence of silicates will result in a resulphurisation of the metal. For this reason, soda-ash cannot be used as a cupola addition. In practice, the time required for the operation is a definite handicap, and the removal of the last traces of the "soda" slag is difficult. The results to be expected are limited to

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* Foundry Trade Journal, Vol. 40, No. 760

a partial and variable desulphurisation, no appreciable improvement in mechanical properties having been personally noted, although there definitely is a reduction in the pitting or marking of the surface of castings where these are due to sulphur.

In passing from desulphurisation, it might be advisable to mention the general attitude of several authorities on this question. They maintain that, " if the manganese be kept at a suitable figure, there does not appear in the ordinary way to be any necessity for desulphurising, particularly if cupola conditions are good and adequate limestone additions are made to the charge." The latter statement, *i.e.*, " if cupola conditions are good," requires a little explanation, for if hot metal, and therefore hot slag, are being obtained, the solubility of both these for sulphur will tend towards a maximum. The manganese content, which is stated to balance the sulphur, is calculated at 1.7, multiplied by the sulphur content, plus 0.3 per cent. manganese. In this ratio the sulphur is said to exist as manganese sulphide, and the iron is at its softest with respect to these two elements. While this rule will generally hold good, it is liable to be upset by other factors. An instance which might be mentioned, and with which most foundrymen are probably familiar, is the formation on the surface of castings of what is known as " shagreen." This takes the form of small pellet-like extrusions, usually in clusters on a flat surface, which are extremely difficult to remove by fettling. On careful removal and examination, these pellets may be found to contain about 30 per cent. sulphur and the balance iron, approximating to the iron-iron-sulphide eutectic, which contains 85 per cent. iron sulphide and 15 per cent. iron and which has the very low melting point of 980 deg. C. If sulphur prints are taken of the casting in the immediate neighbourhood of these extrusions, sulphur segregation will be found to have taken place. The castings will be hard, and will in general be mechanically weak. Yet in nearly every case which has been noticed the manganese was in excess of that required for stabilisation of the sulphur. In one case the sulphur was 0.07 per cent. (average) and the manganese 0.82 per cent., a ratio in which the sulphur should have existed as manganese sulphide, and as this has a very high melting point (1,610 deg. C.), no extrusion should have occurred, but the segregation and throwing out of iron sulphide seemed to contradict this general rule. The remaining constituents were more or less in accordance with the usual practice.

Moulding Sands and Facings

Assuming that a good sound iron, relatively free from impurities, is available, there remains the equally important question of the suitability of the moulding materials, or, what is still more important, the facing material of the mould. The chief properties required of a green-sand mould come under three headings: Permeability, Strength and Refractoriness. The refractoriness of a sand, *i.e.*, its ability to resist the conditions of reduction and fusion which exists in the mould when cast, is controlled by the amount and nature of certain constituents of the sand, such as clay (hydrated aluminium silicate), felspar (alkali aluminium silicate) and other minerals. These may be very fusible and may tend to lower the refractoriness of the sand, causing "burning on." This property of the sand, however, is rarely of vital importance in grey-iron practice, as trouble from this source is infrequent, so that the main points to be considered are permeability and strength.

Permeability is defined as the property of a material for allowing the passage of gases through it, and if the conditions which exist within the mould when cast are borne in mind, the desirability for a fairly high degree of permeability will be understood. With probably 5 per cent. to 10 per cent. moisture and up to

20 per cent. coal dust in the sand, there will be a fairly rapid generation of steam and gas when the liquid metal fills the mould. One volume of water at ordinary temperature becomes about 2,800 volumes of steam at 1,200 deg. C., and this, if escape is not easy and rapid, will, in conjunction with the gases from the binders, cause a back pressure in the mould resulting in faulty surfaces and blowholes. The strength of the sand is its property for retaining its shape and resisting a break down when the pressure and flow of the molten metal act upon it, and this property and the permeability are governed by more or less the same factors. These are:—The size and shape of the particles; the amount and distribution of the bonding material present; the moisture content; and the apparent density of the mould, *i.e.*, the amount of ramming to which the sand has to be subjected. The mechanical analysis of a typical sand shows that it contains two main constituents. The first of these, forming 80 per cent. and more of the total weight, is composed of sharp sand, *i.e.*, grains of silica or quartz, which have no strength in themselves and depend on the second constituent for bond.

This second constituent can be termed clay, and exists normally as a hydrated aluminium silicate. Varying amounts of other materials are also present, and of these might be mentioned hydrated iron oxide, which may be present in amounts up to 4 per cent. Far from being regarded as a harmful constituent, it is found that sands which contain proportions of this oxide will usually have a longer life than those without it. This is due to the ability of the oxide to absorb water and reform the hydrated oxide, thereby maintaining the bond or strength of the sand. The clay bond has not this property of reverting to the hydrated state on the addition of water, so that if the strength of the sand depends principally upon it, there will be a gradual weakening of the material, and it will be found necessary to strengthen it by the addition of new sand. Since the strength of the sand depends on the clay bond, it will therefore vary as the proportion of the clay varies, and as the clay is stronger in the hydrated state, it follows that indirectly the strength of a sand will vary according to the amount of moisture present. This statement is generally correct up to a certain moisture content and will be mentioned later.

These statements assume that other factors do not adversely affect the material, *e.g.*, the size of the quartz grains which, theoretically, should be uniform, and the distribution of the clay bond around the particles. It has been shown (in a Paper on "Sand Testing" by W. Y. Buchanan—Proceedings of the I.B.F., 1931-32) that there is a marked increase in the strength and permeability of a sand when it is properly milled.

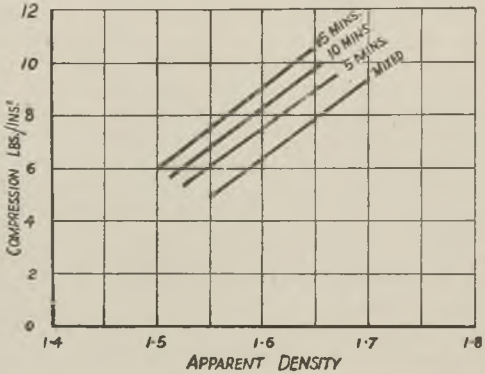

FIG. 3.—INFLUENCE OF MILLING ON THE PROPERTIES OF SAND.

Fig. 3 shows the strength of the sand in lbs./sq. in. against apparent density, and it can be seen that after 10 minutes' milling an increase of about 50 per cent. in the strength was obtained. The permeability of the sand was also increased by about 30 per cent. after the 10 minutes' milling. Assuming, then, that the sand is well milled, its strength appears to depend on the apparent density of the mould and the moisture content, and it will be found that upon these factors also depends the permeability. For a comparison of the strengths and permeabilities of sand with varying densities and moisture contents, several instruments or apparatus have been devised, but as yet no common ground of agreement has been reached. A year or two ago the British Cast Iron Research Association gave details of a sand-testing equipment (modified since then), which, though severely criticised, makes definite advancement towards the problem of sand control in the foundry. The equipment referred to consists, among other things, of a compression tester for the determination of the strength of a sand under direct crushing load, and a permeability instrument for determining this property. More especially in the case of the compression apparatus are objections raised, mainly to the size of the test-piece (which is 2¼ in. by 1 sq. in.) and to the irregularity of the ramming obtained by hand. Modifications have been tried and better results are claimed by lengthening the corebox and using a definite weight of sand for each density required, the core being formed by compression to the usual size by means of the steady downward pressure of a rod of equal diameter to the core, the pressure being applied mechanically. The permeability test consists in ramming a cylinder of 800-c.c. capacity, determining the apparent density by weighing, and passing coal gas at a regulated pressure upwards through the cylinder, and noting the time required for the ignition of the gas at the upper end of the cylinder. To obtain some idea of the conditions under which maximum strength and permeability are obtained, a series of test-pieces are rammed to various densities but at a constant moisture content. The results are obtained and plotted graphically. The moisture content of the sand is then altered and the operations repeated, until a series of curves are obtained correlating apparent density, moisture content, strength and permeability. Generally, the results of such tests show that up to a certain point the harder a sand is rammed the stronger it will become, but after this point the strength will be reduced due to the destruction of the clay bond round the grains.

The permeability will generally drop as the apparent density rises, for the same reason as before, *i.e.*, a filling-up of the inter-grain spaces by the clay bond. It will be found difficult to directly compare the results of tests of different sands because of the difference in apparent density when rammed under the same applied load or pressure. One sand, when its strength is plotted against apparent density, may appear to give better results than another, when actually they may not be quite so good. The graphs (Fig. 4) may illustrate this point.

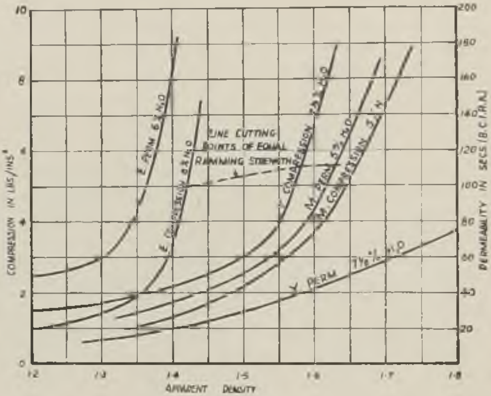

Fig. 4.—Interrelationship of Compression Strength, Permeability and Apparent Density.

From the curves in Fig. 4 it would appear that sand " E " is superior as regards strength to either " Y " or " M." It was found by trial, however, that for similar ramming strengths, the apparent densities of " E," " Y " and " M " were respectively 1.42, 1.58 and 1.66. These are approximate figures, being the mean of several test-pieces rammed by hand with as near as possible the same strength. If the strengths are now compared against equal ramming strengths, " E " is seen to fall slightly below both " Y " and " M," and a glance at the permeability curves further strengthens the opinion that if a comparison of sands is to be attempted, it would be more practical to plot ramming strengths against compression and permeability. In the permeability curves the balance at first appears to be heavily against sand " E," but if ramming strengths are again considered the difference is reduced to a marked degree. It will be noticed that the graphs are plotted with sands containing a definite moisture percentage. It was stated in a Paper on " Sands and Sand-testing " by Dr. Skerl, in the Institute of British Foundrymen Proceedings for 1930-31, that " the sand has little or no strength with only small amounts of water, but by increasing the moisture content the strength is increased until a percentage is reached at which the sand is strongest. Further addition of water results in a decrease in the strength of the sand." In a later Paper by W. Y. Buchanan it was stated that the latter part of the statement was hardly correct. He showed from a series of curves obtained with different moisture contents, that on calculating the densities to a standard moisture content (he mentioned 5 per cent. moisture) the differences in strength disappear and the curves almost coincide. Results show this to be fairly correct, there being a rapid increase in strength up to a certain moisture content above which there appears to be little increase or decrease in strength until a H_2O content is reached which destroys the plasticity of the sand. The moisture content at which this maximum strength is obtained will, as stated before, vary with the amount of bonding material present. In Fig. 5 the curves show the compression strength of " M " sand for various moisture contents, and illustrate the above explanation of the apparent drop in strength with increased moisture above that required for maximum strength.

The results of the permeability tests cannot be explained in the above manner, the permeability of almost every sand increasing with an increase in moisture content considerably above the optimum required for maximum strength, even when allowance was made for the increase in apparent density due to the additional moisture. From the compression curves, however, the maximum strength is seen to be obtained with a moisture content of about 4.8 per cent., and higher moistures appear to lower the strength, but if the densities are calculated back to a 4.8 per cent. basis it will be found that the curves almost coincide. The examination of several types of sand shows results all tending to support the belief that there is an optimum moisture content at which the sand is strongest, and that increase in moisture above this and up to a certain point, has little effect on the strength of the sand.

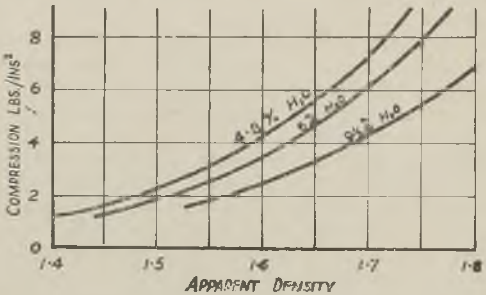

FIG. 5.—INFLUENCE OF MOISTURE CONTENT ON APPARENT DENSITY AND COMPRESSION STRENGTH.

Coal Dust

As it is customary to make additions of coal dust, rock sand or other " binders " to the facing sand, an examination of their effects on strength and permeability should be considered, especially in view of the diversity of opinion regarding their functions. By increasing additions of rock sand up to 10 per cent. a slight increase in strength was shown with little or no difference in the permeability. Additions of coal dust, however, in amounts up to 10 per cent., gave results which might again give rise to confusion, there appearing to be a steady increase in strength as the coal-dust additions were increased.

Fig. 6 shows curves of "M" sand with and without coal dust at the moisture contents at which they were strongest. If allowance is made as before for the difference in apparent density due to the big difference in weight between equal volumes of coal dust and sand, then the curves come remarkably close together. Results on other sands showed very much the same results, suggesting that up to at least 10 per cent. there is no advantage gained in strength by the addition of coal dust. The results are only in accordance with what should be expected, as coal dust has no bond or strength in itself, and should, therefore, if anything, tend to decrease the strength of the sand. On the other hand, the permeability was in most cases reduced by the addition of coal dust, the decrease being greatest in the case of the sand which showed the highest permeability without additions. It would appear, therefore, that the addition of coal dust will have no beneficial effect on the facing sand either as regards strength or permeability, *i.e.*, up to

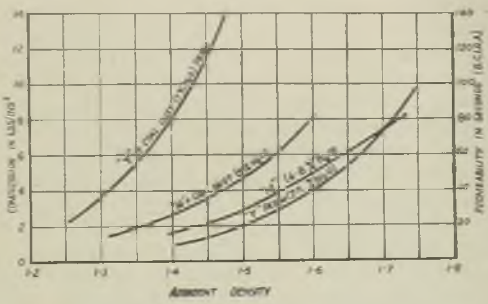

FIG. 6.—INFLUENCE OF COAL DUST ON THE PROPERTIES OF MOULDING SAND.

the percentage already mentioned. If any benefits are to be derived from its addition, then they must extend in some other direction.

Several authorities maintain that the true function of coal dust is to give the surface of the casting a better colour and finish, said to be caused by the film or tarry vapour volatilised from the coal on heating. A Paper by J. Pillon in the Proceedings of the I.B.F., 1931-32, further states that the percentage of coal dust added should vary according to the thickness of the metal to be cast. Again, it has been frequently stated in technical Papers that the advantage from the use of this material lies in the increased permeability obtained, due to the formation of coke particles from the coal dust. These statements appear to contradict each other, for if a gaseous layer between the metal and the mould is aimed at, then permeability can be of little account. Further, the formation of coke particles from the coal dust obviously means an increased volume of material, which can only take place at the expense of the permeability of the sand, which would appear to be much more important than that of the very fine pores of the small particles of coke, and, even allowing that any advantage is gained in permeability, this must be counteracted by the increased volume of gas. As for the statement that the fine blue finish on a casting is due to the use of coal dust, the same effect can be readily obtained from the use of a well-milled and graded sand containing a fair proportion of the hydrated ferric-oxide bond previously mentioned, and with no coal-dust addition. In so far, however, as a fine surface finish and colour for enamelling work is concerned, there would seem to be no reason for aiming at this, then proceeding to destroy it by sandblasting. Like coal dust, blacking and plumbago have no strength in themselves, and if applied to the mould, will at least result in a decreased permeability. Personal experience has shown that in no case has either blacking or plumbago been beneficial to the surface of a casting for enamelling, unless the facing sand has been extremely poor, and that usually the flow of metal causes the material to be "washed" into pockets or seams, resulting in a disfigured surface when the casting is sandblasted.

Gating and Pouring

The question of gating and pouring of the mould, like that of design, is one in which each type of casting requires individual consideration. Whenever possible, however, gates should always be on the edge and not on the face of the casting, and should extend along its length as far as is practical. An economy in gates will only result in an additional burden being thrown upon the facing sand which is directly opposed to the flow of metal, with a consequent "tearing up" of the former. The inference, therefore, is to fill the mould as easily and as quickly as possible. The pouring temperature will then depend, to a great extent, on the method of pouring and gating. The rusting of castings, which occurs when they are allowed to lie in contact with moist sand, is a frequent source of annoyance to the enameller, as it is maintained that, even after sand blasting, the rust will persist and cause trouble during the enamelling process. An examination of several such castings revealed that the depth to which the rust had penetrated was comparatively slight, and the removal of the rust by an abrasive or by filing before sand blasting gave surfaces which enamelled perfectly. This would suggest that "blasting" the surface, either with sand or steel grit, is by no means the best method of removal of the rust, and it might be advantageous, in such cases, to thoroughly clean the surface before sand blasting by means of an abrasive.

Conclusion

In summing up, personal experience has shown that there are two chief sources of trouble. Firstly, there is metal rendered unsound either by mechanically-retained inclusions or by "unbalanced" sulphur. Such iron can be considerably improved by deoxidation or desulphurisation. The second source of trouble is the moulder's sand heap, and without detracting in any way from the ability and carefulness of the average moulder, it may be stated that by far the greater portion of the trouble which develops, especially in relation to dirty and deformed surfaces, orginates in the sand. If more attention is paid to the maintenance of a suitable sand, strong and permeable, the percentage of enamelling-shop rejects will drop accordingly, and the foundryman will find himself able to turn his attention, in greater detail, to this problem.

Lancashire Branch

THE PRODUCTION OF SPECIALLY HARD CAST IRONS FOR ALLOYING AND HEAT-TREATMENT

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In the past, when a cast-iron part was required to be hard, the method adopted was to change the form of carbon from soft graphite to hard iron carbide, a change produced either by varying the composition or by chilling. Although iron carbide is extremely hard, the matrix of white iron is soft, and the hardness of the iron, which is the average of that of the two constituents, is not sufficient for some present-day requirements. In addition, iron carbide is brittle, so that, should a high carbon content be employed in order to increase the amount of hard carbide at the expense of the soft matrix and thereby raise the hardness, the strength and resistance to shock is reduced.

In recent years much interest has been aroused by the properties obtainable in cast iron by increasing the hardness of the matrix. This matrix may be hardened by the introduction of alloying elements or by heat-treatment or by a combination of both. In irons in which medium hardness only is required, hardening by alloying and by heat-treatment has a great advantage over hardening by chilling, because rough machining can be carried out while the castings are in the soft condition, leaving at the most only a light grinding operation to be undertaken after the hardening. In applications where the maximum possible hardness is desired, hardening of the matrix may be combined with hardening by chilling, so that high hardness levels are reached which are comparable with those obtainable in the hardest steels.

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* In the absence of the author, the Paper was presented by Dr. Pfeil.

The Relationship between Alloy Steel and Alloy Cast Iron

An understanding of the effects of alloying elements and of heat-treatment on the properties of cast iron is facilitated by considering cast iron as a steel containing graphite flakes or iron carbide. The effect of alloying elements and of heat-treatment on steel has been thoroughly studied over a period of many years, and some of the characteristics of alloy steels may usefully be considered here.

Steel consists essentially of the two elements, iron and carbon, and the value of steel as an engineering material is largely bound up with the fact that iron can exist in two forms, one of which is stable at ordinary temperatures and does not dissolve carbon to any great extent, whilst the other is stable at high temperatures and able to dissolve carbon up to about 1.8 per cent. At temperatures over, say, 800 deg. C., the steel is a solid solution of the carbon in what is known as gamma iron. When this solid solution is slowly cooled, the gamma iron changes into alpha iron in the region of 750 to 600 deg. C., and the carbon is precipitated as a compound of iron and carbon known as cementite. In carbon steels containing less than 0.9 per cent. carbon the cementite is present as an intimate mixture with a certain amount of iron, the microscopical constituent thus formed being known as pearlite.

When the high-temperature solid solution is cooled rapidly as, for example, by quenching in water or oil, the change of one form of iron to the other and the precipitation of the carbon from solution takes place at temperatures approaching ordinary temperatures, and the result of this low-temperature transformation is the production of what is termed martensite and a hardened steel.

The change in the form of the iron involves a change of volume, and by means of a dilatometer the expansion or contraction taking place in the transformation can be observed. Fig. 1

shows, graphically, the change in length of a steel specimen on heating and cooling. In the left-hand curve the uniform expansion on heating to a temperature of 720 deg. C. will be observed. At this temperature the previously-mentioned transformation commences, this being accompanied by a contraction which continues up to a temperature of 840 deg. C., when the change is complete, and the resulting solid solution of carbon in iron expands normally, though, as will be seen, at a more rapid rate than the iron did below 700 deg. C.

On cooling slowly the solid solution contracts to 780 deg. C. when the reverse transformation commences, accompanied by an expansion which is completed at 680 deg. C., after which uniform contraction of the steel continues to room temperature.

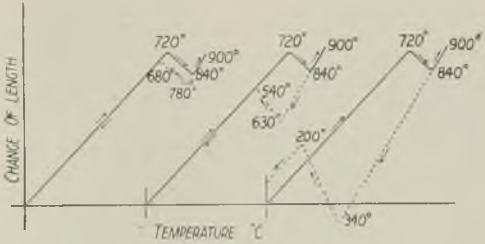

Fig. 1.—Dilatation Curves of 0.35 per cent. Carbon Steel.

The centre curve shows the effect of increasing the rate of cooling from high temperatures. It will be noted that the breakdown of the high-temperature solid solution (austenite) is now delayed until 630 deg. C. and is completed as low as 540 deg. C.

In the right-hand curve is shown the effect of the rapid cooling which results in a hardened steel. In this case uniform contraction goes on until a temperature of 340 deg. C. is reached, and it will be noted that, since the rate of contraction of the austenite is higher than that of the ferrite and pearlite matrix, when the transformation does commence the resulting expansion is greater than that which occurs when the change takes place at higher temperatures, and the steel, in the hardened condition, is in a more fully-expanded condition than when cooled slowly.

This low-temperature expansion is of considerable importance when considering the effect of quenching, since, taking place at a low temperature and, in general, at different times in different parts of the quenched article, it tends (unless suitable precautions are taken) to set up considerable stresses which may cause cracking or fracture.

In general, the effect of alloying elements in steel is to reduce the rate of cooling necessary in order to lower the transformation to the temperatures at which the hardening takes place. In other words, one can harden the steel without such drastic quenching. Indeed, it is possible, with a suitable alloy content, to produce hardening with extremely low rates of cooling

Different alloying elements, of course, act in different ways and to a differing extent, but have only a useful effect on the quenching operation when they are in solution. Nickel dissolves completely in the steel and remains in solution (both at low and high temperatures) so that it has the effect of lowering the change both on heating and on cooling.

Unlike nickel, chromium forms a carbide which is less readily soluble in the matrix than iron carbide, with the result that chromium steels must be heated to a higher temperature and for a longer time than nickel steels to ensure the solution of the chromium in the austenite, for otherwise the chromium would be ineffective in the hardening. Manganese and molybdenum act in somewhat the same way as chromium. They tend to form carbides, which must be taken into solution if effective hardening is to be produced. Silicon tends to render the hardening operation more difficult, and substantial amounts of this element are found only in special steels not required to be hardened.

It is important to note that lowering of the transformation temperature alone is not sufficient to develop high hardness, and the presence of substantial amounts of carbon and its separation from solution during the transformation are essential features of hardening.

Cast irons differ from steels in at least two important ways. Firstly, their carbon content is much higher than that of the average steel, so that a large amount of the carbon is never taken into solution, but exists as graphite in grey irons or as carbide in white irons. This means also that the carbon content of the cast-iron matrix is maintained at a higher level than is usual in most alloy steels. This also results in the transformation on rapid cooling being at still lower temperatures than those indicated in the right-hand curve of Fig. 1, so that during the hardening treatment considerable volume changes are likely to be taking place even at, say, boiling-water temperature. Secondly, the silicon content in cast iron is much higher than that usual in steels, and, of course, has an important effect, not only on the hardening characteristics due to quenching but also in determining whether the iron is grey or white. In the same way as one has to take into account the effect of silicon, one cannot neglect the effect of the addition of other alloying elements on what might be termed the essential qualities of cast iron, and particularly on the condition in which the carbon exists.

Nickel has a refining effect on the graphite in grey cast irons, as a result of which the strength properties of the irons are improved. Nickel also tends to prevent chilling, or the formation of hard iron carbide instead of graphite. Silicon has the well-known effect of reducing chill in cast iron, but it tends to coarsen the graphite and to weaken the iron. Chromium has a high affinity for carbon, forming complex iron-chromium carbides, thereby increasing the tendency of iron to chill. Since chromium is liable to separate as carbide, much of the chromium added to cast iron may be ineffective with respect to the hardening of the matrix. Manganese and molybdenum have effects on the condition of the carbon in cast iron similar to that of chromium, but to a less marked degree.

Grey Alloy Iron

Turning now in more detail to the effects of alloy additions on cast iron, it is convenient first to discuss the situation regarding grey-iron castings. During the past ten years a good deal of attention has been paid to the heat-treatment of this type of alloy iron. Three Papers on this subject have recently been published by J. E. Hurst,[1] [2] [3] while in France researches have been undertaken by Guillet, Galibourg and Ballay.[4] The Paper which Hurst gave before the Institute of British Foundrymen in 1932 on " Hardening Cast Iron " is of special interest. In this Paper the effect of nickel on depth of hardening in bars $1\frac{3}{4}$ in., 4 in. and $5\frac{1}{2}$ in. in diameter was dealt with, the irons being studied containing from 0 to 4 per cent. nickel in steps of 1 per cent. Hurst's work demonstrates well the similar response of cast iron and of steel to alloy additions.

As has already been explained, the general effect of alloy additions in steel is to lower the rate of cooling necessary to produce the hardened condition. An important effect of a reduction in the critical cooling rate is to permit the development of high hardness throughout heavy sections, which cannot be cooled rapidly even if water-quenched. Hurst showed that the addition of nickel progressively increased the hardness in the centre of the oil-quenched bars. In a $5\frac{1}{2}$-in.

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[1] J. E. Hurst, " Oil Hardening and Air-Hardening Cast Irons," Proceedings, I.B.F. Vol. XXIV, page 373.

[2] J. E. Hurst, " Further Experiments on Oil-Hardening and Air-Hardening Cast Irons," FOUNDRY TRADE JOURNAL, 1931, vol. 45, pp. 345–348.

[3] J. E. Hurst, " Hardening Cast Iron, Hardened and Tempered Cast Iron and Nitrogen-Hardened Cast Iron," Proceedings I.B.F., Vol. XXV, page 146.

[4] L. Guillet, J. Galibourg and M. Ballay, " Recherches sur la Trempe martensitique et le Traitement thermique Durcissant des Fontes," Rev. de Met., 1931, vol. 28, pp. 581–596.

dia. plain iron bar a hardness of only about 200 Brinell could be developed in the centre. A 1 per cent. nickel addition was not effective, but 2 per cent. of nickel gave a substantial improvement in hardness penetration, and, in the iron containing 3 per cent. nickel, a hardness of 360 Brinell was developed at the centre of an oil-quenched 5½-in. dia. bar.

In the Papers referred to information is also given on the effects of heat-treatment and alloy elements on tensile strength and other mechanical properties, while Everest[5] has shown how the wear resistance of cast iron may be increased by alloy additions combined with heat-treatment; it is unnecessary to go further into this aspect of the subject here.

Chilled Alloy Iron

There are certain applications where neither the hardness level obtainable by chilling, nor that which can be developed by heat-treatment, is sufficient for present-day requirements. To meet this situation chilled alloy irons have been developed, the extremely high hardness of which is dependent in part on the hard carbide which forms one of the constituents, and in part on the development of the hard condition in the matrix by the introduction of alloy elements.

The alloy content necessary for the production of this super-hard cast iron depends on the size of the castings, which in turn determines the rate of cooling. For small parts such, for example, as the plates for centreless grinders, the total alloy content might be as low as 3½ per cent.; for large castings, however, an alloy content of over 6 per cent. may be necessary since rapid cooling is impossible. An application of outstanding importance is in connection with specially hard cast-iron rolls for products required with a high finish, although there are numerous other applications where extremely high hardness, combined with high strength and high resistance to wear in a relatively cheap material is in increasing demand.

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[5] A. B. Everest, "Cast Iron with Higher Nickel Additions," FOUNDRY TRADE JOURNAL, 1932, vol. 46, pp. 193, 217, and 226.

In determining suitable compositions for any particular application, account must be taken of the various factors which, in themselves, affect the chilling propensities and heat-treating characteristics; the determination of the best compositions for any particular application, therefore, becomes a little complex. With a view to assisting those interested in this type of material, experimental work has been under way in the laboratories of the Research and Development Department of the Mond Nickel Company during several years. The results of this research do not give a complete answer to all the questions which can arise in connection with these unusually hard cast irons, but they are given here as some contribution towards the greater utilisation of what are undoubtedly likely to be extremely useful materials. The subject may be conveniently dealt with under two headings: (1) chilling characteristics, (2) hardness and structure.

Experimental Procedure for Chill Tests

Of the first importance in many applications is the depth of chill, and since this is effected by all the common alloying elements it is not sufficient to confine studies of alloy irons to hardness measurements alone; any mixture studied should be balanced in composition with respect to chilling characteristics. For the laboratory experiments 20- to 30-lb. charges were melted in a gas-fired crucible furnace under standard conditions, including melting time, maximum temperature reached in the furnace and the casting temperature. The iron was cast into a sand mould producing a block of rectangular section, 6 in. by 1 in. at the bottom, 7 in. by 2 in. at the top, and with a height of 6 in. The bottom face of this casting was cast against a chill plate 12 in. by 8 in. by 2 in. thick, which was preheated to 100 deg. C. and coated with clay-blacking wash. The casting was cooled under standard conditions, involving cooling in the mould to a dull-red heat, and subsequently stripping and cooling in an air blast. After this treatment the casting was fractured and the characteristics of the fractured surface noted.

In all the mixtures it was the aim to produce a chill depth of 2 in.; compositions which failed to give results of such an order were rejected, modifications were made and further trials cast. In one case, for example, 3½ per cent. nickel was added to an iron, as a result of which a chill depth of only 1 in. was obtained. When, however, a 3½ per cent. nickel addition was accompanied by ½ per cent. chromium, a chill depth of 4 in. was obtained. An intermediate composition containing 3½ per cent. nickel and ¼ per cent. chromium gave the desired chill depth of 2 in. Proceeding along these lines, the effects of various alloys in balanced proportions were studied, with respect to structure and hardness.

The Chilling Characteristics of Alloy Iron

Two unalloyed irons were employed for the preparation of the alloy mixtures, and the compositions of these two irons are given below:—

Element.	Composition in per cent.	
	Low Carbon Iron.	High Carbon Iron.
Total Carbon ..	2.63	3.57
Silicon	0.54	0.49
Manganese ..	0.37	0.64
Sulphur	0.13	0.11
Phosphorus ..	0.36	0.47

In Table I a series of alloy mixtures made from the low-carbon iron are dealt with, figures being given for composition and depth of chill. The term " depth of chill " refers to the portion which, to the naked eye, appears free from mottle. In some cases the compositions are given in brackets, indicating that they were not obtained by analysis.

It will be seen from these figures that the unalloyed iron gave a 4-in. depth of chill. The addition of 2 per cent. nickel accompanied by 0.29 per cent. chromium in C6 left the chill depth unchanged; 3.64 per cent. nickel together with

0.28 per cent. chromium reduced the chill in mixture C3 to 2 in.; 2 per cent. nickel together with additions of 0.5 per cent. silicon and 0.46 per cent. chromium gave a chill depth of 1.25 in. in C7, and a comparison between mixtures C6 and C7 shows the 0.5 per cent. silicon is more powerful in reducing chill than is 0.17 per cent. chromium in increasing it. Similarly a comparison between mixtures C3 and C9 shows that, at the 3.5 per cent. nickel level, an addition of 0.5 per cent. silicon is more powerful than 0.24 per cent. chromium.

Table I —*Compositions and Chilling Characteristics of Alloy Cast Irons.*

Mark.	Composition.						Chilling Characteristics. Inches.		
	T.C. per cent.	Si per cent.	Mn per cent.	Ni per cent.	Cr per cent.	Mo per cent.	Depth of Chill.	Width of Mottle.	Grey.
Base iron..	2.58	0.51	0.48	Nil	Nil	Nil	4	2	0
C6 ..	2.46	(0.5)	(0.5)	2.02	0.29	Nil	4	2	0
C3 ..	(2.5)	0.53	(0.5)	3.64	0.28	Nil	2	2	2
C7 ..	2.62	1.05	(0.5)	2.10	0.46	Nil	1¼	2¼	2½
C9 ..	(2.5)	(1.0)	(0.5)	3.58	0.52	Nil	1¼	2½	2¼
C12 ..	2.46	(1.5)	(0.5)	(2.0)	(1.0)	Nil	2½	3½	0
C11 ..	2.36	1.55	(0.5)	3.80	1.23	Nil	3½	2¾	0
C73 ..	2.69	(0.5)	2.86	2.52	Nil	Nil	1½	4½	0
C98 ..	(2.75)	1.90	5.15	Nil	Nil	Nil	1¾	4¼	0
C101 ..	2.76	2.65	7.80	Nil	Nil	Nil	[illegible]	4⅝	0
C68 ..	2.70	(0.5)	(0.5)	3.62	0.40	0.28	1⅝	3	1⅜
C79 ..	2.73	(0.5)	(0.5)	(3.5)	0.25	0.72	1¾	2¾	[illegible]

The results for mixture C73 demonstrate the balancing of nickel by manganese, and the conclusion may be drawn that manganese is about as effective in producing chill as nickel is in removing it. In this connection, however, it is necessary to bear in mind the relationship between manganese and sulphur. Sulphur causes chill, but manganese additions which combine with sulphur neutralise the sulphur chill and thereby soften the iron As a result of the researches carried out by the British Cast Iron Research Association[6] it has been found that the

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[6] A. L. Norbury, "Manganese in Cast Iron," FOUNDRY TRADE JOURNAL, 1929, vol. 41, pp. 79–83.

neutralisation of sulphur requires 0.3 per cent. manganese plus that quantity required to form the compound MnS (that is, about twice the sulphur content), hence it is only the manganese additional to this amount which has a chilling effect. Mixture C73 contained 0.13 per cent. sulphur requiring for its neutralisation 0.56 per cent. manganese, thus 2.3 per cent. manganese is left to balance the 2.5 per cent. of nickel. Making due allowances for carbon content variations it may be concluded that 2.3 per cent. manganese is barely sufficient to balance 2.5 per cent. of nickel.

The figures for alloys C98 and C101 show the balancing of manganese by silicon, and indicate that an increase in manganese content of 4.5 per cent. is balanced by an increase in silicon content of 1.5 per cent., while 7 per cent. manganese is balanced by 2 per cent. silicon. Silicon therefore is about three times as effective in reducing chill as is manganese in producing it.

Mixtures C68 and C79 show that molybdenum has little effect on chill, a comparison between these two mixtures indicating that 0.44 per cent. molybdenum has about the same effect as 0.15 per cent. chromium, a ratio of 3 to 1.

Table II deals with a series of irons of higher carbon content, the alloys containing 3.25 per cent. carbon.

It will be seen from these figures, firstly, that the base iron gave a lower chill depth than the base iron previously discussed, due, of course, to the effect of carbon in decreasing the chill depth.

A study of the three irons C15, C16 and C17, containing approximately 3.25 per cent. nickel, indicates that an increase of silicon content from 0.5 to 1 per cent. renders necessary a chromium addition of around 0.35 per cent., while a silicon addition of 1 per cent. necessitates a chromium addition of just over 0.8 per cent. Similarly, mixtures C25, C26 and C27 show that in the presence of 2 per cent. nickel a 1 per cent. silicon addition is neutralised by 0.9 per cent. chromium. It may be concluded, therefore, that when the carbon content is 3.25 per cent., the greying effect of silicon is neutralised by raising the chromium content by an amount equal to about three-quarters of the silicon addition, a conclusion similar to that based on the low-carbon irons.

The effect of nickel may be derived from a comparison between the mixtures C18 and C15, which shows that 3.5 per cent. nickel is more than neutralised by 1.21 per cent. chromium. Mixture C25 shows the 2 per cent. nickel is neutralised by 0.5 per cent. chromium, while a comparison between mixtures C18 and C19 shows that 5 per cent. nickel is counterbalanced by 1.4 per cent. chromium. These results taken together indicate that nickel neutralises the chilling effect of one-quarter of its weight of chromium.

Table II.—*Compositions and Chilling Characteristics of Alloy Cast Irons.*

Mark.	Composition.						Chilling Characteristics Inches.		
	T.C. per cent.	Si per cent.	Mn per cent.	Ni per cent.	Cr per cent.	Mo per cent.	Depth of Chill.	Width of Mottle.	Grey.
C18 ..	3.25	0.48	0.55	Nil	Nil	Nil	1½	1½	8
C15 ..	3.25	0.49	(0.5)	3.52	1.21	Nil	2½	3½	0
C16 ..	3.28	1.03	(0.5)	3.47	1.56	Nil	1¾	4¼	0
C17 ..	3.22	1.56	(0.5)	3.45	2.04	Nil	2¼	3¾	0
C25 ..	3.26	(0.5)	(0.5)	2.05	0.48	Nil	1½	1½	3
C26 ..	(3.25)	(1.0)	(0.5)	1.96	1.1	Nil	2	4	0
C27 ..	3.18	(1.5)	(0.5)	2.02	1.42	Nil	1½	4½	0
C19 ..	3.24	0.50	(0.5)	5.00	1.41	Nil	1½	4½	0
C20 ..	3.26	1.48	(0.5)	4.92	2.20	Nil	2	4	0
C23 ..	3.19	(0.5)	0.60	4.27	1.35	Nil	2	4	0
C32 ..	3.21	(0.5)	1.05	(4.5)	1.15	Nil	2	4	0
C30 ..	3.17	(0.5)	2.02	4.49	1.0	Nil	2	4	0
C34 ..	(3.25)	(0.5)	(2.0)	(3.0)	0.90	Nil	3	3	0
C55 ..	(3.25)	(0.5)	(0.5)	4.52	1.35	0.63	2¼	3¾	0
C77 ..	(3.25)	(0.5)	(0.5)	(4.0)	(1.25)	(0.75)	2¼	3¾	0

A comparison between mixtures C23 and C30 demonstrates that an increment of 1.4 per cent. in manganese demands a reduction of 0.35 per cent. in chromium, from which it follows that manganese acts in the same direction as chromium, but with a chill-producing effect only one-quarter as intense. Mixture C32 represents another type of balanced nickel-chromium-manganese iron.

The effect of molybdenum in high-carbon irons is shown by comparisons between mixtures C55 and C23. Mixture C55 contained 4.52 per cent. nickel, as against 4.27 per cent. in C23, but even making allowance for this, it is clear that molybdenum has only a weak chill-producing effect, its efficiency in this direction being about one-third that of chromium.

Consideration of the results contained in these two tables, together with the studies which have been made on a number of other alloy irons, allows the following conclusions to be reached:—

(1) Under the conditions adopted for this research iron containing about phosphorus 0.4, sulphur 0.1, manganese 0.5 and silicon 0.5 per cent. gave a chill depth of 2 in. when the carbon content was 2.9 per cent.

(2) Any increase or decrease in carbon content from 2.9 per cent. could be counterbalanced by the addition or withdrawal of three-quarters as much chromium.

(3) The addition of nickel could be counterbalanced by the addition of one-quarter as much chromium.

(4) Silicon present in excess of 0.5 per cent. could be balanced by the addition of three-quarters as much chromium.

(5) Manganese present in excess of the amount required to neutralise the effect of sulphur (in this case in excess of about 0.5 per cent.) had the same effect as one-quarter the amount of chromium.

(6) Molybdenum had the same effect as one-third as much chromium.

It will be seen that, in the above conclusions, the effects of the elements carbon, nickel, silicon, manganese and molybdenum have been compared with the effect of chromium, and therefore the relative effects of any two elements can be deduced. For example, if 3 per cent. of nickel were added to cast iron the chill depth would remain constant if the carbon content were lowered by 1 per cent. Similarly, it may be deduced that an increase in silicon content from $\frac{1}{2}$ to 1 per cent. would be neutralised by increasing the manganese content by $1\frac{1}{2}$ per cent.

It is necessary to emphasise that the chill depth produced in cast iron as well as other characteristics depend on factors other than composition, more especially on the source of the iron, on the melting conditions and on the manner in which alloy additions are made. Therefore, the conclusions given above cannot amount to more than a guide to the selection of mixtures suitable for commercial utilisation, and in nearly every case small adjustments in composition would be necessary to take account of the variables to which cast iron is subject.

The Hardness and Structure of Chilled Alloy Iron

It has already been pointed out that the alloy contents required to give extreme hardness in chilled iron depend on the rate of cooling which can be applied, and in some important applications extremely slow cooling only is possible. Attention has, therefore, been given to the hardness and other properties of both slowly-cooled and of relatively rapidly-cooled chill castings.

In the course of this research information regarding the hardness and structure of rapidly-cooled chilled alloy iron was obtained from studies of the chill test-pieces, the preparation of which has already been dealt with. For the investigation into the properties of slowly-cooled chilled alloy iron, various mixtures were cast into a $1\frac{1}{2}$-in. square iron mould. As soon as solid, each casting was transferred to a well-lagged electric furnace, preheated to 1,000 deg. C. In this furnace the castings were allowed to cool to room temperature over a period of three days, following which hardness determinations were made and the microstructure examined.

Although the hardness of cast iron is commonly expressed by scleroscope values, diamond hardness determinations are more satisfactory on chilled iron in the laboratory, and the hardness figures which follow were obtained on the Vickers diamond hardness testing machine.

It will be observed from the figures in Table III, which deals with slowly-cooled castings, that only in a few cases were hardness values below 500 obtained. The generally high hardness-level maintained was due to the fact that the mixtures employed for these experiments were selected on the basis of preliminary tests to contain a sufficiently high alloy content to render likely the attainment of high hardness in spite of slow cooling.

Table III.—*The Hardness of Slowly-cooled Chilled Castings.*

Mark.	Composition.						Vickers Diamond Hardness.
	T.C. per cent.	Si per cent.	Mn per cent.	Ni per cent.	Cr per cent.	Mo per cent.	
C19	3.24	Nil	0.5	5.00	1.41	Nil	645
C20	3.26	1.48	0.5	4.92	2.20	Nil	556
C23	3.19	Nil	0.60	4.27	1.35	Nil	685
C34	3.25	Nil	2.0	3.0	0.90	Nil	610
C98	2.75	1.90	5.15	Nil	Nil	Nil	467
C101	2.76	2.65	7.80	Nil	Nil	Nil	519
C65	2.71	Nil	(0.5)	3.69	0.55	0.26	397
C66	(2.75)	Nil	(0.5)	(3.75)	(0.5)	0.51	536
C67	2.74	Nil	(0.5)	3.72	0.58	0.75	607
C70	3.19	Nil	(0.5)	3.74	1.07	0.24	405
C71	(3.25)	Nil	(0.5)	(3.75)	(1.0)	0.52	578
C72	3.24	Nil	(0.5)	3.77	1.04	0.77	665

The two mixtures C19 and C20 had hardness values tending to show that silicon has a softening influence. Raising the silicon by 1 per cent., which permitted the introduction of 0.8 per cent. extra chromium without alteration of chill, resulted in a hardness loss of 89 points. This experiment alone is not sufficient to prove that silicon has a softening influence, but general experience with chromium in cast iron and the results of a number of experiments not dealt with in this Paper make it certain that the lower hardness of mixture C20 as compared with C19 is due to the 1 per cent. higher silicon content of C20.

Mixture C34 demonstrates the possibility of obtaining high hardness values in alloy irons in which the greying-effect of nickel is partly neutralised by the chilling effect of manganese.

Mixtures C98 and C101 represent irons in which the element producing the hardened matrix is manganese, the chilling effect of which is neutralised by silicon. The manganese-silicon combination, it will be observed, is not so effective as most of the other mixtures, in which hardness numerals nearly 200 points higher were developed in several cases.

The mixtures C65, C66 and C67 are identical in composition, except with respect to molybdenum, while mixtures C70, C71 and C72 differ also only with respect to molybdenum content, but contain 0.5 per cent. more carbon and 0.5 per cent. more chromium than the first three molybdenum mixtures. C65 and C70 were of low hardness, but mixtures C67 and C72, each of which contained about 0.75 per cent. molybdenum, were of high hardness. So far as can be judged from these results, molybdenum has a hardening effect about equal to that of nickel; thus mixture C23 and C72 have about the same hardness and differ in composition by the replacement of 0.5 per cent. nickel, plus 0.31 per cent. chromium by 0.77 per cent. molybdenum.

A comparison between the low-carbon, low-chromium group C65, C66 and C67 and the high-carbon, high-chromium group C70, C71 and C72 serves to demonstrate that higher carbon and chromium contents do not necessarily produce outstanding hardness increments.

Considered broadly, these figures indicate that the four elements nickel, chromium, manganese and molybdenum differ to no substantial extent in the production of high hardness, although none of these elements can be used singly, and, further, that, when the total alloy content exceeds 6 per cent., a high hardness will be reached in spite of very slow cooling.

With respect to small parts required of specially high hardness, interest lies principally in mixtures of lower alloy content, since the parts may conveniently be cooled at a relatively rapid rate. Table IV contains the hardness results obtained on a series of alloy irons, many of which would be suitable for small- and medium-size castings.

FIG. 2.—A NI-CR CHILLED CAST IRON, SHOWING MARTENSITIC MATRIX. × 500.

The first two mixtures demonstrate the effect of adding 2 per cent. nickel balanced by 0.29 per cent. chromium to a low-carbon chilled iron. The effect of this alloying was to raise the hardness from 464 to 498 due to a change in the structure of the matrix from coarse to fine pearlite. Mixtures C18 and C25 demonstrate a similar mild hardening effect by a 2 per cent. nickel addition to a higher carbon iron. To produce a balanced mixture the nickel was accompanied by 0.48 per cent. chromium, and these two alloys together raised the hardness from 536 to 571.

Mixtures C6, C7 and C12 and also C25, C26 and C27 show the hardness changes accompanying chromium additions balanced by silicon, the addition of about 0.75 per cent. chromium accompanied by a balancing addition of 1 per cent. silicon raised the hardness by 42 to 45 points.

TABLE IV.—*The Hardness of Rapidly-cooled Chilled Castings*

Mark.	Composition.					Vickers Diamond Hardness.
	T.C. per cent.	Si per cent.	Mn per cent.	Ni per cent.	Cr per cent.	
Base iron ...	2.58	0.51	0.48	Nil	Nil	464
C6	2.46	(0.5)	(0.5)	2.02	0.29	498
C7	2.62	1.05	(0.5)	2.10	0.46	527
C12	2.46	(1.5)	(0.5)	(2.0)	(1.0)	543
C18	3.25	0.5	0.5	Nil	Nil	536
C25	3.25	0.5	0.5	2.0	0.5	571
C26	3.25	1.0	0.5	2.0	1.1	599
C27	3.25	1.5	0.5	2.0	1.4	613
C3	(2.5)	0.53	(0.5)	3.64	0.28	710
C11	2.36	1.55	(0.5)	3.80	1.21	583
C15	3.25	0.5	0.5	3.5	1.25	803
C17	3.25	1.5	0.5	3.5	2.0	613

Mixtures C3 and C15 contained about 3½ per cent. nickel with 0.28 and 1.21 per cent. chromium respectively, and both were harder than the corresponding unalloyed irons by 250 points. Both these irons had a hard martensitic matrix, the typical appearance of which is shown at 500 diameters in Fig. 2. It is significant, however, that in the slowly-cooled conditions these two irons developed hardness values of only 345 and 429 respectively, showing that the hardening was as much a function of rate of cooling as of alloy content.

Mixtures C11 and C17 gave results of special interest, showing that chromium additions balanced by silicon had, at the $3\frac{1}{2}$ per cent. nickel level, a definite softening influence. In one case the hardness fall attributable to the 1 per cent. silicon addition was nearly 200 points and in the other case more than 100 points.

The results in Table IV demonstrate clearly that the best hardness in castings cooled relatively rapidly is to be obtained with at least $3\frac{1}{2}$ per cent. nickel, a low-silicon content and a chromium level dependent on the carbon content in such a manner as to develop the correct chilling characteristics.

The Effect of Alloy Additions on Spread of Mottle

When, to chilled cast iron, alloy additions are made in such proportions that the depth of chill remains constant, the width of the mottle zone increases to an extent dependent on the quantity of alloys added and the particular combination of alloys which is employed. This spread of the mottle is sometimes considered objectionable on the grounds that it reduces the extent of the grey backing upon which toughness is believed to depend.

Microscopical examination shows that in certain types of alloy iron fine nodules of graphite may occur even in that portion of the casting which, to the naked eye, appears to consist of clear chill. In the course of some of the laboratory experiments, sections at right-angles to the chilled surface were examined under the microscope with a view to detecting the depth at which the first nodules of graphite appeared, and the conclusion was reached that high-chromium content irons were specially susceptible to the presence of fine graphite nodules near the chilled face and within the portion which appeared chilled to the naked eye. The examination of the fractures of the chilled test-pieces demonstrated also the pronounced effect of chromium in spreading the mottle.

It has already been pointed out that, to produce a fully-hardened chilled iron, the presence of a total alloy content of at least 6 per cent. is necessary. To produce a suitable depth of chill it is essential that part of this alloy content should be made up from elements increasing the chill and part from elements decreasing the chill. If, therefore, chromium be omitted, manganese or molybdenum must take its place, and although these elements are perhaps less effective than chromium in spreading the mottle, their use does not completely overcome the difficulty.

FIG. 3.—THE STRUCTURE OF C19 1 IN. BELOW THE SURFACE. × 50.

The amount of elements of the chilling type required in iron depends on the carbon content and some advantage in avoiding the spread of mottle may be gained by lowering the carbon content. An interesting example of the effect of chromium in spreading the mottle was obtained on two mixtures, C19 and C20 (see Table II), both of which contained $3\frac{1}{4}$ per cent. carbon and 5 per cent. nickel. Mixture C19 contained 0.5 per cent. silicon and 1.41 per cent. chromium, while mixture C20 contained 1.48 per cent. silicon and 2.2 per cent. chromium. Although these two

FIG. 4.—C20, CONTAINING A HIGHER CR CONTENT THAN C19, SHOWS GRAPHITE NODULES AT 1 IN. BELOW THE SURFACE. × 50.

mixtures appeared to the naked eye to have approximately the same depth of chill, microscopical examination showed that whereas in the lower chromium mixture there was an entire absence of graphite to a depth of $\frac{3}{4}$ in. from the chilled face, in the higher chromium mixture graphite modules were present within $\frac{1}{4}$ in. of the face. Figs. 3 and 4 show at 50 diameters the structure in these two irons at a depth of 1 in. from the chilled surface, while the Fig. 5 shows at the higher magnification of 500 diameters the nature of one of these soft graphitic spots.

Fig. 5.—A Graphitic Spot shown in Fig. 4. × 500.

Precautions in Producing Irons of Specially High Hardness

In the production of alloy chilled iron certain precautions must be taken if the best results are to be obtained. Firstly, it is not worth while adding alloys to low-grade iron, and for preference a substantial proportion of the charge would consist of low sulphur-content cold-blast iron. From a technical point of view, the electric furnace is the best proposition for melting, but completely successful results have been obtained without difficulty in the air furnace.

Some alloy elements are readily oxidised during melting and while the charge is being held to adjust the temperature or composition. Nickel and molybdenum are not subject to melting losses, but carbon, silicon, manganese and chromium are readily oxidisable elements. Since losses of two of these elements decrease the chill while losses of the other two increase the chill, changes in chilling characteristics are not excessively rapid, and with careful furnace control no difficulties should arise in this connection.

The presence of alloy elements in cast iron alters certain of the characteristics upon which control is commonly based and in particular the " break " of the iron is changed to an extent somewhat disconcerting when first experienced. Iron containing chromium is generally less fluid than ordinary iron, but difficulties due to this arise but seldom.

Where control depends largely on the results of chill trials, the introduction of alloys tends to affect the judgment of the operators, owing to the spread of the mottle zone caused by the chill-producing elements. The composition in such cases should be adjusted until the desired depth of clear chill is produced in the trial and the dispersed mottle zone should not be allowed to affect judgment.

In general it is best to add nickel at an early stage. The easily-oxidised elements chromium and manganese should be held back until the charge is molten, and even then not all the chromium should be added until it has been established that the chill-depth is insufficient. Silicon should be avoided as a means of final adjustments, for the silicon can be kept at a minimum with advantage in alloy chilled iron. As the chill becomes greater its depth appears more responsive to chilling additions, and additions, especially of ferro-chrome, should be made guardedly towards the end. Temperature and time also modify the chill depth and the general effect of holding a charge in the furnace is to deepen the chill.

As has been indicated previously, special attention must be paid to the cooling of highly alloyed chilled iron, particularly where heavy sections are concerned, since the transformation which produces hardness goes on, with its accompanying volume changes, practically down to normal temperatures. Care must be taken that the cooling proceeds, even at these low temperatures, as uniformly as possible throughout the article. Uneven cooling, by for example exposure to cold wind or to rain, is likely to set up stresses which, even if they do not cause obvious cracking at once, may lead either to small incipient cracking or definite fracture when the article is put into service.

When maximum hardness has been developed by alloying and chilling, machining is difficult. The parts to be machined should therefore be cast with the minimum machining allowance compatible with the surface finish required. Grinding is generally necessary for the chilled parts of highly-alloyed iron, but portions cast in sand may be machined in the lathe with special tools. It is possible also in some cases to " let down " the hardness of a portion of a casting by a tempering heat-treatment, the remainder being kept cool by water so that the hardness is unaffected.

The possibility of attaining extreme hardness in cast iron by applying to it the experience already gained of the effect of alloying elements and heat-treatment in steel seems likely to lead to many interesting applications giving a new field of usefulness to the material in which all foundrymen are interested. It is hoped that the data set forth in this Paper may be of some use to them in this connection.

In conclusion, the author wishes to place on record his appreciation of the assistance he has received from his colleagues, Dr. Pfeil and Mr. Hallet—who carried out the greater part of the experimental work referred to—and to them and Dr. Everest for collaboration in the preparation of this Paper.

DISCUSSION

A vote of thanks to the author and Dr. Pfeil was proposed by MR. J. S. G. PRIMROSE, who said it would be quite a revelation to most of the members to think that by annealing, and what they would regard as the softening of cast iron, it could be made to possess, with the additions mentioned, what would be described as exceedingly hard surfaces.

MR. E. LONGDEN seconded the vote of thanks, stating the crux of the remarks concerning specially hard cast irons and the alloying elements was that the hardness was obtained in conjunction with increased strength and less brittleness. The value and strength of a cast iron depended largely upon the amount of, and condition of, the carbon content; any depth of chill could be obtained by controlling the carbon content by the use of silicon, manganese, sulphur, chromium and total carbon. By means of the special alloys outlined the required depth of chill was maintained, but with greater strength and resistance to the duty or the work that the chilled rolls had to fulfil. He recalled that it was commonly understood in the chilled-roll trade that for hot rolling high-sulphur content was taboo, while for cold rolling it was permissible. It appeared that special alloying elements could be produced with greater benefit to the rolls which were used for hot rolling. With regard to the cracking which occurred in chilled rolls, probably the information contained in the Paper would go a long way to aid chilled-roll manufacturers. Even old-established firms had not at their disposal the information which had been communicated that afternoon. There were various types of cracks in connection with chilled rolls. There was a vertical crack which was attributed to the metal mixture or composition principally, although there were other reasons, and there were also horizontal cracks which were attributed to bad moulding practice, such as resistance to the contracting casting by the mould, etc. He stated that the white chilled area could not be machined. Probably he meant the metal with very high Brinell hardnesses, otherwise it was common to machine chilled rolls. His company manufactured machines which run at much greater speeds than hitherto.

The vote of thanks was carried unanimously by acclamation.

Alloyed Roll Practice

Dr. Pfeil, in responding to the vote of thanks, said that he had not been able to discuss in detail the mechanical properties of alloy chilled irons, and, in view of Mr. Longden's remarks, it might be as well to emphasise that, by means of alloy additions, a substantially increased hardness was obtained over that of plain chilled iron of the same carbon content; thus a plain chilled iron having a hardness of 50 Shore could be raised to 70 or 80 Shore by proper alloying, while a higher carbon chilled iron, giving a hardness of perhaps 70 Shore, could by alloying have the hardness raised to 90 or 100 Shore. He was well aware that ordinary chilled rolls could be turned, but these super-hard alloy chilled irons were naturally more difficult to machine, and special tools had to be employed for the hardest varieties. He did not know whether Mr. Longden was referring to the cracking of rolls during manufacture or to fire-cracking in service.

Mr. Longden: In fire.

Dr. Pfeil said that he did not know enough about the roll trade to deal with this point.

Brinell Hardness Machinability

The Chairman (Mr. Phillips) said it had been shown in the Paper how to apportion the elements in order to maintain a certain depth of chill. Those members who were called upon in the future to manufacture chilled castings would no doubt use the excellent Tables which had been placed before them. Referring to hardness and machinability, sometimes castings showed a Brinell number of about 250 hardness. These were machined quite readily. Again, there might be a casting showing a Brinell hardness of, say, 230 and which was very difficult to machine. He would like to have an explanation of why a casting which had a higher Brinell number, which was an indication of its hardness, was more readily machined than another casting which had a lower Brinell number.

Mr. A. Sutcliffe (Bolton) asked whether chilled bowls could be made from cupola metal, and whether the white or grey portion liquefied first on remelting such scrap. He had brought four samples for the members to examine. One was a portion of a high-speed cylinder which had been in use a considerable number of years. A second, a pulley, was made by T. Jacksons, of Bolton, a firm which was now out of existence. He smashed the pulley and found that it had an exceedingly close grain.

Mr. Glen Primrose said it was cold-blast iron.

Effect of Elements on Crucible Life

Mr. J. A. Reynolds inquired whether the lecturer would give him the benefit of his experience with high-alloy irons, and principally of the austenitic form, as to their effect on crucibles. He had had a few years' experience of the high-manganese, nickel and copper type, which seemed to rot the crucible. After less than a dozen heats it seemed to eat away the clay, and the graphite seemed to coat the molten iron, so that when the castings were poured they were simply covered by flakes of graphite and the metal was sluggish and porous.

Was there any remedy for that state of things? He would like to add that chilled rolls could be turned. They were turned in his own works, in common with other rolling mills, but were not turned like ordinary cast iron with a big speed and feed. The turning was done with a fairly wide tool, and the cut made at a low speed; the roll barely turning round. The rolls were ground to the finished dimensions. He had had a fair amount of experience of alloy irons. He was rather surprised that the lecturer should have used (even for experimental purposes) several alloy elements which seemed to balance or fight one another. The majority of irons he had used with success had been of the low-silicon type with nickel alone. His experience was that using higher-silicon irons required chromium adding, which increased the cost, and added another complication. Chromium was difficult to control, being more easily oxidised, and it resulted in hard spots in the metal. It was more difficult to obtain consistent results with chromium alloyed with nickel and high silicon than was possible with low silicon and nickel alone.

Effect of Molybdenum

He had tried molybdenum, but it was the most expensive constituent he had used. Could the lecturer state what was the effect of molybdenum with, say, 1 per cent. silicon, 3 per cent. carbon and 0.5 per cent. manganese; because if it presented any points of interest or advantage over the elements he had used already he would certainly make some more experiments. He found, upon reading all the authorities available, that the results obtained were rather confusing; some stating that it was a hardener, while, in some instances, others stated it was a softener.

Replacing Nickel by Copper

Mr. H. E. Beardshaw asked whether Dr. Pfeil had any views to communicate respecting the substitution of copper for nickel. He would like to range himself on the side of the lecturer and point out that founding practice had now reached a state of extremely high development. It was the type of information contained in the Paper which was going to lead up to the only avenue in which the ironfounding industry could exist. He felt rather sorry for the lecturer when he commenced to read the Paper, because, knowing the Lancashire Branch as he did, he knew the lecturer was going to be immediately in conflict with the moulders and the patternmakers. It should be pointed out that their branches of the trade were intensely developed and did not leave much room for improvement, which was all to their credit. The only avenue for further development was the one outlined in the Paper, and it was worthy of careful consideration.

The Chairman wished to support the statement of Mr. Beardshaw about the use of alloy irons in the near future. When a lecturer came among them and spoke of martensitic, austenitic, pearlite and cementite structures they need not be alarmed and think the Paper did not apply to them. It was merely phraseology, meaning that martensitic structures were hard and austenitic structures soft, and so on; in fact, they came into contact with them everyday in different terms.

AUTHOR'S REPLY

Dr. Pfeil said that the hardness of cast iron was an average value of at least two constituents, and generally more than two constituents. One of these constituents might be very hard, but small in quantity, with the bulk of the metal soft, as a result of which a low average hardness would result. In another case there might be a complete absence of very hard constituents, and yet the bulk of the metal consisted of fairly hard material. The iron containing the hard particles might give the lower hardness value of the two, and yet prove the more difficult to machine, owing to the tool edge being damaged by the hard particles. Machinability could not be judged entirely on the basis of hardness, and he had experience of irons softer than 230 Brinell which were extremely difficult to machine. He referred particularly to improperly-alloyed austenitic cast irons containing nickel, copper and chromium. Machining difficulties in irons of this type could, however, readily be overcome by adjusting the composition so that the iron was in the stable austenitic condition.

Influence of Manganese on Crucible Life

In reply to Mr. Reynolds, Dr. Pfeil said that manganese was a readily oxidisable element, and in non-ferrous alloys, as in iron, manganese in quantity was liable to cause trouble, owing to the formation of manganese-oxide and the high affinity of this oxide for the siliceous material from which crucibles and furnace linings were commonly made. Where high-manganese mixtures were melted in clay graphite crucibles, the manganese would be liable to oxidise, combine with the clay, and form slag, and thereby free the graphite. He did not think it was possible to overcome the difficulty except by preventing oxidation, a somewhat difficult proposition.

Mr. Reynolds, like Mr. Longden, raised the question of machining chilled iron. With the tools ordinarily used for chilled iron it was a commercial proposition to machine the less hard varieties of chilled alloy iron, but where the maximum hardness was developed in the iron, turning in the lathe was not the best proposition for the barrels of rolls, although satisfactory for the necks.

Balancing the Elements

With regard to the adding of alloy elements in balanced proportions, he thought Mr. Reynolds was referring to grey iron and not to chilled iron. In the case of grey iron the addition of nickel was best accompanied by a lowering of the silicon content. Although iron caused difficulties in machining, due to the presence of hard spots, nickel additions might be made without other changes in composition. In grey iron, although a nickel addition improved machinability, it also strengthened the iron, due to its grain-refining influence. Chilled iron was a different proposition, for all alloying elements affected the depth of chill, some increasing it and others decreasing it, and, therefore, one alloy element alone was not usually satisfactory. The control of chromium additions to iron was more difficult than that of nickel or molybdenum, owing to the ease with which chromium was oxidised. Furthermore, high-chromium levels in chilled iron cause a spreading of the mottle zone. Chromium has a somewhat similar effect in grey irons, where its presence is liable to introduce mottle, with accompanying machining difficulties.

Rôle of Molybdenum

He thought it was correct to describe molybdenum as a hardener of iron, as it had a tendency to increase the chill, but he did not know on what grounds molybdenum could be described as a softener for iron. From the experiments which have been carried out in the Laboratory of the Research and Development Department of the Mond Nickel Company on chilled alloy iron, he would be inclined to describe the action of molybdenum as intermediate between that of chromium and that of nickel. He thought that molybdenum made iron easier to harden by quenching, but did not know of any experiments demonstrating that molybdenum was more effective in that direction than other elements.

Mr. Beardshaw raised the question of copper in cast iron. Neither steel nor cast iron would retain a substantial amount of copper, unless some other element were introduced as a carrier. The usual element to employ was nickel, and a good example of this action was given by the austenitic corrosion-resisting and heat-resisting irons, which contained about 7 per cent. copper, together with 14 per cent. nickel. The iron could be made austenitic without the copper, but from the practical point of view it was an advantage to have copper as part of the alloy condition. He agreed with Mr. Beardshaw's remarks concerning alloy irons, and was quite certain that these materials would be used in increasing quantities in the future. By alloying, an iron could be rendered suitable for many applications where plain iron was not good enough, and foundry directorates who turned their attention to these specialised products would reap an advantage.

Lancashire Branch (Preston Section)

THE MANUFACTURE AND APPLICATION OF CENTRIFUGAL CASTINGS

By T. R. Twigger (Associate Member)

A good deal of interesting information relating to the centrifugal casting of metals may be found in various technical journals covering the past ten or fifteen years, but perhaps of even greater interest is the large number of patent specifications relating to the process, for these show in no uncertain manner the hopes and aspirations of their authors and the particular difficulties which they hoped to overcome.

It is very probable that the idea of using centrifugal force to improve the quality of castings or to facilitate production by avoiding the use of cores had often exercised the minds of our forbears in the foundry industry, but the first official record appears to be the wonderfully complete patent taken out in 1809 by Anthony G. Eckhardt. This inventor not only appreciated the possibilities of using both horizontal and vertical moulds, and envisaged the casting of spherical bodies by rotating the mould round two axes, but shows in his eighteen illustrations a number of cases where the mould (itself rotating) revolves at a distance from the main axis of rotation. Also claims were made for the casting of bars and hoops or rings by using suitably-grooved moulds, but no mention is made of how the rings were to be removed. In his description of the process Eckhardt refers to the desire to produce castings " more perfect and neat."

It is the purpose of this Paper to give an outline of the present applications of centrifugal-casting methods, particularly those with which the author is intimately connected rather than to attempt a review of the development of centrifugal-casting methods. This has to some extent been done by others.[1] It may, however, be of interest to illustrate here two essentially practical applications as illustrated in the centrifugal casting of tyres for railway wheels, using a vertical axis as proposed by J. Whiteley in 1865 (Fig. 1), and a horizontal-mould process, patented by W. Thomson in 1873, for the casting of lead tubes, which were afterwards formed into sheet (see Fig. 2). The various methods in use at the present time may be broadly divided into two classes—those using a mould rotating on a vertical axis and those in which the axis is horizontal. In each class it is obvious that the mould may be either of metal or lined with material of a refractory nature. In

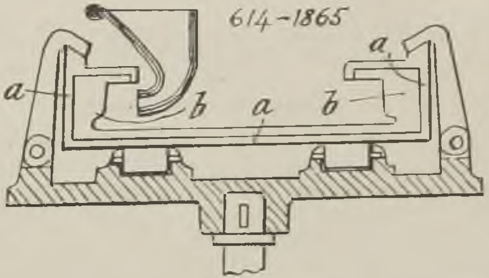

Fig. 1.—An Early Attempt at Centrifugal Casting by Whiteley.

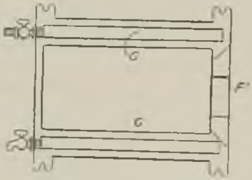

Fig. 2. — A Second Attempt made in 1873.

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[1] Proc. I.B.F., 1919-20. Foundry Trade Journal, July 15, 1927.

the case of metal moulds there may be a further subdivision, depending on whether the moulds are used hot or cold. The vertical-axis method has been extensively used in this country for the production of bronze gear wheels and bushes, it being claimed that the combination of rapid cooling and fluid pressure gives a greater density and finer distribution of the copper-tin eutectoid.

In view of the Whiteley patent already mentioned it is of interest to note that railway and tramway wheels are now produced centrifugally, advantage being taken of the process to secure greater hardness and resistance to wear in the rim by the addition of ferro-manganese at the commencement of pouring, this higher manganese steel going to the outside of the casting while the centre remains relatively soft and ductile.

Fig. 3.—Centrifugal Casting Machine used by the British Piston Company.

In addition, particulars have recently been published of a vertical axis machine.[2]

The horizontal axis method appears, however, to be in much more widespread use, being used for the production of large tonnages of pipe by

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[2] Foundry Trade Journal, July 23, 1931.

the Stanton and Staveley Companies, the former using water-cooled metal moulds as compared with the sand-lined moulds used by the second-mentioned firm.

Apart from the production of pipe, the horizontal axis method finds extensive application in the production of castings for piston rings, cylinder liners, valve seat inserts and brake-drum liners, a portion of the cylinder liner castings being produced in sand-lined moulds, but the remainder of the castings mentioned are produced in metal moulds operated at a fairly high temperature.

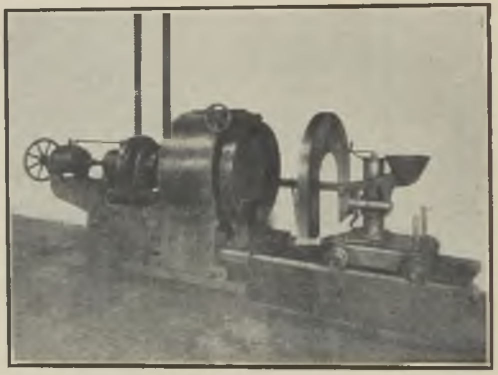

Fig. 4.—A Machine used for Cylinder Liners.

The machine used by the author's firm for the production of iron castings for piston rings, cylinder liners and valve-seat inserts are illustrated in Fig. 3, while Fig. 4 shows the machine used for the larger castings for piston rings and brake-drum liners. The essential features of these machines (which are the subject of patents) are the ready means of extraction of the casting and the provision of means for compensation for the varying expansion of the mould under heat. As will be seen from Fig. 5, the mould is essentially cylindrical, being closed at one end with a "front plate" (the hole in which, in conjunction with the amount of metal poured in, governs the thickness of the casting) and closed at the other end by a "plunger" which in the case of the small machine has only a very small movement, the casting being exposed by withdrawing the mould over the plunger. In the case of the machine for castings up to 30 in. dia. the front plate holder is drawn forward and the casting then ejected from the mould by moving the plunger itself forward. Fig. 6 illustrates more closely the mould and plunger arrangement on the smaller machines.

The operation of casting consists of closing the mould against the front plate under spring pressure, introducing dry material of a refractory nature to form a protective coating on the mould, and pouring into the rotating mould through the runner trough the requisite quantity of molten metal, any excess over the quantity required to give the desired thickness being ejected through the hole in the "front plate." When the casting has solidified the rotation is stopped, a hand-brake applied to bring the machine to rest, and the mould opened for the extraction of the casting. It will be noticed that cores and runners are completely eliminated, the only surplus metal being the piece about $\frac{1}{4}$ in. wide on the plain end of the casting (which being slightly rough and chilled by contact with the plunger is cut off on rotary machines), and the flash which is formed if excess metal enters the front plate. On removing this the casting is trued by grinding the base end on special machines so that the base is perfectly

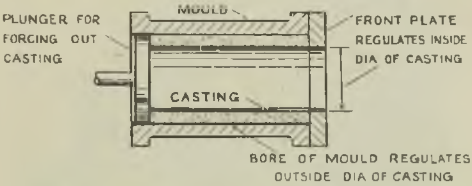

Fig. 5.—Showing Type of Mould Used.

square with the axis of the casting, thus ensuring accuracy when the casting is chucked for machining.

Rotation Speed

In connection with the production operations, the speed of rotation of the mould, its working temperature and its life may be mentioned. The mould on all but the larger sizes is itself centrifugally cast from a special high-chromium cast iron and is heat-treated before machining, being secured in a cast-iron holder which is bolted to the machine. The "plungers" are likewise of high-chromium cast iron. The speed of rotation is governed by the diameter of the casting, the normal range on the British Piston Ring Company machines being 1,400 r.p.m. for 2 in. dia. to 400 r.p.m. for 30-in. dia. castings.

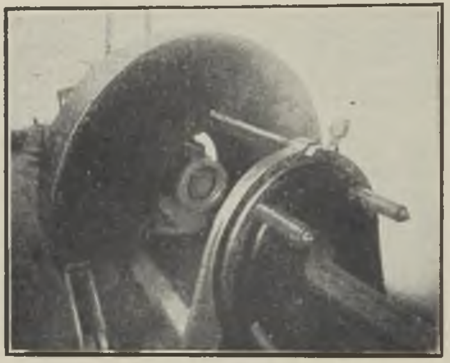

Fig. 6.—Close-up View of Mould and Plunger.

Life of Moulds

The life of the mould varies considerably, being very much less on the larger sizes than for the smaller castings. The conditions are obviously severe, since, although the mould temperature as indicated before pouring the metal may be no more than 500 deg. C., the interior of the mould must momentarily attain a temperature approaching that of the molten metal, but a life of over 2,000 castings on the smaller sizes is quite common, and figures of over 4,000 have on occasion been reached. The question of the most suitable material is a matter of constant experiment, and it is fairly certain that finality has by no means yet been reached. In general, it may be stated that cast iron has been found greatly superior to steel, as it is free from the warping tendency of the latter material.

No description of any process would be complete without some mention of its advantages and limitations. It will be obvious that the process, especially in the case of moulds worked hot, is essentially continuous, demanding a constant supply of molten metal over a normal working day. The process can, therefore, only be worked to maximum advantage where sufficient machines can be regularly employed to take the output from a continuously-running cupola. Where this obtains the process, although largely mechanical, has its own peculiar difficulties, it being only too easy to produce castings showing porosity when machined in the bore or which contain " pinholes " extending to varying depths through the casting.

Equally it is possible if the closest control is not exercised over metal composition and mould temperature to produce castings which are either excessively hard and difficult to machine or which, on the other hand, have too low a combined carbon content and, consequently, bad-wearing properties. The process, in short, calls for a specialised technique which can only be attained by long and costly experience. There are, however, advantages which greatly outweigh the disadvantages of sand castings, provided the centrifugal process is operated on a satisfactory footing.

These advantages may be divided into two headings:—(1) Improvement in quality of castings and (2) improvement in strength properties of the material. Under the first heading it is sufficient to say that of the cylinder liner and piston-ring pots produced by the author's firm the percentage of cylinder liners rejected in the machine shop is extremely low, especially when it is considered that the slightest flaw means rejection, and the total scrap through material defects on piston-ring production, where each ring goes through a very large number of operations, is normally between 3 and 4 per cent. The absence of sand avoids the usual fettling operations and naturally gives less wear on the machining tools. In addition, there is obviously no risk of sand inclusion in the casting when metal moulds are used. It will be obvious that, while certain precautions have to be taken, centrifugal castings are practically self-feeding, since solidification progresses evenly from the outside of the casting.

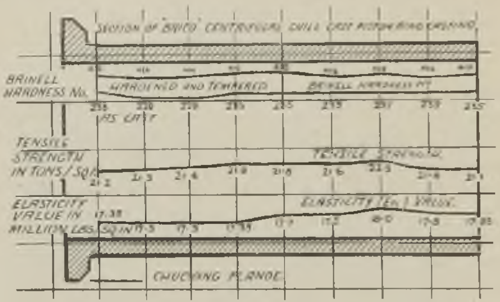

Fig. 7.—Properties of Centrifugally-cast Material.

Quantity of Product

As regards the quality of the material, provided there is adequate metallurgical control, the use of metal moulds ensures a remarkably close grain and fine-graphite distribution, together with a high-tensile strength and elasticity and freedom from excessive permanent set, three factors which are of the greatest importance in material required for piston-ring production. As will be seen from the chart, Fig. 7, not only are the strength properties exceedingly good but the values are remarkably uniform along the length of the casting. It should be noticed that since it would be impossible to cast a separate test-bar which would represent a centrifugal casting and impracticable to machine test-bars of the usual form from the castings, the procedure adopted is to machine test samples of ring form from the castings themselves, as laid down in British Standard Specifications 4.K.6 and 5004.

The uniformly close grain of centrifugal chill castings is of great value in connection with the improvement of the strength and wear-resisting properties of cast iron by heat-treatment. This is now regularly practised on a number of automobile components, the principal examples in the case of centrifugal castings made by the author's firm being piston rings and cylinder liners. The latter will be referred to in more detail later.

As an example of the properties which may be obtained by oil-hardening and tempering centrifugally-cast iron the following figures may be given:—

Sample. Chemical Composition.

Total carbon	3.35
Combined carbon	0.72
Silicon	1.87
Sulphur	0.071
Phosphorus	0.48
Manganese	0.60

	As-cast.	Oil hardened 830 deg. C. Tempered 350 deg. C. 20 mins.
EN (Nominal Young's modulus of elasticity)	16.4×10^6*	—
Tensile strength	19.0†	21.2†
Brinell hardness	240	415

* Lbs. per sq. in. † Tons per sq. in.

As will be seen from photomicrographs Figs. 8 and 9 the operation of hardening and tempering results in a change in the structure from fine pearlite in the normal condition to martensite-sorbite after hardening and tempering, there being no change in the phosphide or graphite contents or their distribution. The latter fact is no doubt of very great importance, since the excellent resistance to wear of cast iron in both the normal and hardened and tempered conditions is undoubtedly bound up with the oil pockets formed by the graphite flakes or voids. It will be noticed that not only is the Brinell hardness value doubled, but that the strength values, far from being impaired by the heat-treatment, are greater than in the as-cast con-

FIG. 8.—PEARLITIC STRUCTURE OF UNHARDENED CENTRIFUGALLY-CAST CYLINDER LINER. × 1,000.

dition. In addition it has been shown[3] that the resistance of the material to fracture under repeated impact is very considerably increased by hardening and tempering.

FIG. 9.—STRUCTURE OF HARDENED AND TEMPERED CENTRIFUGALLY-CAST CYLINDER LINER. × 1,000.

Some Applications of Centrifugal Castings

It will be noticed that, apart from castings produced by the vertical axis process, centrifugal casting is adopted only for articles of essentially cylindrical form. The difficulties

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[3] T. R. Twigger, FOUNDRY TRADE JOURNAL, December 17, 1931.

attending the use of jointed moulds are considerable, and do not appear to make their use economical. For example, so far as the author is aware, air-cooled cylinders have not so far been attempted. The better plan appears to be to use bushes or liners of cylindrical form in suitably-shaped holders. This method is extensively adopted for cylinder liners, valve seat inserts and brake-drum liners, castings for which are centrifugally (chill) cast by the author's firm in addition to the castings required for piston-ring production.

Fig. 10.—Group of Castings made by the Centrifugal Process.

Fig. 11.—Centrifugally-cast "Wet" Liner.

A group of such castings is shown in Fig. 10. The piston-ring and cylinder-liner castings are made from a high-grade cylinder-iron mixture conforming to Air Board Specification 4.K.6, small additions of nickel and chromium being standard practice. For valve-seat and brake-drum castings a special nickel-chromium mixture is used to give additional wear and heat-resisting properties. Typical illustrations of cylinder liners are shown in Figs. 11 and 12. In the case of the wet liners, in which the liner forms the actual cylinder barrel, the cylinder block is greatly simplified, while with either wet or dry types the use of liners overcomes the possibility of having to scrap the block through porosity in perhaps only one bore.

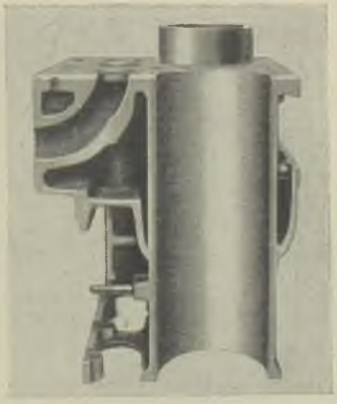


FIG. 12.—CENTRIFUGALLY-CAST "DRY" LINER.

The great advantage of cylinder liners is, however, the ability to use strong, close-grained material of good resistance to wear where it is most required, a condition which is difficult to meet in the ordinary type of cylinder block, and the ease of subsequent renewal when wear has become pronounced. This is of very considerable value, especially in the commercial vehicle field.

An illustration of a renewable valve-seat insert made from a Bricomium centrifugal casting is given in Fig. 13. In this case the cylinder block is machined to such a size that the insert is fitted with an interference fit of not less than 0.006 in., which is necessary to ensure that the insert does not come loose in service. For valve seats it is considered the best practice to fully harden the material and then temper at temperatures which will give material in which the seatings can be formed with a cutter after the insert has been pressed in position.

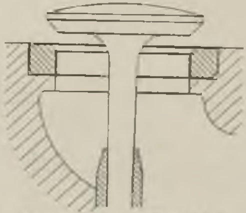


Fig. 13. — Renewable Valve-Seat Insert.

Brake-Drum Liners

Cast iron is unquestionably the most satisfactory braking material on account of its high coefficient of friction and on account of the fact that it does not score like steel. While complete drums of cast iron are used in some instances, composite drums consisting of liners of centrifugal cast iron pressed in steel drums are also used, and this method is used on an extensive scale for renewing worn steel drums. An illustration of a typical composite structure is given in Fig. 14. As already mentioned, in this instance a special nickel-chromium alloy cast iron is used in order to give good wear and heat-resisting properties. The chromium is of particular advantage in this respect, as it improves the thermal conductivity of the iron and so accelerates the flow of heat from the braking surface.

Service Results

The following figures which have been obtained in commercial-vehicle service will be of interest. In this field the conditions are particularly severe and very close attention has to be paid to the principal engine and chassis wearing parts. Amongst these, cylinder bores, valve seats and brake drums are particularly important. Reports indicate that on steel drums lined with centrifugally chill cast iron mileages of at least 100,000 may be obtained, the liners even after this mileage being quite free from scoring. In the case of the cylinder bores, liners of centrifugal material have offered a definite contribution to the serious question of cylinder wear. As already mentioned, they have the advantage that the bore can be of ideally suitable material. This is best exemplified by hardened and tempered cast-iron cylinder liners which are now in very widespread use. It will be obvious that to

FIG. 14.—BRAKE-DRUM LINER.

produce a cylinder block having a Brinell hardness in the bore of 450 would be quite impracticable, especially when one considers the difficulty there would be in machining. Such a hardness can, however, readily be attained on hardened and tempered chill-cast centrifugal liners. It has been found that when such liners are fitted into an internal-combustion engine the mileage per 0.001-in. cylinder wear is increased by approximately 100 per cent. when using centrifugally cast piston rings. It has, however, been found that if the hardened and tempered liners are used in conjunction with hardened and tempered piston rings, still further improvement in life is obtained. A recent report on hardened and tempered cylinder liners used with hardened and tempered piston rings in a Diesel engine for road transport work indicates that the wear ranges from 0.0003 in. to 0.001 in. per 10,000 miles. The lower figure is equal to 33,000 miles per 0.001-in. cylinder wear. It is stated that wear is always confined to a very small portion of the liner near the top of the stroke, no wear being detectable in any other part after 40,000 miles of running.

In another case a petrol engine, also used for commercial-vehicle work, fitted with hardened and tempered liners and hardened and tempered piston rings, showed after 100,000 miles a wear equivalent to 12,500 miles per 0.001 in. cylinder-bore wear. An advantage of hardened and tempered centrifugally-cast liners over materials having only a superficial surface hardness is that, being uniformly hard all through, they can be reground so as to obtain a further life should this be desired.

The above results, coupled with the fact that after exhaustive tests one of the principal builders of engines for commercial vehicles in this country has standardised throughout on hardened and tempered centrifugal (chill) cast liners indicates without question the great advance represented by this material. In conclusion, the author would acknowledge his thanks to the directors of the British Piston Ring Company, Limited, for permission to give this Paper.

Birmingham, Coventry and West Midlands Branch

PATTERNMAKING

By F. C. Edwards (Associate Member)

In discussing the subject of patternmaking, two postulates should be kept constantly in mind, the first being that a pattern (unlike, say, a piece of furniture) is not an end in itself, but an intermediary between design and casting: a mould-forming agent. The second postulate is that the degree of refinement economically justifiable in any specified pattern will vary with the accuracy or quantity of the castings required. An early recognition of these postulates and their co-relationship should go far to explain many of the apparent contradictions met with in the art and craft of patternmaking, and, as a corollary, help one more justly to estimate the merits and demerits of any particular pattern.

It should be understood, for example, that the pattern for a " one-off " job—say, a tool-jig or fixture, which may never be required again—will generally lack those aids to quick and accurate casting production demanded in repetition work. This does not mean, of course, that the making of a " lack-lustre " pattern is as simple as its unfinished appearance may suggest; on the contrary, since one is expected to produce a pattern of this kind in, perhaps, one-half or one-third of the time spent on a similar pattern for production work, constructive thought must travel at double or treble its normal speed. The elimination of non-essentials, and the adoption of short cuts, becomes a necessity. Here, as elsewhere, successful short cuts imply a clear view of the objective along with the discriminative ability to select the one best path to its attainment.

The Rule of the Craft

With these "one-off" jobs, again, the patternmaker (quite properly) enjoys greater latitude of action. He is licensed to inflict on the foundry "exhibition" work which would never be tolerated with ordinary "production" patterns. This licence, however, is limited to *possible* moulding methods, and does not cover the *impossible* contraption, which occasionally finds its way into the foundry to embarrass the moulder and humiliate its creator. That is to say, although the most unorthodox expedients may be employed in this class of work, the faculty of inventiveness cannot be allowed to run riot. Imagination must be subservient to practical politics. For the moulder of the job may not happen to possess that flair for executing the "impossible" in which the "invincibles of the old school" pardonably gloried. Then the patternmaker is called upon to explain the way out! If his methods are based on logical reasoning from experience, all is well—since the moulder, given the cue, invariably proves equal to the occasion: his reach exceeds the patternmaker's grasp. If, on the other hand, speed has obscured the lessons of experience, or dethroned logic, the patternmaker is found guilty of breaking the first rule of his craft: "A pattern must be made to mould!"

This leads to a recognition of the tuitionary value of the "rush, one-off" jobs. By speeding up thought action, and allowing insufficient time for the balancing of pros and cons, "rush" jobs inevitably engender questionable practices—in the concrete. These form valuable object lessons to the young patternmaker on "what *not* to do"! With the actual pattern before him, the moulder is in a better position to express his likes and dislikes than he could be expected to do from a hypothetical case based upon a blue-print.

Yet more fortunate is the novitiate patternmaker—from an educational point of view—when his mistakes remain undetected until they are buried. For just as the actual, wooden mistake, if observed, converts the taciturn moulder into a voluble (and valuable) critic, so it enables the still less articulate mould to preach an excellent sermon. And the mould never misses a mistake! These "sermons in sand," moreover, are not only very lively, but (as the author can vouch from personal experience) they live in the mind as permanent pictures—ineffaceable, unforgettable! A pattern, then, that sticks doggedly to the mould is worth one's attention during its exhumation—from the point of view of "what *not* to do." Here the patternmaker becomes an interested spectator. To stand by, sheepishly impotent, conscious that he is responsible for the mess, as mould eruption follows the small-scale earthquake, is an experience calculated to awaken the patternmaker's sympathy for the moulder; to develop his foundry sense; haply, to extend his vocabulary; and, generally, to accelerate his education!

Early Lessons

The author vividly remembers one of his first lessons on "how *not* to make a pattern"—although it occurred over forty years ago. In this case, the pattern (it is only fair to remark) was supplied by an outside firm, and was in the nature of a bedplate, measuring about 7 ft. by 4 ft. and 12 in. in depth, as moulded. The pattern had been rammed up in the mould, and preparations were in hand for its withdrawal. After several men had exhausted all their available energy, applied in every available manner, in an attempt to separate mould and pattern, and the foundry manager (the author's father, by the way) had arrived at the last shred of his patience, an overhead crane finally exhumed the "body"—more or less dismembered. Needless to say, the mould—or, rather, what was left of it after the outrage—was useless!

Such a lesson could never be forgotten. The trouble originated in the improper construction of the pattern—a cross section of which is shown in Fig. 1 as moulded, that is, table-side downwards (to secure a clean machining surface). The bottom plate, A, had been glued together as one piece, with close joints, and allowed to extend the full width of the job. Then the varnish was deficient in shellac. Here was just the ideal combination of bad practice to create mischief. No provision whatever had apparently been made for combating the influence of mould moisture. The damage would not have been so great had the sides of the pattern been allowed to extend the full depth of the job. This, at least, would have prevented the "step" effect

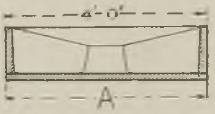


FIG. 1

FIG. 2

of the protruding base plate. Moreover, the pattern would have been, as a whole, far more moisture proof if it had been given, say, two coatings of really good shellac varnish, instead of the single-coat "make-believe"!

After a night in the damp mould—or (memory fails on this point) it may have been all the week-end (a very objectionable practice when it can be avoided)—the plate expanded. Glue and brads (screws were nowhere to be seen), which before contact with the mould, had kept the plate flush with the outside of the frame, proved ineffective against the superior force of mould moisture. The lower part of the mould was forced outwards, and the plate itself projected quite enough to ensure that pattern and mould would never part company—on peaceful terms! Fig. 2 shows the pushed-out sides (slightly exaggerated for purposes of illustration) and the projecting plate, B. The lesson might be stated as the second rule of patternmaking: A pattern should be constructed in such a manner as to render negligible the influence of mould moisture.

Inverse Seasoning

The above rule is based on the well-known natural phenomenon of shrinkage across the grain that timber undergoes as its moisture evaporates when exposed to drying conditions. Well-seasoned timber, of course, is usually employed for patternmaking. It should be kept in mind, however, that a pattern is not a piece of furniture, but a moulding agent, and, as such, it is brought into close contact with moist, and even steaming-hot sand, in which it may be buried for several hours, or, in the case of a large pattern, for some days. Then, as moisture is re-absorbed through the pores of the wood, the action of seasoning is reversed, and the timber tends to *expand* across the grain.

It follows that the more carefully seasoned the timber employed in a pattern, the greater the need for anti-growth measures in construction. Of the various methods practised to achieve this end, the principal are:—(1) The "open joint," which localises any expansion or shrinkage that may occur, and leaves the overall dimensions practically constant; (2) the outside frame with panelled centre, which also remains constant under extremes of drying, and moisture-saturating conditions, and (3) segmental construction. This latter method is of almost universal application. It is simple, as well as reliable. By glueing together a number of pieces of wood (segments) in such a manner that the straight, stable grain of one piece is utilised to correct the possible warping tendencies of its neighbours, an interlocked, dependable whole is secured. In this way almost every conceivable shape—minute or gigantic, multi-angled or polyplaned—can be made to "stay put." The corrective interaction of a multitude of segments neutralises potential evils and produces a reliable structure.

Pattern Usage

Here, the author begs leave to digress, for a moment, from " Patternmaking " to " Pattern usage." It is one thing to make a pattern proof against normal mould humidity, but an entirely different matter to render it invulnerable to every form of moisture attack—for instance, the moulder's water pot! Admittedly, mould joints may need a little extra moisture bond before the pattern is withdrawn. Granted, too, that the moulder can scarcely be expected to realise (as the patternmaker naturally does) the deleterious effect upon the joint of a pattern (sparingly varnished, as a rule), or on the light-plate type of construction, of repeated " shower baths "!

Consider for a moment this baneful practice. The water—under pressure, as it is flung from the water brush—is driven into the exposed crevices, and percolates, more or less, into the interior recesses of the pattern, where it devitalises the glue, and gives rise, sooner or later, to the disintegration of the whole structure. The author feels constrained, therefore, naturally with the utmost diffidence, to suggest a warning on this point for the guidance of the moulder who would have his pattern retain its original state of perfection. The warning would be most effective, of course, if it could be made to issue, at the appropriate moment, gramophone-fashion, from the pattern! If this be found inconvenient (and the author must confess he has not yet managed to try out the method), the warning might be clearly inscribed on the joint, or the plate of the pattern, so that, as the moulder was about to apply the cold douche, he would read: " *Don't water the pattern; it is not a garden plant!*"

The importance of Rule No. 2 is further exemplified in the following case, where inattention to the rule led to the depreciation, in less than a month, in the value of a pattern, from thirty pounds sterling—its cost, to thirty pence—its sale price as scrap!

Learning from Experience

Upon taking charge of a pattern shop, some years ago, the author found, in course of construction, a platform pattern, nine feet by eight feet, with a panel three-quarters of an inch in thickness. The panel was formed of two- close-jointed, mahogany slabs of equal thickness, with the grain of the wood on one side running at right angles to that of the other, the whole being securely screwed together. It was immediately obvious to the author that this attempt to defy natural law would prove abortive. As the pattern was nearing completion, however, he decided to allow this gross error of construction to demonstrate its own unworthiness. The slight additional cost it was felt would be amply justified in the accelerated education of all concerned.

No finer lesson could have been staged! It should be noted that the pattern was required to be in service almost continuously. This meant day-after-day subjection, for several hours, to the expansive influence on each side of the plate of the moist and more or less steaming sand. This expansive action, moreover, on account of the grain of one side running at right-angles to that of the other, was similarly right-angled in its operation, on the respective sides of the plate. Imagine the effect: Nine feet of well-seasoned mahogany tending to expand across the grain against the restraining force of the lengthwise grain of another piece, which, in turn, tends to extend its eight feet of cross-grain whilst remaining constant in length! The result was tantalising to the moulders. Increasingly charged with moisture, the flat plate rapidly assumed a kind of saucer shape.

Now, moulders have certain, coercively-persuasive methods of dealing with refractory patterns. Usually, the pattern succumbs to the treatment. That the patternmaker does not always agree with this treatment is beside the point—it secures the desired result. In the case under consideration, however, the moulders realised they had caught a " Tartar! " Neither by coaxing nor coercion could the plate be induced to lie on the bed prepared for it. In vain, the moulders piled up 56-lb. weights on each corner. The plate won! As the weights were removed, it regained its self-determined, concavo-convex shape, with the resiliency of a laminated spring!

Consider the main essentials to be observed in making a reliable pattern of the above type. It is desired to produce a flat plate, 9 ft. by 8 ft. and $\frac{3}{4}$ in. in thickness. Now, a wooden plate of such an area and thickness is bound to sag, and, generally, to take the shape of the surface upon which it rests. It is not sufficiently rigid in itself to remain true without support (even if it were perfectly true to commence with), and one has to depend upon the moulder to strickle off a level bed upon which the pattern will be laid preparatory to the ramming-up process. It is important to note that since one is obliged to depend upon this bed to give to the plate its correct surface shape, it must clearly be a complete dependance. That is to say, the pattern will not only not be expected to possess rigidity, but must be constructed so that it cannot develop rigidity under any conceivable circumstances in which it may be placed in the foundry. To the end of its days, in short, it must remain as passive as a pancake.

Two Essentials

The two outstanding essentials, then, in a pattern of this kind, are: Suitable material and proper construction. If either of these factors be neglected, it matters not how carefully the pattern be made in other respects, or how accurate may be its dimensions; it is bound to prove, sooner or later, a complete and—as in the example referred to—a very costly failure. Furthermore, the loss may conceivably amount to many times the cost of the pattern. The probability being, of course, that the first two or three trial castings will measure up correctly. The foundry will then proceed full speed ahead. After this, the size of the scrap heap will depend upon the number of plates immediately on order, and the time that elapses before they are required in the assembling department! (This points to the advisability of an occasional inspection of patterns in constant use. Here, " out of sight, out of mind " sometimes proves to be an expensive attitude.)

Now, since the plate under consideration is intended to be a " standard " pattern, that is, one which will be in constant use, durability should be secured, as far as possible. The term " as far as possible " is used advisedly; it must be durability, plus reliability. One might employ mahogany, for instance, which is much harder, and consequently more durable than yellow pine. Its very strength, however, fatally militates against its adoption in certain situations. Where it is inclined to warp, especially if it has wide, exposed surfaces, the absorption of moisture renders it (as was shown in the case mentioned) completely intractable. Yellow pine will not wear so long, but by a suitable arrangement of grain it will remain true to its original shape until—like Oliver Wendell Holmes' " One-Hoss Shay "—it goes to pieces all at once, by senile decay!

Here one is faced with the direct question: Should the pattern be constructed of a material which is exceedingly hard and durable, and which may permit of, say, three thousand castings being made before it is worn out, but which, on account of its inherent tendency to warp, may become quite useless before three castings have been made; or, should a lighter and milder material be used, of admittedly less durability, but upon which one can rely for, say, one thousand castings? Well, patternmaking is not gambling; it is a scientific, creative art. Pine (*pinus strobus*) should, therefore, be employed for the body of the pattern, at least, because, whatever may be its potential refractoriness, as pine, it is possible, by appropriate methods of construction, to keep it under complete control.

Type of Construction Necessary

What form of construction is likely to prove most reliable in this case? It has been previously mentioned that timber is not affected by moisture length-wise of the grain. This is the key to the situation. The construction of the pattern should be such that the length-wise grain of the timber permanently controls the overall dimensions of the plate, whilst eliminating, or at least overcoming, whatever warping tendency may be present.

Now, a " framed-up " structure, as shown in Fig. 3, completely satisfies these conditions. The whole of the ground work is of yellow pine. The outside frame, with " half-lap " corners, is stiffened by the centre cross, which is " half-lap " dovetailed, and securely screwed into the sides and ends of the plate. The remaining spaces are closed in with open-joint panels. The ends of the panels, it should be noted, are rebated down to fit on a mahogany strip of $\frac{3}{8}$ in. square section. This strip is glued and well nailed along the inner edges of the frame, as seen in enlarged section at C, Fig. 4. The hardwood strip, of course, obtaining support from the body of the frame by the long nails, D, is more dependable than the yellow-pine lip would be, rebated on the inside of the frame.

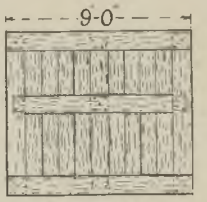


FIG. 3

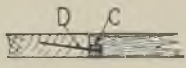


FIG. 4

With a foundation of yellow pine, one may safely employ mahogany for the superstructure. Such harder, closer-grained material is less vulnerable to those ultra-vicious vent-wire stabs, and the concussive effect of misguided rammer blows, for which the salient features of a pattern seem to possess a sort of magnetic attraction! Since the width of these mahogany trappings, again, is comparatively small, the deleterious effect of any potential warping tendency on the part of any piece, that is not locally nullified by a complementary tendency on the part of an adjoining piece, may be regarded as negligible. In a word, one should make the most efficient use of the length way of the grain (upon which one may implicitly rely), whilst keeping the width of every piece in the structure within manageable bounds.

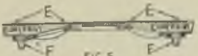


FIG. 5

FIG. 6

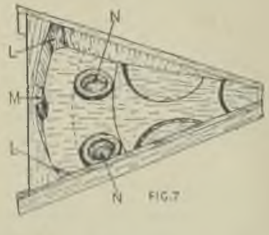


FIG. 7

Quite an appreciable advantage of the above method, from the foundry point of view, is the entire absence of battens which are required to hold the plate together with the frameless method of construction. Such battens, moreover, in this class of work, would need to be in the top-part box, since stopping-off would deface the surface.

Making Large Circular Plates

Large circular plates may also be constructed on the foregoing plan. In these, however, instead of the outside frame being "halved" together (which, of course, is feasible), a ring is built up of segments, and the centre panelled as before. Any deviation from the single-plane plate usually necessitates a corresponding variation in the construction of the pattern. An example of a plate pattern, which was actually required to be concavo-convex in form, is illustrated in Figs. 5, 6 and 7. This plate is 3 ft. 6 in. in diameter, with a $\frac{3}{8}$-in. panel. It has seven 6-in. dia. holes midway between the outside and the centre of the pattern, and fourteen small-diameter holes near the rim. These are shown in the right-hand half plan of the casting, Fig. 6.

Now, it would be absurd to expect such a flimsy pattern—made, that is, exactly like the casting—to remain true whilst being rammed up in the mould; some sort of external support is imperative. Admittedly, a metal pattern might be employed, if sufficient castings were on order to justify the expense. Even then, a wooden pattern would first be necessary. Here, one must resort to the patternmaker's well-known " catalytic agent "—his Open Sesame in all sorts of construction and moulding problems—the coreprint. By the employment of segmental cores, as shown in dotted section, at E, Fig. 5, a reliable working pattern may be produced, which, with fair treatment, should last for at least a thousand castings.

As will be seen in Fig. 5, the annular coreprint extends well over the edge of the pattern (at least 2 in.), and serves as the outside bearing for the cores. The fourteen round cores—which are formed on the main cores—are positioned by long well-tapered coreprints—F, Fig. 5—on the under side of the pattern, as moulded. The seven 6-in. dia. holes in the web of the casting—which, fortunately, provide further bearings for the main cores—are formed in the corebox, Fig. 7. It should be noted that the radial joints of the cores pass through these large holes. This reduces fettling: it eliminates the possibility of fin to the extent of the diameter of the holes. The small, outer holes, positioned in the centre of their respective facings in the corebox (which forms the upper surface of the casting), and located by the coreprints, F, emerging from the centre of the facing on the lower side of the pattern, ensure the absolute accuracy of each facing over its counterpart.

The construction of the pattern is featured on the left-hand half of Fig. 6. The upper quarter refers to the top side, as moulded—E, Fig. 5. A double row of segments, G, forms the outer ring, which is rebated on the inside to receive the open-joint panels, H. This ensures an unshrinkable and unwarpable foundation. Stiffening is secured by superimposing a layer of radial segments, J, seen in the lower left-hand quarter of Fig. 6. It should be noted that the radial segments do not extend to the periphery of the pattern. Their perimeter is bounded by annular segments, K. This is a refinement in construction (perhaps not of vital importance), intended to seal the absorbent end-wise grain from moisture attack. It also confers a better moulding surface on the edge of the coreprint.

Two features in the corebox, Fig. 7, deserve notice: the flats, L, and the locating piece, M. Now, in a so-called theoretical arrangement of the job, these pieces are quite superfluous. One might assume, apparently by unshakeable logic, that perfection would be attained if the outside coreprint end of the corebox was made exactly one-seventh of the periphery of the pattern, and the small holes in the corebox were arranged to form long, tapered pins on the core, of the required relationship with each other, and with the coreprints on the pattern. The moulder would then merely need to position the cores in the mould, one after the other, replace the cope, and cast the job.

A Perfect Defence

This mode of reasoning is very common. It is also very expensive; for it is a prolific source of scrap—and the foundry pays! The patternmaker, of course, easily exonerates himself. There appears to be no answer to the specious argument that he has worked to contraction rule and blue-print. He proves, by means of templates, that pattern and corebox possess the required relationship with each other. The moulder may sense injustice, but cannot prove it. The evidence against him is too damning. The

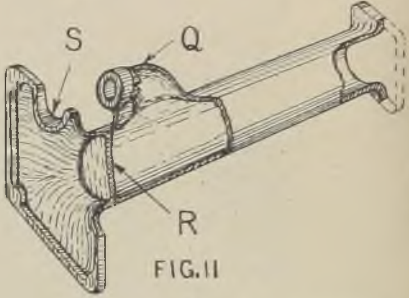


FIG. 11

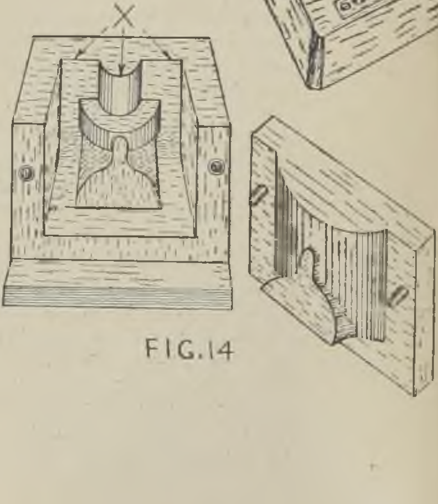


FIG. 14

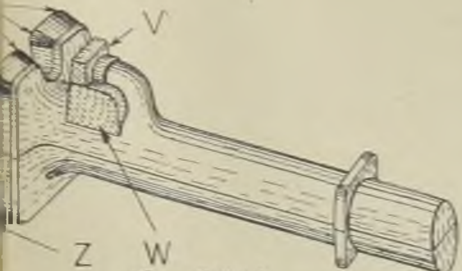


FIG.12

G.13

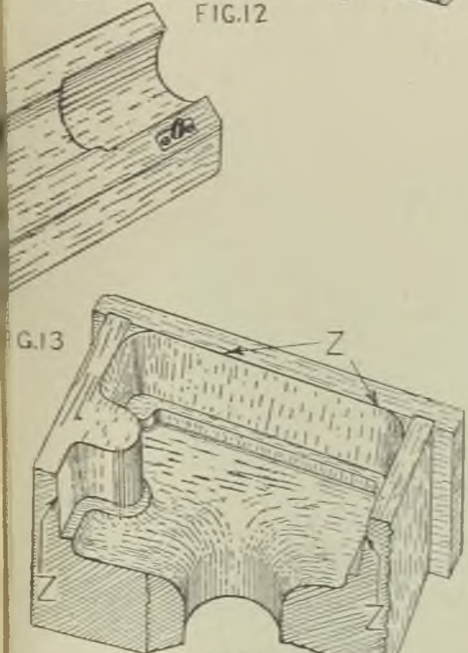


FIG.15

scrap is there; and the pattern measures up to blue-print quite correctly. Nevertheless, the patternmaker is either very inexperienced, or dishonest, with himself, if, though proved innocent, he does not feel, to some extent, guilty! The author cannot deny that, on more than one occasion, his reluctance to reverse a verdict given in his favour has over-ruled his hatred of moral cowardice!

The plain truth, which cannot too often be reiterated, is that any theory of pattern arrangement which leaves out of account relevant foundry practice is fundamentally wrong in principle. Sound logic (as Dr. Johnson would say) primarily implies sound premises. Accuracy, and perfect agreement of pattern and corebox are not, in themselves, reliable criteria of first-class patternmaking. Before the core is finally housed in the mould, it must be made, removed from its corebox, dried and positioned. And before the mould can receive the core, the pattern must be withdrawn. Now, unless these essential operations are intelligently anticipated by the patternmaker, various interferences may creep in " like a thief in the night." The result may easily be complete chaos! And this in spite of—indeed, perhaps on account of—a too-exclusive attention to dimensional accuracy to the neglect of foundry requirements. Hence, accuracy, *per se*, is not sufficient. The goal to aim at is that optimum arrangement of pattern and corebox which " locks, bolts and bars " against operation interferences.

In the case under consideration, the acute angles of the corebox (that is, minus the pieces L)—in conjunction with the sides of the box unavoidably deficient in taper—do not conduce to easy core withdrawal. This means the possibility of core distortion. The pieces L eliminate the offending corners without materially detracting from the bearing of the core in the core-print. Such corners, moreover, are well tapered.

The block, M, again, provides a core location that can be kept in view. For the projecting " dowels " of core, formed by the small holes, N, Fig. 7, prove in practice (with apologies to G. K. Chesterton) to be locations that cannot be located! It would be found that, as the core is being placed in the mould, the outside, overhanging coreprint, seen in Fig. 5, shuts out the view of the small projecting cores before they enter the impressions formed by the coreprints, F. The outer edge of the coreprint, E (Fig. 5) is recessed to correspond with the space left in the core by the block, M. As a further aid to accuracy, hardwood blocks are supplied, shaped to fit the recesses, but sufficiently deep to be securely gripped by the outside of the mould, as seen at O (Fig. 6). These are also made, say, 2 in. deeper than the coreprint, and serve as more reliable guides than green-sand cores.

Plywood as an Asset

Before taking leave of the construction aspect of patternmaking, a passing reference should be made to plywood. No one needs to be reminded, of course, that plywood does not shrink. This is a valuable asset in patternmaking. One may use it (as the author regularly does) in widths, say, up to 3 ft. and over, without fearing any variation of dimensions. This could not be done with ordinary wood. The fact that it may be obtained in sheets of from slightly under $\frac{1}{8}$ in. to $1\frac{1}{2}$ in. in thickness, combined with an unvarying thickness-dimension of each sheet, makes it a very useful auxiliary in patternmaking.

An auxiliary, however, is not a panacea. Plywood is no cure-all. To be useful, it must be understood. And real understanding comes, mostly, from experience. "Plywood is of no use for patternmaking!" said a patternshop manager to the author some time ago. Naturally, the author then asked his friend if he had given it a trial. The answer was a contemptuous "No!" Such an attitude is not, perhaps, uncommon. Yet it is neither scientific nor justifiable. Plywood, of course, has its weak points; but these, when known, may be avoided. It does not take very long to discover that, although plywood does not shrink, it may warp. Even

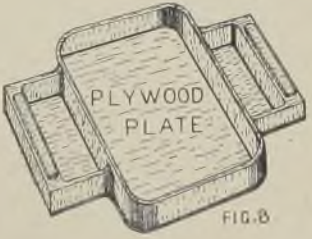


FIG. 8

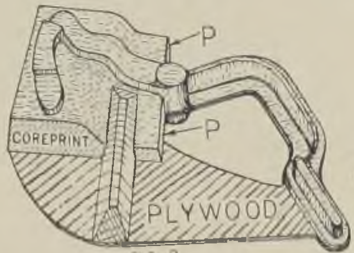


FIG. 9

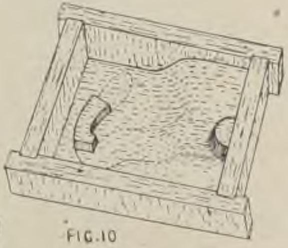


FIG. 10

the 1-in. gauge material (made up of seventeen laminations), given a sufficient width, or unevenly exposed, might, conceivably, deviate to some extent from the plane truth, if allowed time unlimited to imbibe mould moisture.

Education here, as in the art and craft of patternmaking generally, is largely a matter of inductive reasoning from experiment and observation. An occasional mistake is the best tutor! In this way, the enterprising patternmaker learns just how far plywood may be trusted. It is difficult to formulate rules for universal guidance, since patterns vary so widely in shape and dimensions. One may safely use plywood, however, where the general structure of a pattern is sufficiently rigid to neutralise whatever warping tendency may be present. As a "drum-head" connecting medium, plywood excels. It does not develop "shakes"; it has no open joints to annoy the moulder with loose sand as he withdraws the pattern; and its multiple cross-laminations invest the wide sheet with a "mild-steel" tautness quite unattainable with ordinary wood. To the conservative patternmaker, then, sceptical as to the serviceability of plywood, the author's advice is: "Try it."

Application of Plywood

A typical example (from actual practice) of the employment of plywood, in a "drum-head" capacity, is illustrated by Fig. 8. This represents the general structure of a shute pattern, 3 ft. wide by 4 ft. long. The finished pattern contains other members, which are omitted from the sketch for the sake of clarity. The job was first marked out on a sheet of plywood, $\frac{3}{8}$ in. in thickness. This was cut to shape, and securely glued and screwed to the outside frame—which had been separately constructed. As will be gathered from the sketch, such a framework possesses sufficient rigidity, in itself, to nullify any possible warping tendency on the part of the plywood. The main purpose of the plywood is that of a general connecting medium, which can be relied upon to keep the overall shape and dimensions constant.

The fact that plywood has no weak "short grain" is a strong argument for its employment in such patterns as that shown in Fig. 9. It will be seen that this component lies in two planes. The connection (merely the small-diameter boss) between these planes is so frail that to attempt to make such a pattern exactly the shape of the casting would be to court disaster—probably before the pattern reached the foundry, and, certainly, before it had been withdrawn from the mould. Frailty is converted into strength, however, and moulding is simplified, by the employment of the coreprint, P (the corebox for which is seen in Fig. 10).

Here, again, plywood forms an ideal foundation. The various centre lines are marked on the non-shrinkable plate, and the job built up on it. When this point is reached, it pays to "hasten slowly." The immediately obvious thing to do is to trim the plywood round to the shape of the pattern. But the obvious, here, is not advisable.

A pattern is essentially a moulding tool. As a tool, its serviceability must ever take precedence over its rank as a "work of art." To trim the plywood neatly round to the shape of the pattern might improve its appearance as a work of art, but would considerably detract from its value as a moulding tool. It would rob the pattern of much available strength—literally, of its built-in backbone. Since the plywood forms part and parcel of the structure, then, why not allow some of it to remain as a connecting piece between the weak, outlying limb and the stout coreprint—similarly as shown in Fig. 9? The core automatically stops off one end of this connecting piece, along with the stiffening batten, and the moulder makes short work of the other end. It is understood, of course, that if many castings were required a metal pattern would be made.

A Pipe Barrel Pattern

A somewhat different type of pattern is illustrated in Figs. 11 to 15. The casting (torn to facilitate portrayal) is shown in Fig. 11. The special feature of this casting is the elbow, Q, which, in conjunction with the midriff, R, presents one or two interesting moulding problems. It will be seen that the midriff forms a "dead end" to the pipe barrel, and thus prevents the adoption of the double-end bearing for the main core. It should be noted that the pipe was required to be petrol-proof. This meant that arrangements had to be made for anchoring the main core without resorting to chaplet support. The close proximity of the gap, S, in the base made it inexpedient to mould the job with the joint through the elbow.

The actual method adopted was as follows: The pattern, seen in Fig. 12, was jointed through the centre, to mould upside down to that shown. The inside elbow core was formed on the main pipe core, as seen at T (Fig. 13)—which shows one-half of the corebox. The outer end of the elbow core was formed as a "Tee" piece—U (Fig. 13). In order to insert this tee piece into its coreprint, V (Fig. 12), the coreprint, W, was employed—the core for which was made out of the corebox shown in Fig. 14. This core served as the main anchorage medium for the elbow end of the pipe, besides forming the undercut portion of the outer part of the elbow.

In coring up the mould, the recessed surface (X, Fig. 14) of the anchoring core is linked up to the neck (Y, Fig. 13) of the main core, and the two are inserted into the mould together. Two long nails driven through slots previously made in the anchor core into the body of the mould effectually holds down the main core. A little finishing, of course, is necessary where the anchor core joins the green-sand mould. For the base of the job, a core is made from the box seen in Fig. 15 (torn to facilitate portrayal). It should be noted that an outward taper—Z—is given to the base coreprint. This is not of immediate assistance to the moulder, but, reflected in the corebox, at Z (Fig. 15) facilitates core withdrawal. Another welcome feature in the eyes of the moulder is the absence of a " set-off " where the coreprint meets the flange. As a general principle, the " sharp corner " of sand should be avoided wherever possible ; such corners are easily disturbed as the core is being lowered in position—not to mention the greater risk of lowering the cope over the core—and the molten metal does the rest! In the case seen in Fig. 12, the generous outward bevel, Z, forming the " key-stone " coreprint, is found to be an adequate locating medium for the core.

It may here be of interest to mention that the last example, owing to increased orders for castings, was converted into a metal pattern. This meant increasing the overall length of the pattern, to the extent of the shrinkage taking place in producing the iron pattern from the existing wooden one, and adding $\frac{1}{16}$ in., for contraction, all round the base. Stripping and carrying plates were made for machine moulding. No alteration was made to the coreboxes.

Metal Patterns

Metal patterns, of course, require similar attention to moulding principles as wood patterns. The use of the stripping plate, however, reduces the need for excessive taper. Where comparatively heavy coreprints occur on metal patterns, it is better to cast the outside shape in its entirety—that is, as a shell—and block up the interior with wood, rather than remove the coreprints altogether and subsequently fit wood prints. In this way, the shape and position of the coreprints is assured : it is part and parcel of the casting, and runs no risk of future displacement.

Importance of Varnish

By no means the least important part of a pattern's equipment is its coat. Here the " nudist colt " cannot be too strongly deprecated! Every pattern worthy of the name deserves painting. And yet, " handsome is as handsome does," for paint, in patternmaking, has a threefold function : it protects the wood from mould moisture ; it gives surface smoothness ; and it imparts instruction to the moulder. The examples already referred to in this Paper of the deleterious effects of mould moisture on wood sufficiently emphasise the first-mentioned need of paint. And the fact that a pattern has to be withdrawn from the mould—or (a weightier reason) the mould withdrawn from the pattern—is, again, sufficient emphasis on the need for the second-mentioned purpose of paint-smoothness. As a medium of instruction to the moulder, distinctive painting is, of course, invaluable. Core-prints, and those parts of the pattern where the core will " cut through " in the casting, should be of a different colour to the parts which are to form the casting. Machined faces, again, should be clearly indicated. Such indications will often determine the " way of moulding," the position of risers, as well as the gating of the job. Those portions of the pattern not required to be produced in the casting—strengthening bars, battens, etc.—should be ornamented with the well-known " zebra stripes." The absence—or even the ambiguity—of such instructions has brought many a casting to the scrap heap. In the case of the frail pattern, indeed, it may not be amiss to remind the moulder, in legible, painted script, that he " should temper the wind to the shorn lamb "—or some such " arresting " phrase!

Pattern Colours

Whatever kind of paint is used, it should be capable of drying, say, in a few minutes. Patternmaking is not, usually, a leisurely occupation. As soon as patterns are completed—often, indeed, before they are commenced—there is an urge to " get them into the sand." Paint, therefore, must dry hard, and quickly. Shellac varnish satisfies these conditions. The colouring powder should be finely ground. Two colours are sufficient for all purposes. Since distinction is the aim, yellow chrome and spirit black serve admirably. The body of the pattern may be yellow and the coreprints black. The machined surfaces should be indicated by " M " or " machined."

Apropos of pattern colouring, a recently-issued British Standard Specification (No. 467—1932) contains a scheme for the marking and colouring of patterns. The object, presumably, being to identify the metal of the casting from the colour of the pattern. The colour chart places metals in two categories: " iron and steel," and " non-ferrous." The utility of this specification is extremely problematical—if not precisely *nil*. Of what practical use, for instance, are three colours—as suggested by the specification—as a means of differentiation between the vast array of metal mixtures in common use to-day? " Iron and steel " may mean: " light, general " cast iron, "heavy, general" cast iron, "cylinder" cast iron," steel-mix, malleable iron and a host of other variations of Fe—not to mention the innumerable different classes of steel. " Non-ferrous," again, may mean: Brasses, gunmetals, bronzes, aluminium alloys, white brasses, babbit metals, magnesium alloys, zinc-base alloys—with a legion of others!

The specification is further stultified by the fact that it is no uncommon thing for castings to be requisitioned off patterns originally made for another kind of metal. Aluminium castings, for example—to secure lightness—are made from patterns which are ordinarily used for iron castings. Steel castings, again—to secure an accession of strength—are requisitioned off patterns made, originally, to produce iron castings. In such cases—and they are not so infrequent as to be negligible—the specification could only be met if the pattern in question possessed the chameleonic power of changing its coat to suit the exigencies of the situation!

The most serviceable link between pattern and metal is found in the very simple practice of giving each pattern a distinctive number—preferably in raised characters—and quoting this number on the casting requisition form. The moulder reads, say: " One poise casting, pattern No. B34, metal, light general cast iron." Another requisition may read: " One poise casting, pattern No. B34, metal, aluminium."

Here there is no possibility of confusion. It will be understood, of course, that in all cases where patterns are used for metals of different contractions, the patternmaker will suitably adapt the pattern. In small work, no alteration may be necessary.

Numbering Forms

" Numbering " forms the last phase of patternmaking. Pattern identification should be simple, speedy and certain. " Wrong pattern given out " is one of the worst of many reasons for scrap. This may be the fault of the pattern storekeeper, or the ordering department may be to blame, but it should rarely—if ever—happen. Successful works management—like the control of an army in the field—largely hinges upon the facility with which orders are interpreted. An order should never permit of more than one interpretation, and should immediately convey to the executive concerned the requirements of headquarters. The fact that this " easily-digestible food for action " may entail difficulty in its preparation must not be permitted to militate against simplification. Such difficulty, indeed, is both proof and justification of the policy of simplification. Surely, where doubt is likely to arise in the process of translation, it is better dealt with at the source from which the order emanates than at a subsequent stage!

In the well-ordered foundry, castings are made from patterns each bearing its own particular mark of identification. This mark is entered in the patternstores register, or card system, with the number of the locker in which the pattern will be kept when not in use. Whenever a casting is required, the identification mark is specified on the order received by the pattern stores. This stores is usually common to all the various departments of the firm—that is, one in which all the patterns for every department are housed. Since many castings are required the same day as the order is received, it is essential that the storekeeper should be able to locate the required pattern, or patterns immediately.

With the pattern stores common to all departments, then, one may not unfairly assume that each ordering department—whether of workshops or drawing office, is more conversant with its own requirements than the pattern stores could be expected to be. Each of the former, moreover, handle but a fraction of the pattern orders dealt with by the latter. The requisition of one pattern means, to the pattern storekeeper, one pattern to be located from a collection of many thousands. One should bear in mind, again, that patterns have not only to be given out, but they must also be collected from the foundry and returned to their place in the stores.

Here lies the key to the type of pattern identification most likely to lead to efficient handling. The system adopted, whilst serviceable, of course, to the ordering departments, should especially conduce to the speedy and certain location of the pattern required. In the language of chance (which seems to operate here occasionally), the dice should be loaded in favour of the pattern stores.

Location of Patterns

Now, location—speedy location, at least—implies an easy recognition of the thing sought. As a general rule, therefore, the men whose duty it is to serve out and collect the patterns should be able to trace many of them merely by the mental picture reflected by the identification mark—without referring to the register. That is to say, although one may obtain from the register the locker number of any pattern, advantage will accrue, in the way of speed and general economy, by the adoption of a method of identification in which memory is given a chance to work gratuitously. In this way, the wear and tear of books, time, and wages may be saved. The slogan should be: " A personality for every pattern!"

It is a well-known principle of mnemonics that memory very largely functions by the " association of ideas." Our earliest " cultured " ancestors instinctively sensed and applied this principle in their " Picture-writing." The main difference, by the way, between what is called the "civilised" and the "uncivilised" mind lies very largely in the fact that the former has brought the crude, picture-writing of the latter to a very high and complicated pitch of perfection. It may here be of interest to recall that the peculiarly picturesque nature of the Chinese language enabled Confucius (born 551 B.C.) to express the "Golden Rule" in one character, which we may translate in English by "Reciprocity." The ideogram is composed of two other characters, one denoting "heart" and the other —itself composite—denoting "as"; that is, my heart, as, or in sympathy with yours.

It is also pertinent to mention that our barbaric ancestors did not employ cyphers. They preferred pictures to mathematics. Their method of counting (still extant among our less-advanced brethren) being: "one," "two" and "a great number." And the "great number" appears to have been correctly registered as a picture on the mental retina of the savage.

Now, applied to the question of pattern identification, the foregoing points to the advisability of coupling, with the specific allocation of cyphers, a generic letter. This letter would have the effect (to continue the picture phraseology) of projecting on the pattern-storekeeper's mental screen the category to which the particular pattern belongs. The first step (proverbially difficult) to recognition would in this way be secured. The generic letter may either refer to distinct classes of work or to departments. In any case, they would afford considerable assistance to the pattern-storekeeper.

The author makes no apology for devoting so much attention here to the question of pattern identification. It is the last operation on the pattern; but it is certainly not the least in importance. As a postscript, it may be observed that the registration of Treasury notes and motor vehicles is on the lines above enunciated. The most "catchy" advertisements, again, use this method. The system works. And, lastly, the present year will, in the æons of ages to come, be referred to as: A.D. 1934.

Conclusions

This Paper began by postulating the pattern as an intermediary between design and casting. The note will serve to end upon. It sounds the patternmaker's "charter of liberty": liberty to create, to invent and originate. Translating two-dimensional design into a three-dimensional moulding agent can never become a routine job. Such translation essentially demands the interpretative flair of the linguist, plus the pioneer's urge for an ever-better way. Here is scope for genius, as defined by Dr. Johnson: "A mind of wide, general powers accidentally determined in some particular direction." The facile reading of blue-print; the mental picture of the casting; questions galore; to core, or not to core; how best to mould the job—with special reference to jointing; the imperceptible metamorphosis from the naked casting to the fully-accoutred pattern; then, grappling with powers of construction—to secure service strength and checkmate warping; into the realm of action: the ambidextrous manipulation of tools—where kaleidoscopic adaptation of force and direction uncannily suggests deep, mutual affection, and proves the perfect co-ordination of hand and brain! This—with interludes and variations—is patternmaking. Whether its pursuit is, to the patternmaker, inspiring music or a mournful dirge, depends entirely upon himself. He may make it (to quote Prof. T. H. Huxley's reference to man's life in general)—either a funereal march or a triumphal procession!

In conclusion, the author wishes to express his thanks to his employers—Messrs. W. & T. Avery, Limited—for their kindness in connection with this Paper.

DISCUSSION

Mr. J. F. Greenway, proposing a hearty vote of thanks to the lecturer, said that he had obviously taken account of the difficulties of the foundryman and the moulder, and had shown he was possessed of true foundry sense. The small points in the finishing up of patterns counted a great deal in the foundry, and Mr. Edwards had given them food for thought in this direction. Mr. W. James, in seconding, urged that the Paper ought to be circulated among employers to show what patternmaking was. Many patterns were constructed contrary to the plan Mr. Edwards advocated, which was unfortunate for the foundryman. In too many cases the idea was something cheap, ignoring the practical aspect of how the moulder was to produce the casting. Sometimes patternmakers put in a lifting plate contrary to the method of moulding. He considered that patternmakers should spend six months in a foundry in order to realise the practical difficulties the moulder was up against. The motion was carried most cordially.

The Branch-President (Mr. E. J. Lewis), referring to the bedplate spoken of, said that in patternmaking of the description cited most designers liked to put a fancy bead round it. To construct a pattern with a half-lap joint and then cover in as shown on the slide would be difficult. In such cases of a fancy bead he thought the usual method was to make a master pattern, and cast a light metal frame and cover in round that. This plan imparted strength, stopped expansion and contraction from the pattern point of view, and held the pattern straight. Admittedly, it was something expensive, but taking the requirements of 1,000 to 3,000 castings mentioned by Mr. Edwards, this extra expense would not make much difference to the ultimate cost of the castings. He thoroughly agreed that prints should be cast as part of the pattern. But he himself always extended any prints outside so as to lighten out the job. Mr. Lewis instanced a metal pattern $\frac{3}{8}$ in. thick, and said that instead of using a print the ultimate size of what it was to be on the job, he cast the print on the metal pattern and then extended another one outside it, making a rough corebox to ensure the print being on the metal pattern which he was making.

Regarding the painting of patterns and rushing them into the foundry to "get one off," he was dead against painting when patterns went straight to the foundry for moulding. In such cases they were bound to get a sticking of the sand and a dirty mould. The best plan in an urgent job was to send the pattern back for painting and finishing after the rush casting was done.

Varnishing and Camber

Mr. W. James considered it possible to varnish a pattern so that mould moisture became a secondary consideration. By applying a number of coats of good varnish, any damage from mould moisture became almost negligible. In making tooth wheels from a pattern 5 ft. in dia., he had no trouble owing to the use of a good strong varnish of sufficient coats. Camber was a subject which he found few knew much about. In making handrails to fit on the top of square rods—they were 9 ft. long—he suggested an allowance of $\frac{1}{8}$ in., as the rails had to be dead straight. The foreman stood out for $\frac{1}{4}$ in., so they split the difference. Difficulties arose; in the first five or six not one was straight. He subsequently learned that the usual attitude had been not to recognise camber. As Mr. Edwards had a good deal to do with flat material, perhaps he could enlighten them further as to camber. Mr. James added that he could confirm what had been said in praise of plywood.

The Way to Make Bed Patterns

Mr. J. B. Johnson, as an old patternmaker, was glad that so many members had turned up to hear so eminently practical a Paper. He remembered a set of patterns being forwarded to his firm's foundry for a gas engine with a long bed. This bed was made exactly as the lecturer illustrated in Fig. 2. It lay in the sand all night, and the air was "blue" next day when efforts were made to get the pattern out. The real common-sense way, as pointed out, was to carry the sides down to the bottom. Thus, this trouble was avoided. Elementary points were important in practice; small things which were necessary, if ignored, only brought trouble and waste. He thought it advisable that a patternmaker should have some knowledge of foundry work. The suggestion of six months' tuition and work in the foundry might be improved upon; they might require patternmakers to work off some of their own patterns. Recently he had been casting some large plates 9 ft. by 8 ft. He checked the pattern over on one side, and it stood up very well. He did not attempt any striking-off of the bed, nor bedding them in, and good castings resulted. It was essential that in the foundry they should see that their tackle was right, and this ensured good castings and lengthened the life of their patterns.

Pattern Colour Specification

Mr. G. M. Callaghan believed he was correct in saying that a large percentage of the troubles of anyone managing a jobbing foundry could be put down to the patterns; either they were not right on entering the foundry, or were not right when they were worked off. A casting was made and went to the machine shop, being placed either on the machine table or in the lathe. It was carefully examined in a more microscopic way than was the pattern when drawn out of store. For measuring purposes as between casting and pattern he preferred to use the callipers and rule himself, because he had found engineers and patternmakers not particular to $\frac{1}{16}$ in. in measuring, and if a waster was made, it came back as the responsibility of the foundry. Patterns, if faulty, should be corrected before the moulder had to work them off again. He was not sure that two colours for painting were sufficient. A pattern ought to show which was metal, which was coreprint and machine face; and also where loose pieces fitted, as well as where pieces should be stopped off. The little pamphlet which Mr. Edwards thought of no value was, he considered, rather useful if everybody adhered to it; but they did not.

How Inferior Varnish Hinders

Different mixtures were used for painting in various pattern works, and he was faced with many patterns which seemed to have been painted with treacle. He did not think patternmakers realised the tremendous suction and pull required to release some of the patterns in big jobs. In one marine cylinder job of 7½ tons weight the crane used registered 15 tons in pulling out the pattern. Some patterns which had been rammed up some weeks were quite sticky. He had known patterns which had been varnished which were definitely sticky after being in the sand for some time; these were on big jobs. One little refinement came under his notice some years ago which worked very well in connection with coreprints on pipes, and he believed few patternmakers were aware of it. He had used it very successfully, and illustrated his point on the blackboard. This was a small fillet round a pipe print against the flange, which prevented the core from breaking away the corner of the sand; the core did not, as he showed, touch the top part at all.

Pattern Sketch Usage

Mr. J. W. Gardom remarked that the specification in regard to marking patterns was actually recommended by the Institute, and while he agreed with the lecturer's criticisms, he thought it would be more satisfactory if patternmakers were to try and keep to the specification. One thing which the Committee which considered the matter recommended was that the contraction of the metal should be stamped on all patterns so made, which would meet Mr. Edwards' point in that respect. Marking of patterns was very important. One firm with which he was connected made a sketch of every pattern and gave it the original number. On the blue-prints of the parts issued there was noted any question of cores and any difficulty and the price. The percentage of scraps from the last order was recorded also, so that at a glance full information was available.

Mr. J. F. Greenway, referring to the illustrations of releasing the core from core boxes, suggested that bolting would be a simple and convenient method, and said the screw holes would not become enlarged.

Taper Difficulties

Mr. G. W. Brown thought the supposed traditional feeling between patternmakers and moulders was exaggerated. However, it was exasperating to find that, while for a 6-in. deep job a patternmaker would allow plenty of taper, when it came to a matter of $\frac{1}{8}$ in. deep, the patternmaker seemed to forget all about it. Now suppose a patternmaker was arranging a corebox and print, a discrepancy of $\frac{1}{8}$ in. was nothing to him. He sent the box in with that discrepancy and caused endless trouble; whereas, if he took a little more care, he could eliminate much petty trouble which the moulder had to face. He recognised that it was a responsible job and that the patternmaker must take the initiative. It was not always possible for him to co-operate with the moulder, and some consultations might lead nowhere and delay the job unduly. On rush jobs, obviously, the patternmaker had little time for consultation with the moulder. His sympathy was with the patternmaker; but, all the same, moulders were good, hearty fellows who put up with various difficulties and made the best of them. Mr. Brown quoted a case as showing that the job could not possibly stand a thousand castings. He referred to flywheels and rope pulleys some 12 ft. in diameter and 6 ft. wide. These were made in a segment of coreboxes, with the arm of the pulleys going through the middle of the box to the outside, the rope grooves being built up in cores. The mere fact of handling the boxes would end in them being in pieces long before a thousand castings were made.

Camber

As to camber, Mr. Brown recalled the making of ornamental gates, with cast-iron segments, which were 14 ft. high and 2 ft. wide. They were made in four flat sides and bolted together, and sometimes it took three or four moulders two days sprigging the mould for the ornamentation. To decide on the camber was a question of trial and error. The men had an idea of how much camber to put on, but most of the panels had to be heated over the blacksmith's fire and placed under the steam hammer to straighten. It was very seldom one came out straight, and the question generally was a difficult one. Probably some of their troubles as moulders would be obviated if patternmakers had the opportunity to work from their own patterns in the foundry.

AUTHOR'S REPLY

Mr. Edwards, replying to the discussion, said that if there was one thing he had studied for over 40 years it was how to assist the foundry. While he agreed to some extent with a patternmaker having some foundry experience, any patternmaker worth his salt would consider the moulders' difficulties. Incidentally, he should read the "Foundry Trade Journal." In that way a patternmaker could learn a good deal about foundry problems in relation to patterns. The President spoke about a metal frame to keep patterns true. The only objection he had was that a metal frame added weight to the pattern and rendered the work of the moulder still harder. His idea was to reduce moulding work to the lightest possible degree consistent with sound results; the moulder would still have plenty of arduous work to do. He would rather adopt some plan for strengthening up a pattern by appropriate means, such as "framing," rather than add a quantity of metal. He agreed that if patterns were to be thrown off into the foundry straight away they were just as well without paint as with paint. They could then get them rubbed down and painted. Regarding the point of mould moisture raised by Mr. James, he agreed that patterns well varnished would defy moisture. He still had wooden patterns, from which 5,000 to 8,000 had been run off. Perhaps twenty coats of varnish had been applied. Patterns should be well rubbed down after use and given another good coating inside and out. A varnish which was reliable, and which they might call a good enamel, would defy most moisture conditions that the moulder could subject it to. As to Mr. James' remarks on camber, he appreciated the work of Longden on that subject. It was the most advanced of the kind, and although it did not apply to every case, it was very valuable. But if the individual moulder could manage to deal with camber correctly, good luck to him.

Camber

The method of using a board sufficient to resist the bending of plywood was, as Mr. James indicated, quite useful in regard to camber. Reverting to foundry practice for the patternmaker, Mr. Edwards said he did not hold with the latter spending six months there. He himself had obtained much knowledge by talking to good moulders. No patternmaker could learn moulding in six months. He advised patternmakers to question moulders on certain points. The way to obtain knowledge, he found, was bit by bit, and not to try to secure too much at once. They would find opportunities for going into the foundry and enlisting the goodwill of the moulder, watching the patterns being drawn from the mould and noting how the cores went into the mould.

That Pattern Colour Specification

He endorsed the method mentioned by Mr. Callaghan in preventing pipe snags; and with reference to Mr. Gardom's allusion to the British standard specification, he had spent forty years in pattern shops, and spoken to hundreds of moulders and handled thousands of Patterns, and his experience led him not to agree with it. He said this from his own knowledge of patternmaking, from his acquaintance with foundry work and with general engineering practice, and he considered it useless. He believed the idea was first suggested by America, and was then approved by the British Committee. In the long list of sponsors, headed by the Admiralty and the mechanical engineers, the poor patternmakers were placed at the bottom. He regarded it as a presumption that those who knew nothing about patternmaking should put forward a pamphlet and want 2s. 2d. for it in order to tell them how and what to varnish and so on. It was the patternmaker who should decide what to do with the paint. The whole thing was an effort to tie the patternmaker down to a standardised principle which was wrong, and if adhered to would cause trouble. What about patterns which have to be made under stress, or patterns which have to be produced at the cheapest price? Surely they could point where the metal was, or the core print, or what should be stopped off as occasion demanded, without a rigid standardisation which was uncalled for. He must confess that he had met with several curious methods or systems devised by people who did not know much about the subject, but he was fortunate in respect to his present firm. Mr. Gardom suggested that the stamping of the contraction of the metal employed in the pattern as recommended by the pamphlet would be helpful. In some cases this would be unworkable; as, for instance, in the cast iron and aluminium combination which he had spoken of. The patternmaker should use his own judgment, and he considered the works' management would be wise in leaving the patternmakers to work out their own difficulties, without imposing systems arranged by people who did not realise whether they were practicable. As to Mr. Greenway's idea of core boxes being screwed together, if it was a standard job this plan could be usefully followed. In the case of the core box with tapered shell, this formed a collapsible core box without thumb screws. Finally Mr. Edwards said he agreed with consultations between the patternmaker and moulder, but the moulder did not generally understand drawings. The foundryman preferred a clear cut question and not a series of theoretical inquiries. Some of the patterns he had shown had stood up to 1,000 castings, and were made twelve to fifteen years ago, but admittedly they were light in character.

Scottish Branch

PROBLEMS IN WOODWORKING MACHINERY CASTINGS

By Robert Ballantine (Member)

Castings used in the construction of woodworking machinery are extremely varied in design, consequently problems continually crop up, and these problems are mostly solved in the hard school of actual practice. The finished machines are classed as machine tools, but one cannot associate the castings used in construction with the massive and weighty units required for metal-working plant. To classify this work is difficult. It neither comes within the light-castings heading nor the heavy-castings section, but the fine finish of the former is essential, coupled with the easy-machining qualities of the latter—truly a problem in itself, due to many causes.

Modern machine-shop practice limits the machining allowances to a degree unheard of formerly, and this degree of accuracy can only be attained by intensive study, right from design to the machined castings. The tendency in woodworking machinery design is for *box sections* in place of *H sections*, large rounds in place of sharp corners, and a blending of perfectly flat surfaces into artistic contours. In comparing designs of castings on old machines with the castings of modern design, one cannot but admit the superiority of the modern product. In comparison with woodworking machines of the eighties the modern design is a work of art. Moreover, from 20 to 30 times the number of castings are now required for the modern machines.

In the majority of castings produced, machined faces are everywhere; metal thicknesses are very irregular and a large area of the metal is comparatively thin. To be successful, logical reasoning is all important in design, pattern construction, moulding, coring, gating, venting, densening and camber. In the first instance, many foundry problems arise through badly-designed patterns, apart from drawing-office design. The ancient practice of giving a blue-print to an individual patternmaker and allow him to saunter through the job is *dead*.

As the management of Messrs. White's is continually evolving new designs and new types of woodworking machinery, a thorough examination of all blue-prints is necessary, before proceeding with the work. Being fortunate (or otherwise) in controlling the pattern shop and foundries, the author is in a position to plan operations right from receipt of blue-prints to the castings. Co-operation with the drawing office is, happily, most harmonious, and any suggestions put forward are generally accepted. The result is, jobs are planned with all the foregoing points taken into consideration.

One of the greatest problems is, how to make the older type of pattern suitable for the economical production of satisfactory castings. Nothing short of scrapping is the only remedy if quantities off are required. Box-section patterns must be substantially constructed for foundry usage, especially where large rounds are shown. Moreover, it has become second nature to the foundry craftsman to make his parting to the flat. The result is that fettling charges soar and castings never have that rounded appearance which is so desirable.

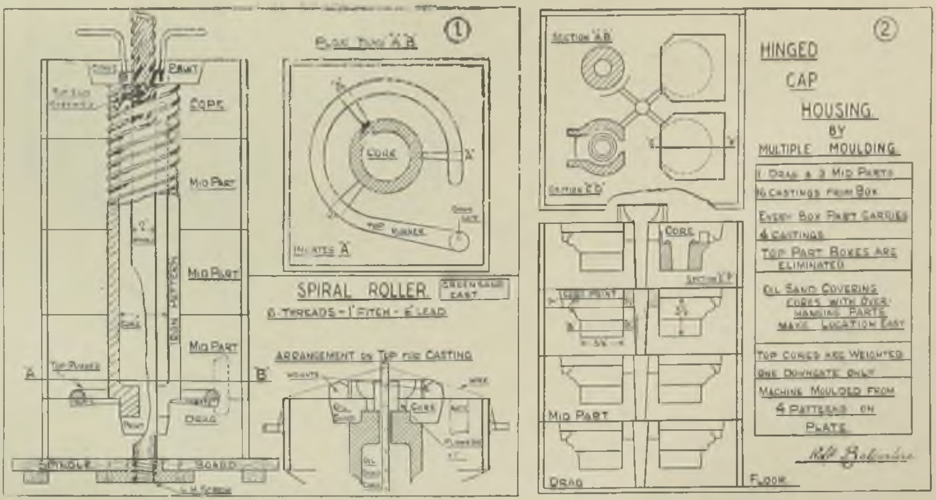
In many cases temporary bars are cast in panels and cut out afterwards. The majority of these box-section castings must be slackened and the core irons broken. True, it is much costlier —but the designer wants *large rounds* and *box sections.* Generally the finished product justifies his desires. Surely, foundrymen are not looking for the line of least resistance? Personal experience is that the cheapest and easiest design for foundry production does not always mean design should be altered to suit their needs.

Over 80 per cent. of our work is done in green-sand moulds, with oil-sand cores, including planing-machine main frames 20 ft. in length. Many of the larger castings are now made two in a box, and a time-study of production costs proves it a much more economical method than working separately. They are poured from the same head box but separate downgates are preferable. Another very important question is that of densening. Mr. E. Longden, of Manchester, once said " We have developed a densening technique which is giving splendid results," and the author agrees with his observations. The saving in rod-feeding time, and the low percentage of rejections due to porosity, more than repays the initial study which is given to this problem.

The insatiable demands of the modern machine shop keeps an attached foundry always on edge. The result is, departure from the recognised and orthodox methods must be made. Four examples of castings have been chosen for study:—The *first* represents an example of unorthodox methods for production; the *second* an example of mass-production castings; the *third* a case where the author objected to design alterations to an existing pattern and looked for the line of least resistance, and *lastly* an older type of pattern made two in a box to cheapen production, and which ought to be redesigned in patternmaking for further economies.

Spiral Roller

This roller is 30 in. long, 6 in. dia., and has six starts or six definite R.H. threads at an inch pitch. This means that one complete turn of this roller periphery makes a movement of 6 in. As hundreds of these castings are required, the machining was important, every thread being turned from the solid metal. At one period a wooden pattern was made, in halves, with the screws cut in. The results were hopeless, as it was necessary to have a side-screwing movement in drawing the pattern. To make matters worse, the delicate edges were always being broken in the mould. A very visible joint on the casting could not be helped, and finally the original method of casting solid was reverted to.



FIGS. 1 AND 2.—MOULDING DETAILS OF A SPIRAL ROLLER AND A HINGED CAP HOUSING.

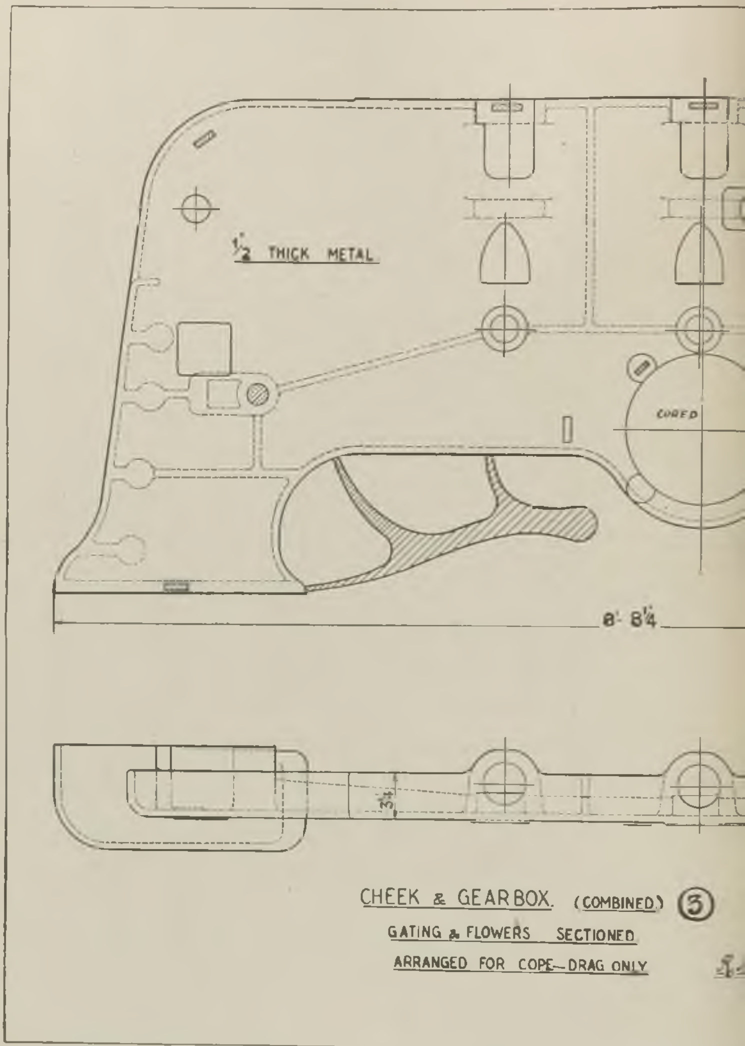
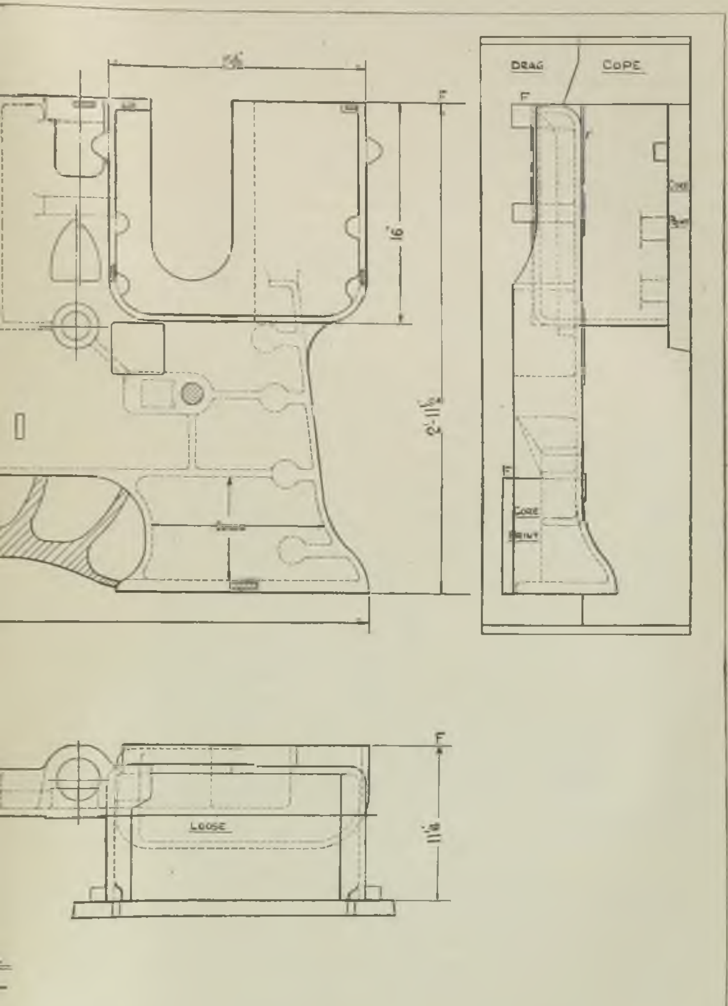


Fig. 3.—Moulding Details of a Che



D GEAR COMBINED INTO ONE CASTING.

On going through the machine shop one day and seeing the turning operations, the author suggested that if satisfactory pattern equipment were supplied there was no reason why these should not be cast. Frankly, the administration was a little sceptical.

However, excellent castings were turned out. These castings are produced in green sand with the main centre and the top covering cores in oil sand. A solid iron pattern was turned in the machine shop and made suitable for moulding on-end. The centre 2-in. spindle, as a centre guide, was also supplied, along with a service board. Inserted in the board was a flange, which has a left-handed screw to take the spindle. This makes the spindle perfectly rigid. The top-half of the spindle is screwed and also the top-half of the roller pattern in way of the end-boss. These screws have the same lead and pitch as the roller pattern.

The procedure in moulding is as follows:—The service board is laid on the foundry floor and the centre spindle inserted. When the pattern is lifted by the overhead crane, the plain bore in the bottom of the pattern allows the pattern to slip down over the centre spindle until the threads on both spindle and pattern mesh. The pattern then rotates down to a fixed position from the service board. The drag box is level with the bottom edge of the roller and is rammed up with the ingates in position. A top runner, as shown on the plan (Fig. 1), is placed on the drag, and the mid-parts placed on, one at a time, to allow of uniform fingering and ramming.

When fully rammed, the pattern is screwed out by the handles on top, and lifted away by overhead crane. The complete mid-parts are then lifted off, and the spindle removed through the drag. After the drag is set on a sand bed, the main core is inserted. It will be seen here that the core is enlarged to 2 in. in way of the print, to give a better seating, and also saves altering the spindle hole, which acts as a print. The mid-parts are now lowered into position, and the top covering core ensures true location of the main core. Wire is used for holding down the main core, this passing over the core tube to the box handles. The top covering core provides the two flowers on the top boss.

" Sterling " boxes suitable for multiple moulding are used on this job and are found to be ideal for this work. A specially-prepared facing sand is used with plumbago additions, and a very noticeable feature is the sleeking effect the turned pattern has on the mould when being screwed out. A slight alteration is made in the placing of the ingates since making the drawing (Fig. 1). The three ingates shown on the plan run direct to the centre, but in the castings now being made these ingates are placed at an angle. This is a much better method. With the radial ingates shown on the plan (Fig. 1) the metal has a tendency to churn against the outstanding sand when rising in the mould. The result was, slight washing and fusing took place and coarsened the bottom threads.

The angular ingates allow the metal on entering to rotate upwards on the screw thread. This has eliminated very considerably the coarseness at the bottom threads. Conveyor screws are sometimes made by this method, but these are generally single threads, and when one considers that these six separate screws must synchronise perfectly with the guide spindle threads, great credit is due to the engineering department for this fine work. To watch this pattern being screwed out of the sand gives one the feeling that mechanical innovations and unorthodox methods are certainly necessary in progressive foundries.

Hinged Cap Housings

Fig. 2 shows an arrangement for the multiple moulding of hinged cap housings. A tree of castings discloses how top-part boxes are eliminated. As these housings are required in multiples of 48, loose pattern methods were useless. Even four in a box in green sand did not make for satisfactory castings when an alteration was considered. It was found that the neck portion of sand next to the inside facing had a tendency to wash.

A pattern plate, with four patterns was made with provision for coring the inside, an overhanging print being the ideal type. The downgate was tapered with four ingate sprays attached and was pinned separately. It will be seen this method is a plain machine squeeze and pattern draw. Sixteen castings are produced from four one-part boxes of the " Sterling " type. One pouring basin and one downgate serve these 16 castings. The top cores are weighted and boxes clamped.

An examination of the tree will show two features which are outstanding:—(1) The downgate taper makes for a clean fall of metal when pouring and (2) the step made by the covering cores on the ingates acts as a top runner, and these stop any floating impurities from entering the respective moulds. As an experiment, two boxes were skinned in oil sand and dried to compare the finished castings along with those made in green sand. It is still a debatable point in this type of work which is the more satisfactory —green sand or dry sand. Personally the author favours green sand, as it gives a " catchiness " to the skin which is ideal in holding the filling prior to painting and varnishing of the finished machines.

Considerable saving in production times have resulted from this multiple method of moulding, as much as 75 per cent. in some cases. Moreover, floor space is conserved, only one pouring basin is necessary and one downgate for every 16 castings, therefore a bigger return of castings produced for metal melted. Square " Sterling " boxes are used, on the same 12-in. principle as shown in Fig. 2. [An aluminium tree exhibited at the meeting showed 80 castings made in five drags. The castings were 2 in. cube in shape and cored. They were poured from the same headbox, but with two downgates. The top runners were inside the cores and the ingates on the patterns.]

It is all these economies, multiplied by the number of times they occur, that make the difference between profit and loss.

Combined Cheek and Gearbox

This example has been chosen as an instance where foundrymen sometimes look for the line of least resistance. It shows a combined cheek and gearbox for a triple drum sander, and is approximately 8 ft. 8 in. by 3 ft. by $\frac{1}{2}$ in. metal. As this is an old type of pattern, and has always been made without the gearbox which is seen on the top right-hand side, the author naturally objected to this addition, because it meant that an additional mid-part 9 ft. by 4 ft. by 8 in. had to be rammed up extra every time this was made, and all for the gearbox. His objects were upheld, but in this case one must needs work to the drawing. As twelve were required in this instance, a new top-part box was made. The top-part bars, which were in the way of the gearbox, were left out and a square formed. On the existing pattern the gearbox was pinned, and an overhanging print added.

The pattern is laid on a turn-over board, and the drag rammed up, with ingates in position as is shown by the sectioned lines in Fig. 3. When turned over, and the partings made to ensure nice rounds, the cope box is added. As the top of the overhanging print is level with the top of the cope box, location is perfect when closing. By this method the mid-part has been eliminated. These cheeks are made in green-sand moulds. The gating and position of flowers are shown. These castings have a tendency to swell in thickness if proper care is not taken, but it is found that if the facing sand is rammed fairly hard and the backing sand normally, no swelling takes place. In addition, all this work is well vented by pricker rod. Machining allowances on this job are of the order of $\frac{1}{8}$ in. where marked " F."

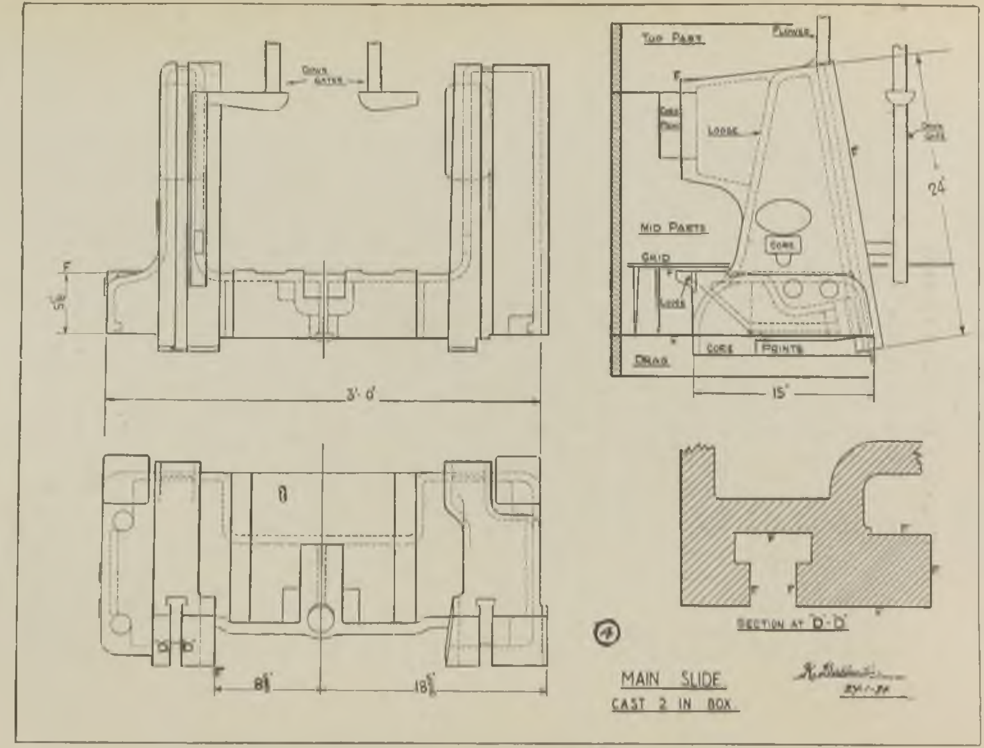


FIG. 4.—MOULDING DETAILS OF A MAIN SLIDE CAST TWO IN A BOX.

Main Slide for a Planing, Moulding and Matching Machine

Fig. 4 shows a main slide for a planing, moulding and matching machine, and is of a type which is machined extensively. There is in this instance a combination of objectionable features. The patterns were old and were not designed for production. Machined faces come within the category of being all over and metal thicknesses are very irregular, and, above all, it is quite a difficult job moulding and closing, although it is made in dry sand. They are cast as they sit, and made two in a box. From the slide it will be seen the cores must be tied down in the drag. A fairly strong grating carries the sand in the mid-parts, and clearances are allowed for easy removal for the re-using of this grating.

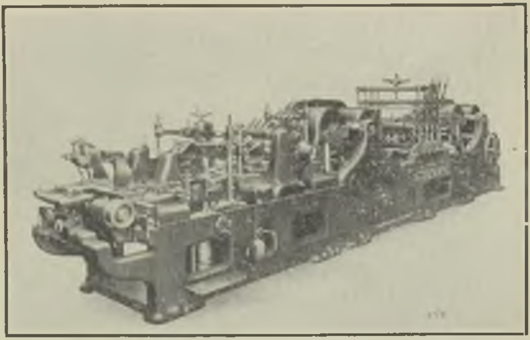


Fig. 5.—A Modern Planing, Moulding and Matching Machine.

In closing the mould, the parting at the top and mid-parts allows accurate setting of the leg core for metal thickness. The Tee slots shown are not cored out but cast solid. From a study of the section through D, D, it is obvious the metal varies very considerably and from 2½ in. to ½ in.

Formerly these were fed by rod, but this has since been stopped and denseners inserted in the mould and core. Nails are placed from the core at an angle to penetrate the slide projection on the right-hand side of Tee slots. A fairly large self-feeding head is placed on top.

Metal for all slides is treated with soda ash, as it gives a much finer sliding face. The porous patches liable to be present at the base of these slots are also eliminated. When the time comes for renewal of these patterns they will be arranged for moulding the opposite way down, and made practically a core-assembly job, with overhanging prints and self-centring locating parts.

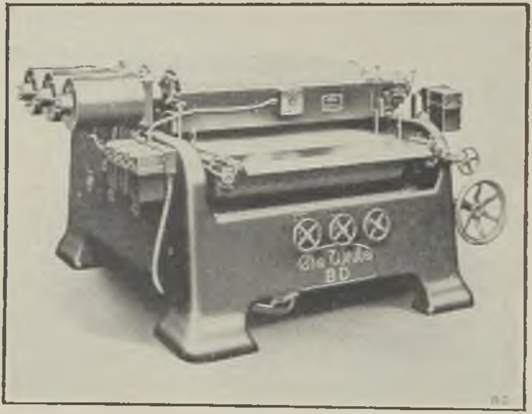


Fig. 6.—A Triple Drum Sanding Machine containing the Cheek Casting shown in Fig. 3.

A number of photographic slides were shown of finished woodworking machines and the outstanding castings were described.

Fig. 5 shows a modern planing, moulding and matching machine. The main frames are 20 ft. long and made in green sand. When the outside face of the cheek is cast upwards no camber is necessary. These cheeks are extensively ribbed inside and perfectly flat outside, with the exception of the feet, beads, facings and rounds. At one period, these were cast the other way up, *i.e.*, the main plate in the drag. Camber allowances from $\frac{7}{16}$ in. to 1 in. were essential according to length. In explanation the following reasoning is offered—when the plate is cast up the ribs fill first and the plate last; with the result that the ribs are sufficiently rigid to withstand the rise of the plate in cooling, which, of course, fills last. When the methods are reversed, the plate fills first and the ribs last, consequently there is no resistance to the rise of the plate. This means camber is necessary. The foundry is restricted to $\frac{3}{16}$-in. bare machining allowance on this cheek, and these are gated from the bottom side.

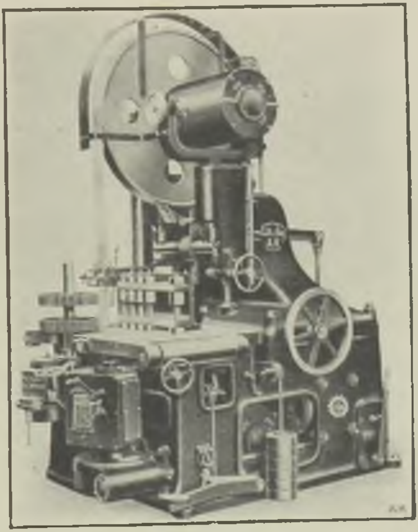


Fig. 7.—A 60-in. Vertical Band Saw.

A main slide, as shown on Fig. 4, is seen in position. These must be perfectly rigid. The top head cutterblock, carrying 10 knives and running at 4,000 revs. per minute on a 7½-in. dia. periphery, must have stability. On this type of machine, feather and grooving flooring can be produced at over 600 ft. per min. Any vibration is disastrous, as it furrows the wood and a series of ripples appear.

Fig. 6 shows a completed triple-drum sanding machine. The cheek casting described in Fig. 3 is seen here, but without the gearbox. The general outline of this machine is very pleasing to look at, and, apart from the utility of this product, very little dust can lie on it, due to the flat surfaces and easy cleaning facilities in design. About 90 per cent. of these castings are moulded in green sand.

Fig. 7 shows a new type of saw, namely, a 60-in. vertical band re-saw, with synchronised motors driving both top and bottom pulleys. The pulleys are 5 ft. in dia., and in this machine every casting was made in green sand. The lightening cores seen in the web are no longer necessary. The pulleys are turned all over and dynamically balanced. Despite the perfect turning, the author noticed a series of countersunk holes just under the rim to a depth of ⅛ in. and four in number at four places. The only conclusion arrived at was that four flowers were taken off the rim and these caused a difference in the density of the metal.

Conclusion

As with all progressive steps taken to eliminate unnecessary labour in a highly-mechanised engineering shop, an attached foundry such as we are, must do likewise to keep pace with that machine shop. The unfortunate position is that evolution is a process in so far as these foundries are concerned.

Unless these foundries are definitely on production jobs, unlimited trouble arises and the best-laid schemes " gang aft agley," due solely to good customers having pet themes of their own, and desiring improvements to be incorporated in standard machines. The result is first-class patterns are butchered and eventually there are more alteration-pieces attached to the pattern than comprises the pattern itself.

Problems in woodworking-machinery castings demand sand control, whilst metallurgical knowledge is essential, but if satisfactory patterns are supplied, half the battle is over in making this type of casting. Departure from the orthodox methods of pattern construction and moulding, especially where quantities off are required, will repay many times over the initial cost. Accuracy, speedier production, less fettling charges and uniform castings follow as a result of giving the moulder the minimum of trouble.

In conclusion, the author desires to record his indebtedness to the directors of Messrs. Thomas White & Sons, Limited, "Headquarters of Woodworking Machinery," Paisley (and incorporating Messrs. John McDowall & Sons, Limited, Sawmill Engineers, Johnstone), for granting him permission to give this Paper.

THE TECHNICAL COMMITTEE
OF THE INSTITUTE
OF BRITISH FOUNDRYMEN
IN COLLABORATION WITH
THE BRITISH CAST IRON RESEARCH
ASSOCIATION.

TYPICAL MICROSTRUCTURES OF CAST IRON.

Series 1. 1933.

This series of photomicrographs has been prepared in order that metallurgists should have some common standard to which their own observations of microstructures might be compared.

The specimens have been collected to show characteristic structures, and are not necessarily the best or only structures permissible in the class of casting from which they have been obtained. In view of this declared purpose, compositions have been purposely omitted.

The structures have been classified chiefly in decreasing order of graphite size, as it has been desired to emphasise this feature.

The explanations of the structures have been given in the simplest possible manner so that they can be appreciated by those foundrymen who are unfamiliar with the subject.

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The best thanks of the committee are due to Mr. L. W. Bolton, who has been responsible for the collection and photography of the specimens.

RECOMMENDED METHODS OF POLISHING AND ETCHING SPECIMENS FOR MICROSCOPIC EXAMINATION.

Extracted from the British Cast Iron Research Association's Research Report No. 105, from which fuller details may be obtained.

Sampling.—The structure of a casting varies from the cast edge to the centre of the thickness. For examination of the general structure of castings, specimens should be examined on a surface rectangular to the cast surface.

Specimens should be kept small for ease of polishing, an ideal size being ½-in. square surface area and ¼-in. thick. Several small specimens are preferable to one large one. In preparing specimens of grey cast iron the size of the specimen is of particular importance, as with sections 1 sq. in. surface area and over it is practically impossible to avoid covering over the graphite by burnishing in the centre of the specimen.

The position from which specimens for microscopic examination may be most usefully taken can often be decided by examination of a fractured or machined surface.

Polishing.—The surface to be examined must first be made flat by grinding or filing. Care must be used to avoid tearing or distortion of the surface. Overheating during preparation must be avoided, especially where the structure is such that it may be modified by such treatment. The face of an ordinary grinding wheel may be used if the following points are borne in mind:—

(1) The speed should not be high, *i.e.*, less than 1,500 revs. per minute and preferably about 800 revs. per minute.

(2) The surface of the wheel must be flat.

(3) The grain should not be coarse enough to cause tearing of the specimen.

(4) Adequate cooling of the specimen should be maintained by means of water or some other medium.

If a file is used it should be fixed in a vice and the specimen rubbed on it. Should particles of metal become embedded in the file, these will cause tearing of the surface of the specimen unless immediately removed. Rubbing the file with chalk before use will help to obviate this clogging.

When a flat surface has been obtained the specimen

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STRUCTURE No. 1.

Taken from a No. 1 Phosphoric Pig-Iron.

Unetched Structure.

Graphite in long straight flakes shows up against the metallic background.

Etched Structure.

Graphite Flakes (black) usually entirely surrounded by Ferrite (white). Groundmass of Pearlite (half tone). "Pools" of Phosphide Eutectic (herring-bone pattern) in centre of pearlite areas.

STRUCTURE No. 1.

Unetched. × 50.

Etched. × 200.

STRUCTURE No. 2.

Taken from a No. 4 Hematite Pig-Iron.

Unetched Structure.

Large quantity of evenly distributed medium size graphite flakes.

Etched Structure.

Similar to Structure No. 1, but with smaller graphite size and extremely small phosphide eutectic areas.

Manganese Sulphide is visible in both photographs as grey cubes.

STRUCTURE No. 2.

Unetched. × 50.

Etched. × 200.

STRUCTURE No. 3.

Taken from a Common Iron Casting.

Unetched Structure.

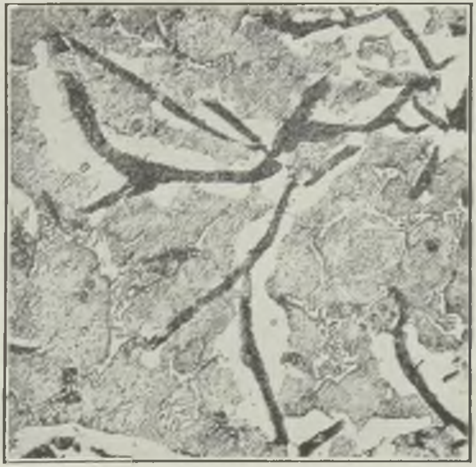
Medium sized Graphite Flakes.

Etched Structure.

Graphite, Ferrite, Pearlite and Phosphide Eutectic.

STRUCTURE No. 3.

Unetched. × 50.



Etched. × 200.

STRUCTURE No. 4.

Taken from an Engineering Casting.

Unetched Structure.

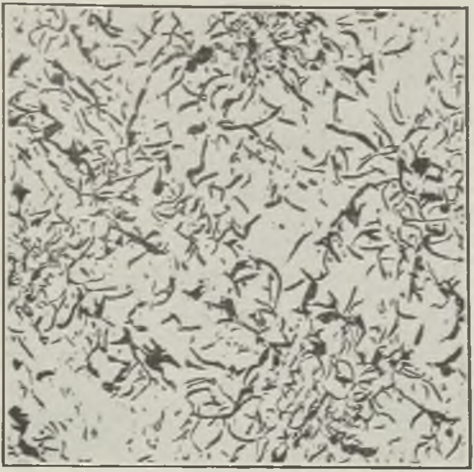
Small Graphite Flakes arranged in "Cluster" formation.

Etched Structure.

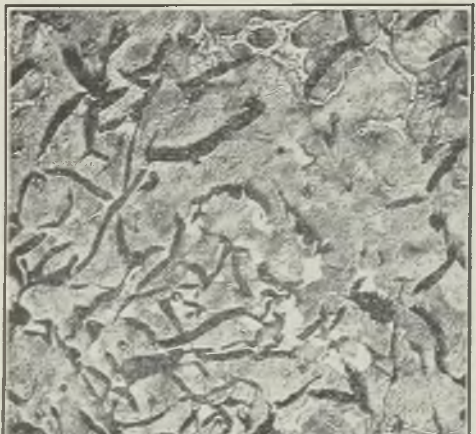
Note diminution of quantity of Ferrite as compared with previous structures.

Medium amount of Phosphide Eutectic.

STRUCTURE No. 4.



Unetched. × 50.



Etched. × 200.

STRUCTURE No. 5.

Taken from a Light Cylinder Casting.

Unetched Structure.

Note fineness and reduced quantity of Graphite as compared with previous structures.

Also note the appearance of a Dendritic Structure, in which the Graphite Flakes lie in straight lines parallel with, or at right angles to, one another.

Etched Structure.

Ferrite is completely absent and amount of Phosphide Eutectic is small. The Pearlite grain size is smaller. Manganese Sulphide is again visible. (cf. Structure No. 2.)

STRUCTURE No. 5.

Unetched. × 50.

Etched. × 200.

STRUCTURE No. 6.

Taken from a Light Casting.

Unetched Structure.

Note areas of Fine Graphite, with small amounts of Flake Graphite.

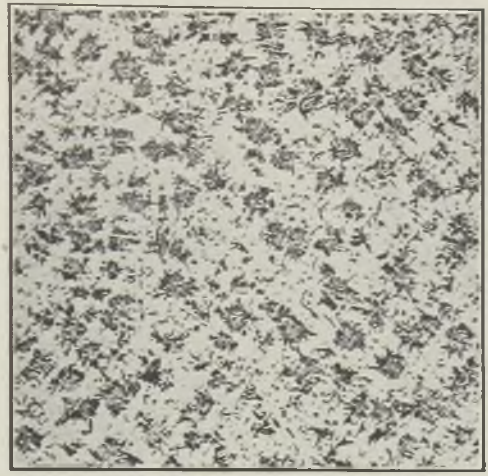
Etched Structure.

The chief feature is the "Ferrite-Fine Graphite" which occurs in rounded areas of fine graphite in ferrite.

Flake Graphite, Pearlite and Phosphide Eutectic are also present.

This type of structure is generally met with only in very light castings, although it may sometimes be found near the surface of heavier castings.

STRUCTURE No. 6.



Unetched. × 50.

Etched. × 200.

STRUCTURE No. 7.

Phosphoric Iron showing Free Cementite.

The Cementite (Iron Carbide) shows in a white banded formation, which is due to its being associated with the Phosphide Eutectic. Graphite Flakes and Pearlite are also present.

An Iron showing small quantities of Cementite such as this would not have a mottled fracture but would be fairly hard.

STRUCTURE No. 8.

Taken from a White Iron Casting (Non-phosphoric).

Graphite is completely absent, the whole of the carbon being in the combined form. The structure is composed entirely of Free Cementite and Pearlite.

Iron Sulphide is present as grey patches in the Cementite.

STRUCTURE No. 7.

Etched. × 200.

STRUCTURE No. 8.

Etched. × 200.

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should be rubbed on a fairly coarse emery paper at right angles to the scratches from the file or grindstone. Rubbing must be continued after the whole of the scratches have been removed to ensure that the distorted layer beneath the scratches is removed. The depth to which this layer penetrates depends on the method of preparation of the specimen and the physical condition of the metal.

The grades of French emery paper recommended for polishing are as follows:—

1G or some other paper coarse enough to remove file or grindstone scratches;
1F, 0, 00, and 000.

These papers should be firmly held on a hard flat surface, *e.g.*, plate glass, marble or hard wood. As a general rule rubbing should be continued after removal of the scratches from each paper for as long again in order to remove all traces of distortion in the surface layer.

Iron dust and emery which collects round the edges of the specimen after rubbing on each paper should be removed by wiping.

The specimen should be well washed before final polishing to ensure that all traces of emery and iron powder are removed. The polishing pad should consist of a hard flat surface covered with cloth or chamois leather. Selvyt cloth has been found to give satisfactory results. If the polisher is power-driven the speed of the pad should not exceed 1,000 r.p.m. and should preferably be in the neighbourhood of 600 r.p.m. Whether polishing is carried out by means of a power polisher or by hand, the pad should be kept moist and a plentiful supply of polishing powder used. This may be applied to the pad as a powder, being worked into the previously damped cloth with the fingers, or it may be shaken up with water and applied suspended in the liquid. By the latter method coarse and heavier particles of powder are prevented from reaching the pad. The following polishing powders have been found to give good results:—

Rouge;
Green chromic oxide;
Alumina (Diamantine) and Magnesia.

In order to avoid dragging of the surface in one direction the specimen should be slowly rotated during polishing. Immediately after polishing the specimen should be washed free from polishing powder and the surface quickly flooded with rectified spirits or some other volatile liquid. preferably from a dropping bottle.

The specimen should then be dried by one of the following methods:—

(1) Wiping with absorbent cotton wool.
(2) Use of an air blast (preferably warmed).
(3) Washing in hot water before flooding with alcohol.

These methods of drying are also used after etching and after thorough washing in running water.

Etching.—Before etching it is necessary to be sure that the polished surface of the specimen is free from grease and traces of polishing powder. Any grease present can be removed by alcohol dropped on the surface from a dropping bottle, or if necessary a small amount of soap can be lightly rubbed over the surface with the tip of the finger and the specimen washed in running water. Polishing powder may also require removing by the latter method. Specimens which are to be etched in an aqueous solution as a general rule give a more uniform etch if dried before placing in the etching reagent.

The specimen should be completely immersed in the etching reagent with the polished surface uppermost Tongs of metal such as nickel or brass may be used for holding the specimen, but under certain conditions local action is set up between the tongs and the specimen, and in these cases it is necessary to use either the fingers or tongs made of an electrical insulating material.

If an alcoholic solution is to be used, specimens will be found to etch more evenly if flooded with alcohol before immersion in the solution. This only applies when the action of the etching reagent is fairly rapid. In all cases it is necessary to agitate either the specimen or the reagent during etching in order to get a uniform attack over the whole surface of the specimen. Etching reagents which consist of an alcoholic solution of an acid may as a general rule be used repeatedly for a long period and will be found to improve with use. Care must be taken. however, to avoid concentration of the acid by evaporation of the alcohol and the solution must be kept free from contamination by water. Tongs which have been used to swill specimens in running water should either be thoroughly dried or swilled with alcohol before placing in the solution. and this also applies to specimens which are found to require further etching after washing.

The specimen should then be washed with alcohol and dried as before.

REAGENTS FOR ORDINARY CAST IRONS.

Picric Acid.—The most generally used etching reagent for ordinary cast iron and steel is a solution of picric acid in alcohol (rectified spirits). A 4 per cent. solution is recommended for etching grey cast iron, but, owing to ease of preparation, a saturated solution is often used. The time required for etching in order to reveal the ordinary details of the structure on microscopical examination varies with the character of the metal and the strength and temperature of the solution. With a saturated solution at 60 deg. Fah. five to 10 seconds' immersion is sufficient for a normal grey cast iron.

Nitric Acid.—A 2 per cent. alcoholic solution of nitric acid in alcohol (known in U.S.A. as Nital) is useful for developing the grain boundaries in ferrite, and for this reason is mainly used in etching wholly ferritic material, *e.g.*, black-heart malleable cast iron. The development of ferrite-grain boundaries by means of this reagent takes from thirty seconds to two minutes, and as a general rule this time is sufficient to over-etch any pearlite which is present.

The ferrite grains can be made to take on a colour contrast if the etching solution is heated to approximately 100 deg. Fah., and this will also shorten the time of etching.

Ammonium Persulphate.—A 10 per cent. aqueous solution of ammonium persulphate will darken both ferrite and pearlite, leaving phosphide eutectic unattacked, and is useful for revealing the phosphide eutectic distribution. Cementite is also unattacked by this solution.

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Sodium Picrate (Alkaline Solution).—This reagent will darken cementite while leaving ferrite unattacked, and for this reason is used for distinguishing between cementite and ferrite. Phosphide eutectic is somewhat discoloured by this reagent, and it is, therefore, difficult to differentiate between this and cementite by means of this reagent. The solution can be made up in the following way:—

> 2 grm. of picric acid are added to 100 c.c. of water in which 25 grm. of caustic soda are dissolved. This is gently warmed until the picric acid is dissolved.

The specimen is immersed in the boiling solution for approximately five minutes. Loss by evaporation should be made up from time to time.

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