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FOUNDRY IRONS

A PRACTICAL TREATISE

ON

FOUNDRY IRONS:

COMPRISING

PIG IRON, AND FRACTURE GRADING OF PIG AND SCRAP IRONS;
SCRAP IRONS; MIXING IRONS; ELEMENTS AND METALLOIDS;
GRADING IRON BY ANALYSIS; CHEMICAL STANDARDS
FOR IRON CASTINGS; TESTING CAST IRON; SEMI-
STEEL; MALLEABLE IRON; ETC., ETC.

BY

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PAPERS ON CUPOLA PRACTICE.

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PREFACE.

THIS volume has been prepared at the earnest request of many founders seeking practical information on FOUNDRY IRONS and their manipulation in the production of the various lines of castings.

It has been the aim of the author to present, in a condensed form, only such matter as is of practical value to the founder and to eliminate as far as possible all theories that have not been established as principles and all laboratory experimental work that has not been fully demonstrated to be useful in actual foundry practice.

It has been endeavored to give all useful up-to-date data on the manipulation of Foundry Irons as actually practiced in foundries, by both the old and the new methods; and thus, it is hoped to place before the founder, foundry foreman, moulder and melter such a variety of methods that he cannot fail to obtain desired results under any and all of the various conditions met with in the manipulation of these irons.

SEMI-STEEL, the new foundry iron, has been treated on to the fullest extent, from knowledge gained by the author in producing this metal and from information obtained from practical foundrymen casting it. But by reason of the wide variations in foundry pig the satisfactory production of this metal will be uncertain until, by experimental work with a grade of pig iron used in its manufacture, a standard mixture shall be attained. When this has been done a semi-steel may be produced with as great certainty as to quality as any of the various grades of cast iron.

The author would acknowledge his indebtedness especially to the Report on the Coke Industry by Dr. Richard Moldenke and to the Reports of various committees of The American Foundrymen's Association, The Philadelphia Foundrymen's Association, The American Society for Testing Materials from all of which he has freely quoted, as well as to "The Iron Trade Review," "The Foundry," and other journals. A few papers by other authorities have also been included as they are germane to the scope of the book, and to which due credit has been given in the text, as well as to various other sources of information.

Finally, it remains only to be stated that the publishers, as is their long-established custom, have caused the book to be provided with a copious Table of Contents and a very full Index, which will render any subject in the book easy and prompt of reference.

EDWARD KIRK.

PHILADELPHIA, JUNE, 1911.

CONTENTS.

CHAPTER I.

HISTORY AND SOURCES.

CHAPTER II.

Pig Irons and Fracture Grading Pig and Scrap Irons.

PAGE

CHAPTER III.

SCRAP IRONS.

CHAPTER IV.

MIXING IRONS.

PAGE

CHAPTER V.

LOSS AND GAIN OF IRON IN MELTING.

CHAPTER VI.

CASTINGS BY DIRECT PROCESS.

CHAPTER VII.

FOUNDRY CHEMISTRY.

CHAPTER VIII.

Elements and Metalloids.

CHAPTER IX.

IRON AND OTHER METALS.

CHAPTER X.

GRADING IRON BY ANALYSIS.

CHAPTER XI.

Chemical Standards for Iron Castings.

CHAPTER XII.

Analysis and Foundry Chemists.

PAGE

CHAPTER XIII.

TESTING CAST IRON.

CHAPTER XIV.

STANDARD TESTS.

CHAPTER XV.

SEMI-STEEL.

CHAPTER XVI.

MALLEABLE IRON.

CHAPTER XVII.

ANNEALING OF MALLEABLES.

CHAPTER XVIII.

PRODUCTION OF MALLEABLES.

CHAPTER XIX.

FOUNDRY NOTES.

FOUNDRY IRONS.

CHAPTER I.

HISTORY AND SOURCES.

Iron.—Pure iron as a metal is more rare than pure gold, it being met with only in laboratories and very seldom there, for it is of no value in the arts or industries. Unlike gold, it is not found in the pure state, but in combination with almost all of the known elements and when smelted from its ores remains to a greater or lesser extent combined with them. All commer-mercial irons are therefore compounds or alloys of metallic or non-metallic elements or substances. These foreign substances as we term them, for they are not all metals or elements, give to iron the characteristics that fit it alike for the plow share and the sword, the construction of huge vessels that plow the ocean, of tall buildings that almost scrape the sky, of men-of-war, large cannon, and for watch screws so tiny that they can be seen only by the microscope or glass, appearing to the naked eye like black grains of sand. Without these substances in combination with it, iron would for many purposes for which it is employed be worthless, and its application would be very limited indeed. Iron was known to the ancients, and has from the earliest historical period been obtained in more or less pure metallic state from some of its various metalliferous sources, yet new sources from which to procure it and new methods of working it have in modern times so multiplied as to almost rank it in importance with the discovery of a new and useful metal. These discoveries have kept pace with the scientific discoveries and improvements of the times so that the application of iron to the useful arts has made its use universal, and the manufacture of it has become indicative of the importance of a nation. And all civilized nations of the world seem to vie with each other in its production, and to this fact we owe all our modern improvements in its manufacture and working. In these new discoveries and improvements, the Americans have kept pace with the world, and why should they not do so, or lead the world in the production of iron suitable for every purpose for which it can be used, for our resources of this metal and of fuel are unlimited, and all that is necessary to do is to develop them. This we seem in a fair way to do with our million, hundred million, and billion dollar iron and steel companies. There is but one iron and that is pure iron, but there are many compounds of it and because of its preponderance in them, the generic term iron is applied to all of them. Many of these compounds have been produced by nature in the ores of iron and many are formed in the manufacture, working, and preparing of the metal to suit it for the purpose for which it is to be used. Of these, there is an endless variety, such as pig irons, wrought irons and steels, all of which present different characteristics, as well as a large number—not less than thirty-two—of preparations of iron which do not exhibit its solid characteristics and are employed for medicinal, and an endless variety of other purposes. No attempt will be made to describe all these irons, the processes of preparing them and their uses, as it would be impossible to do so within the limits of this volume. We shall therefore confine ourselves to cast iron and endeavor to describe its sources, manufacture and characteristics, as well as its uses in the art of founding, in such a way as will be of value and interest not only to the founder, but also to the moulder, melter and all those interested in the working or study of cast iron.

Iron Ores.—Iron is the most abundant of all the metals of which we have any knowledge. It is found in combination with almost all the known elements, in all parts of the world. It is found in the blood of human beings and of animals, as well as in the ashes of plants. Many minerals contain it in considerable quantities and in fact, there are very few of them entirely free from it. However, the principal source from which we obtain our supply is from the oxides and carbonates of iron or iron ores. These are known by various names derived from their different chemical constituents, and from the particular localities from which they are obtained, as red hematite, brown hematite, black band, spar ores, magnetic ores, iron pyrites, Lake Superior ores, Iron Mountain ores, Cornwall ores, etc. All these ores contain more or less iron locked up with oxygen in an apparently useless stone. Some of them are very rich in iron, while others are very poor. Some of the Iron Mountain ores of Missouri contain as high as 90 per cent. of iron, and are said to be the richest in the world. The Lake Superior ores are the next richest ores in this country that have been found in large bodies, while some of the Pennsylvania ores found in small quantities, are equally rich in iron. The poorest ores are the bog and surface ores, some of which only contain from 10 to 20 per cent. of iron. These ores were the principal source from which we obtained our supply of iron in early days, but since the increase of facilities for transportation, the richer ores are generally smelted and the poorer ones only when suitable for fluxing the richer ones. Besides these rich and large deposits of iron ore, some of greater or less extent have been found in almost every state of the Union, some of them being very rich in iron. Thus it may be said that our supply of iron ores is at the present time unlimited and apparently inexhaustible for hundreds of years to come. Almost every other civilized country also seems to be equally well provided with iron ores, and the country that is not, or has not the quality desired, may readily obtain a supply by importing ores of a desired quality from other localities, the same as we are now doing from Cuba and from the far-off Mediterranean Coast. This was not thought of by some of the old iron masters of this country thirty or more years ago, for in 1870, when the prices of pig iron went up to $45 and $50 per ton, they predicted that it would never again sell below these figures, giving as a reason that the iron ore deposits of Great Britain, at that time the greatest producers of iron in the world, were almost exhausted, and the supply of ore in this country was limited. Since that time pig iron has sold as low as $12 per ton in the district in which this prediction was made, and the output of pig iron in this country has increased from 1,665,179 tons in 1870, to 25,795,471 tons in 1909, and that of Great Britain in a like proportion, and there still being an abundance of ore in sight, the founder need have no fear of having to close his foundry for the want of pig iron due to the exhaustion of iron ore. There is an abundance of it and iron will probably continue to be smelted from it as long as there is a demand or market for it.

Mixing Ores.—In the early days of blast furnace practice it was the custom to locate the furnace near an ore deposit and smelt only the ores from this deposit, or one quality of ore. The ore sometimes produced a foundry iron in which case it was frequently cast direct from the furnace into such castings as there was a market for in the immediate vicinity of the furnace. Many of the castings made in this way were cast iron pots for household use and from these the metal received the name of pot metal, by which term it is still known and designated by many people. When the iron smelted from the ore was not suitable for castings, a small rolling mill was sometimes constructed for making the iron into wrought iron, or other ways of using it had to be devised. The ruins of many of these furnaces and small iron works may yet be seen in different parts of this country. With the building of wagon roads a market was found for pig iron, and a product of a desired quality was obtained by mixing irons from different furnaces which frequently produced an iron having when remelted and cast entirely different characteristics from any of those which entered into the mixture. After the construction of canals and railroads which gave facilities for transporting ores, furnacemen began to mix ores from different ore beds with a view of obtaining a desired quality of iron from their furnaces as had been done by mixing the iron from these ores when remelted. Prior to this furnaces were mostly located near ore deposits and we find the ruins of them in the most unexpected places, and wonder what ever possessed the man to build a furnace in such a place. But probably the builders of these furnaces would be as much surprised as we are if they were to return and find furnaces, as they now are, at a distance of hundreds of miles from the beds from which they receive their supply of ore. For the production of iron of a desired quality the ores were mixed in different proportions and the resulting iron was tested for the purpose for which it was to be used. By varying the proportions of the different ores smelted, furnacemen were able to produce a foundry, mill, or steel iron. But the quality of ore from the same mine or district varied and, with the same mixture or proportion of various ores, a furnace frequently produced an entirely different quality of iron from that which it had been turning out without it showing any indication of the changes that had been effected in its quality. This caused a great deal of uncertainty as to the quality of an iron, and furnacemen that were making a first class foundry iron with a high reputation would frequently find piles of their irons condemned in foundry yards and the high reputation of this product gone. To overcome this difficulty resort was had to varying the mixture of ores and testing the iron by having it melted in foundries and run into work to be cast. This did not always prove satisfactory and many furnacemen producing a foundry iron with a high reputation and on the road to fortune were ruined by these changes in the quality of iron, and the making of foundry irons, while far more profitable than that of mill irons, was regarded by many furnacemen as a lottery in which they did not care to take any chance. This uncertainty in the quality of foundry iron and the desire of steel manufacturers for iron of a special quality led to an investigation as to its causes and the employment of chemists to determine the quality of iron, and this led to determining the property of ores from which the iron was made. This was done by analysis of the ores and iron and has resulted in a system of analysis of ores that indicates accurately the quality or characteristics of iron that may be obtained from them when properly smelted. But ores are not always properly smelted in furnaces owing to the variation in the quality of fuel and bad working of the furnace, and the quality of iron indicated by analysis of the ores is not always obtained from them. This difficulty is overcome by a system of analysis of the iron which indicates accurately the characteristics of an iron and kind of casting it may be used for when remelted. But here again the iron is liable to change from poor fuel and bad melting and while foundrymen are more certain as to its quality they cannot be absolutely sure of obtaining the desired quality in their castings.

Blast Furnaces.—It is not our purpose to describe in detail the construction or management of a blast furnace, but only to give such a description of it as will enable the founder to comprehend what kind of a furnace it is, and to more fully understand the terms or names by which the various foundry irons are designated.

Blast furnaces are constructed upon the same general principle as the cupola furnace, although much larger. They are cylindrical in shape, have an opening at the top through which they are filled with fuel, ores, flux, etc., for smelting, and are supplied with air for the combustion of the fuel and smelting by a blast forced through tuyeres placed near the bottom. Iron is drawn from the furnace at the bottom through a tap hole, and slag is drawn off at a point just below the tuyeres upon the same plan as that of a cupola in long heats or continuous melting.

They are designated hot blast, and cold blast furnaces according to the temperature of the blast when forced into them. Those supplied with a blast of the normal temperature of the atmosphere are called cold blast furnaces, and iron from them, *cold blast iron.* Those supplied with a blast heated to a temperature of 300° to 500° F. before entering them, are known as hot blast furnaces, and iron from them *hot blast iron.* The cold blast furnaces all use charcoal fuel for smelting the ores, and iron from them is designated *cold blast charcoal iron* or *cold blast iron.* Charcoal is also used as fuel in a furnace with a hot blast. The iron from these furnaces is called *hot blast charcoal iron* to distinguish it from the cold blast iron. A warm blast charcoal iron intended to take the place of cold blast iron has also been made, but this does not appear to have come into general use, or to have been placed upon the market under this name. Iron from furnaces using anthracite coal as fuel is designated *anthracite iron;* that from furnaces using coke as fuel is known as *coke or bituminous iron;* that from furnaces using a mixed fuel or charcoal and coke, as *charcoal and coke iron*, and that from furnaces using anthracite coal and coke fuel, as *anthracite coke iron*.

The blast furnaces of this country in early days were all cold blast charcoal furnaces, some of which did not produce more than five tons of iron in twenty-four hours, and a ten to twelve ton furnace was considered a large one. Later on, this class of furnace was to some extent enlarged, and with the production of the hot blast their output of iron was increased, but the charcoal furnaces are still small ones in comparison with the anthracite and coke furnaces. This is due to the fact that charcoal does not carry as heavy a burden of ore as the harder fuels. With the disappearance of forests, the source from which charcoal is obtained, and the development of the country, the number of charcoal furnaces has gradually decreased until the output of charcoal iron is very limited, and this will probably be still further decreased from year to year until the industry becomes extinct.

After the discovery of anthracite coal, in Pennsylvania in 1808, and the opening of mines in 1820, many anthracite furnaces were constructed and operated. They were of a larger type than the charcoal furnaces, and their output of iron greater, but in some respects inferior to both the cold and hot blast charcoal iron. However, for many purposes, the product was considered a good iron, and soon came into general use as a foundry iron. These furnaces were principally located in the anthracite coal fields or convenient to ore beds in Eastern Pennsylvania, New Jersey, Maryland and New York, and were the source from which these sections of the country, as well as the New England States, for many years derived their principal supply of foundry irons. In these districts this iron almost entirely replaced the charcoal irons for foundry use, but in its turn has been compelled to give way to coke iron so that the output of it has been gradually decreasing until at the present time it is small compared with that of years ago, and will probably be still further decreased, as many of the anthracite furnaces are adopting coke fuel exclusively, while others are using a mixed fuel of coal and coke. The coke furnaces when first constructed were small ones, a twenty-four ton furnace being considered a large one, and owing to the poor quality of coal used for coking and lack of knowledge in coke-making, the iron produced by them was of a very inferior quality as a foundry iron, and was principally used as a mill iron in the manufacture of wrought iron. But with the discovery of a good quality of coal for coking, and advance in the manufacture of coke, the quality of iron became better, furnaces were gradually enlarged and improved so that this iron has now become the leading product, and the furnaces the largest in the country, some of them being capable of producing 500 tons of iron in 24 hours.

Coke iron takes up in smelting many impurities from the coke, but in the manufacture of wrought iron, a commercially pure iron, these impurities are removed in the puddling process, and in the manufacture of steel in the converter or furnace, so that for the production of wrought iron and steel, coke-smelted iron answers the purpose equally as well as a charcoal-smelted iron, but as a foundry iron it is far inferior to the latter.

Improvement of Foundry Iron.—With the introduction of foundry chemistry, it was hoped that the quality of foundry iron would be improved at least to the extent of giving to the founder a material having all the fine characteristics of the cold and hot blast charcoal irons of years ago. But in this chemistry has completely failed, and the founder is compelled to get along with the inferior foundry iron of to-day, while the chemist is only a manipulator of these irons, and the field is still open for improvement of them.

This field seems in a fair way to be covered in the near future and a better iron will very likely be produced at the blast furnace by the improvement in the quality of coke as a smelting fuel. So great an improvement has in the past few years been made in the coking process of foundry coke that hundreds of the old style beehive coke ovens in the great Connellsville coke region, that formerly supplied the foundries with more than three-fourths of their coke, are now grown over with grass and weeds, and as one travels from Pittsburg to Altoona, over the Pennsylvania railroad, not one of the many coke ovens is seen to be in operation. This celebrated coke has been almost entirely replaced in the West by the Solvay Process By-product Coke, and to a large extent in the East by this and other coke. The reason for this is that the by-product coke is free from sulphur and other impurities injurious to iron, and higher in carbon, and gives better results in melting than Connellsville coke. It has not been used to any great extent in blast furnaces, owing no doubt to the limited supply, but it is only a question of time when the great Connellsville coke region will seek to regain its lost prestige in the coke business by the adoption of by-product ovens or even better ones, and an improved quality of coke be produced in abundance for both blast furnaces and foundries. The improvement in blast furnace smelting fuel is what is more than anything else required for the improvement of foundry irons, for the fuel used in smelting ores imparts to the resulting iron certain desirable or undesirable characteristics for foundry use, as illustrated in a charcoal and coke smelted iron, and the nearer a coke can be brought to the pure carbon standard of charcoal the better the foundry iron smelted by it will be. What is desired in a coke smelting fuel is the elimination of sulphur and silicon, for these two elements are detrimental to iron in any proportion. Sulphur hardens and weakens iron, while silicon softens and weakens it. This weakening effect of silicon is due to its presence in the iron and to the flaky condition in which it places carbon in it, the carbon begin thereby prevented from entering into combination with the iron and producing a soft, strong metal as in a charcoal-smelted product, the fuel used for smelting the latter being almost free from silicon. Carbon is the true controlling element in cast iron as well as in steel, and all impurities in a smelting fuel that tend to destroy this control are detrimental to iron as a foundry iron, and the sooner this fact is recognized by makers of foundry iron, and a better smelting fuel provided, the sooner there will be an improvement in these irons.

As a foundry iron coke-smelted iron is the most complicated body known with which man has to deal on a large scale, for in it may occur not only many of the elements or substances found in combination with the iron in the ores from which it is smelted, but also impurities taken up by the iron from the smelting fuel. These give to it such varied characteristics, that it has baffled the experts of the various Foundrymen's Associations in establishing a standard analysis for the sale and purchase of foundry iron. Their first standard proved a failure and their second one amounts to this,—All foundry irons are good irons, if the founder and chemist know how to work them. The same is the case with analysis for mixtures, and an analysis for a mixture of iron that gives a satisfactory iron in one foundry, is of no use with a different brand of iron in the mixture for another foundry making the same line of work. It is not the fault of chemistry that a satisfactory standard of analysis for pig and mixtures has not been established, but it is due to the wide variation and the characteristics of this iron when made from different ores and smelted with different qualities of coke.

With the wide variation in the characteristics of this iron there seems at present to be no probability of a solution of these problems. Probably the only way that they will ever be solved is to go to the fountain head and improve the quality of coke iron at the blast furnace.

Analysis of Connelsville Coke.—This coke is all made in beehive ovens and from coal mined over a large area, all of the mines however not producing a good coking coal, which accounts for the wide variation in analysis.

		Best		Worst	Average	Good Connellsville Coke
Moisture	From	1.50	to	3.50	"	2.50
Volatile Matter	"	0.50	"	1.50	"	1.00
Fixed Carbon	"	89.00	"	83.00	"	86.00
Ash	"	9.00	"	12.00	"	10.00
Sulphur	"	0.70	"	1.40	"	0.90

The sulphur is weighed in the ash, hence the totals run that much over 100 per cent, if the sulphur is added extra again.

Analyses of Other Coke.—The following very interesting report on the coke industry as affecting the foundry and analysis of various cokes was recently prepared by Doctor Richard Moldenke for the United States Bureau of Mines, and published by them in Bulletin 3. The Doctor says in other parts of the report, that many coke tests have shown conclusively that much can be done to improve a coke by adapting the process of making it to the requirements. This being the case it would appear as though the quality of the product of a furnace exclusively making foundry iron could readily be improved by a proper coking process and a better iron turned out than is now the case with the use, as is probably done, of the lower grades of coke shown in the following analyses; for the best coke goes to the foundries at a higher price than furnacemen are willing to pay.

COKE DISTRICTS OF THE UNITED STATES

General Statement.—Fortunately for the foundry industry it is possible in practically all the important centers of the industry to get good cokes, at reasonable prices through competitive rates, from the several coal fields. The foundryman, however, who is so placed that he can get, for example, a Clinch Valley coke cheaply, but insists upon having Connellsville coke at a dollar or two higher, incurs a direct and avoidable loss.

Coal-washing methods have now progressed so far that it is possible to make very creditable foundry coke out of what was formerly considered almost too poor material for the blast furnace. Hence, if the producers give proper attention to the wants of the foundry, and the users of coke take into account the differences in its structure and composition. with existing facilities for shipment, there should be little trouble in the marketing of coke from any part of the country. It will be well, therefore, to describe briefly the coking districts of the country and point out some of the characteristics of the coals to be found in each.

Coal from five of the seven great fields of the country is used for the manufacture of coke. These fields are the Appalachian field, embracing Pennsylvania, Virginia, West Virginia, Ohio, Tennessee, Georgia, Alabama, and eastern Kentucky; the eastern interior field, in Illinois, Indiana, and western Kentucky; the western interior field, in Iowa, Kansas, Missouri, Nebraska, Arkansas, Oklahoma, and Texas; the Rocky Mountain field, in Colorado, Montana, Wyoming, Utah, and New Mexico; and the Pacific coast field, in Washington.

DESCRIPTION BY STATES.

Alabama.—Alabama is one of the large producers of coke and has an advantage in home markets. Its coal is rather high in impurities, and nearly all the slack and more than half the run-of-mine coal used for coking is previously washed. Probably the chief cause of objection to Alabama coke is the rather high sulphur content, which is injurious for stove castings and similar articles. Otherwise the coke of Alabama is used satisfactorily for the foundry. Alabama coke has about the following composition:

Average Composition of Alabama Coke.

	From run-of-mine coal.	From washed slack.
Moisture	1.34	0.75
Volatile matter	1.03	.75
Fixed carbon	83.35	86.00
Ash	14.28	11.50
Sulphur	1.30	.90

The analyses show up better for coke made from washed coal.

Colorado.—Practically all coal from Colorado used for coke purposes is washed. Average analysis is about as follows:

Average Analysis of Colorado Coke.

Moisture	0.44
Volatile matter	1.31
Fixed carbon	82.18
Ash	16.07
Sulphur	.44

The coke should be improved with respect to its high ash by better development of the washery practice.

Georgia.—Very little coke is made in Georgia, but that little is good. The industry is confined to the extreme northwestern corner, in Dade County; "Durham" coke is known, in the market which it reaches, as a good low-sulphur foundry coke, easily operated.

Illinois.—In Illinois much foundry coke is made in by-product ovens from coals drawn from West Virginia. This coke has become standard for foundry practice in northern Illinois and tributary regions. The Illinois coal itself gives a rather poor coke even when washed, though doubtless it can be used to advantage by mixing with other coal possessing better coking qualities. An analysis of a coke made from a washed Illinois coal is as follows:

Analysis of a Coke made from a Washed Illinois Coal.

Moisture	2.78
Volatile matter	.74
Fixed carbon	83.35
Ash	13.13
Sulphur	2.49

In spite of its quality this coke has its uses, though probably one would do well to keep clear of it for ordinary foundry work. Foundry men will recognize in the above analysis a material much like that which they sometimes get during coke famines.

Kentucky.—Kentucky draws its supplies of coal from two of the great coal fields. Most of the coke is made in the western part. The analysis of Kentucky coke shows normal components except the sulphur, which runs above 1 per cent. and sometimes nearly to 2 per cent. The sulphur in the coal is chiefly in the form of pyrite, much of which is eliminated by washing.

New Mexico.—New Mexico is becoming an important factor in the coke production of the West, as one sees on visiting its coal regions. The coal is so dirty, however, that for coking purposes it must be washed, and when it is so treated some analyses still show over 10 per cent. of ash. The sulphur content is rather low, being between 0.60 and 0.70 per cent.

The great coke plant at Dawson, N. Mex., is interesting. The gases from the modified beehive ovens are used for raising steam for the plant, but the other by-products are lost.

Ohio.—Ohio is coming up as a coke-producing State, though not so rapidly as it should, probably on account of the proximity of the Pennsylvania fields. Many of the coals have to be washed, and the sulphur and ash are generally a little high.

Pennsylvania.—Pennsylvania is, of course, the banner State for coke. Coke is made in ten districts that are geographically distinct. The amount of slack that is washed before coking is considerable, but not so large as in other coal fields. Nearly all of the coal mined in the Connellsville district is used for coke making, and most of the coal so used is unwashed run-of-mine. As detailed statements of the statistics can be found in the volumes of Mineral Resources annually issued by the United States Geological Survey, it will suffice here to give the range in composition.

Range of Composition of Pennsylvania Cokes.

Moisture	0.23 to 0.91
Volatile matter	.29 to 2.26
Fixed carbon	92.53 to 80.84
Ash	6.95 to 15.99
Sulphur	.81 to 1.87

The upper limits for ash, sulphur, and volatile matter denote nearly extreme cases either of imperfectly made coke or of coke made from coal that is not generally used for the purpose. As the foundryman is liable to have such coke sent him, it is included in the statement.

Tennessee.—The bulk of the coal used to make coke in Tennessee is washed. In fact, all the slack is so treated before coking. Washing is necessary on account of the bone and the occasionally high sulphur. The coke analyses, which reflect these properties, are as follows:

Range of Composition of Tennessee Cokes.

Moisture	0.22 to 1.67
Volatile matter	.11 to 1.60
Fixed carbon	92.44 to 76.87
Ash	7.23 to 19.86
Sulphur	.61 to 2.45

This statement shows plainly the necessity for washing, but also the fact that very good coke is to be had.

Virginia.—The southwestern portion of Virginia is rapidly becoming an important coke center. The coals are high grade, producing a coke comparable with those from the Flat Top and New River districts of West Virginia. The range of the following analyses indicates what excellent material the State produces:

Range of Composition of Virginia Cokes.

Moisture	0.16 to 1.52
Volatile matter	.80 to 1.67
Fixed carbon	93.24 to 88.52
Ash	5.80 to 8.29
Sulphur	.42 to 1.02

Washington.—The coke industry of Washington, though not large, is important, not so much for its quality as for the fact that metallurgical coke is made at all on the Pacific coast. The coal for coke making is all washed. The importance of this treatment is shown by the following analysis of a Washington coke the coal for which had not been washed.

Composition of a Washington Coke from Unwashed Coal.

Moisture	1.02
Volatile matter	2.10
Fixed carbon	77.53
Ash	19.35
Sulphur	.44

Everything in this coke will pass except the ash and the volatile matter, the first of which can be reduced by washing and the second by suitable changes in the coking process.

West Virginia.—West Virginia is the second largest producer of coke in the country. The quality of the coal of this State is shown by the fact that the greater part of its coke is made from slack, but little of which has to be washed. Hence the following range of analyses is interesting:

Range of Composition of West Virginia Cokes.

Moisture	0.07 to 0.60
Volatile matter	.46 to 2.35
Fixed carbon	95.47 to 84.09
Ash	4.00 to 12.96
Sulphur	.53 to 2.26

Value of a Standard Composition.—It may be useful to give a desirable composition for foundry coke, so that a foundryman can compare it with the analyses given above for the several States and with the coke that he purchases. This function really should be performed by a standard specification, and the fixing of such a standard, it is hoped, will some day be carried out in a manner acceptable to all interests concerned. The following composition, however, would be considered excellent —better, in fact, than is actually required:

Desirable Composition for Foundry Coke.

Moisture	0.50
Volatile matter	.75
Fixed carbon	89.75
Ash	9.00
Sulphur	.70

Solvay Coke.—This is a retort oven coke made in Solvay ovens located at Syracuse, N. Y.; Dunbar, Lebanon and Steelton, Pa.; Wheeling, W. Va.; Ensley and Tuscaloosa, Ala.; Chicago, Ill.; Milwaukee, Wis., and Detroit, Mich.

This coke is made under the patents of the Semet-Solvay Company but the quality varies considerably at different ovens, and even at the same ovens, due to different kinds and mixtures of coals used. The coke made at the Detroit ovens is of the very highest quality and is made from West Virginia coals mixed in such proportions as to give a coke having a structure best suited to the different purposes for which it is to be used.

Coals low in sulphur, phosphorus and ash are selected from mines known to give a coke of a structure most satisfactory to the consumer. The coal is most carefully prepared in mining and again at Detroit any remaining impurities in the form of sulphur balls, bone and slate are eliminated in the process of pulverizing. Mixed coals are pulverized so that 80 to 90 per cent. passes a ⅛-inch screen in order to give uniform coke structure, various coals being mixed in any desired proportion in order to give different kinds of coke suited to any particular use. The pulverized coal remains in the retort approximately 18 hours before the coke is pushed.

By selecting varying mixtures of coal a coke can be made, as at Detroit, to bear a heavier burden than Connellsville or any other coke made in beehive ovens. The burden-bearing quality of coke varies of course at different Solvay ovens according to the character and proportions of the coal used. Cokes less dense and requiring less blast can be made equally well in these ovens. The standard here is 75 per cent. for shatter test. There is no coke made anywhere in the United States to our knowledge, except coke made at Chicago in similar ovens, that has as low a uniform content of sulphur and ash as does Detroit Solvay coke. The average melting ratio in this coke is one in nine on short melts, but on continuous pouring it runs as high as one to twelve. Its very high content of carbon makes it a rapid melting coke and under a very low blast, Detroit Solvay coke requires approximately 200 cubic feet of air per pound of coke to combust it. This is a practical formula and with 9-oz. blast the very best results can be secured with this coke. Much less of it may be used in the bed, and considerably less in the charges.

This coke is sold as a specialty and therefore obtains a much higher price than other cokes. In the Detroit market there is a difference of approximately 75 cents per ton between general coke prices and Detroit Solvay.

Average Monthly Analyses of Detroit Solvay Coke During 1907, 1908, 1909 and 1910.

Month.	Moisture.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
1907.					
January	.123	1.27	88.15	10.44	.744
February	.121	1.35	88.46	10.28	.642
March	.14	1.15	87.77	10.58	.611
April	.13	1.23	88.33	10.34	.703
May	.14	1.68	88.09	9.66	.641
June	.30	1.88	87.49	9.99	.702
July	.18	1.33	89.33	9.15	.684
August	.242	1.14	90.11	8.60	.685
September	.27	1.17	89.51	8.97	.787
October	.175	1.58	88.79	9.43	.807
November	.11	2.28	87.92	10.86	.772
December	.09	2.63	88.87	9.28	.887
1908.					
January	.116	2.44	86.86	10.58	.723
February	.124	1.90	88.90	9.07	.649
March	.09	1.79	88.32	9.53	.689
April	.104	2.07	88.40	9.36	.683
May	.14	2.05	88.28	9.76	.707
June	.19	1.66	87.92	10.29	.710
July	.15	1.53	88.98	9.42	.701
August	.10	1.85	88.02	10.00	.694
September	.09	2.60	89.10	8.90	.705
October	.11	2.62	88.30	9.48	.713
November	.06	2.50	88.90	9.00	.736
December	.05	2.32	89.04	8.63	.704
1909.					
January	.05	2.41	89.16	8.36	.660
February	.03	2.41	89.82	7.78	.658
March	.03	2.20	89.73	7.99	.629
April	.06	2.02	90.02	7.92	.648

May	.04	1.79	89.60	8.60	.693
June	.05	1.94	89.38	8.66	.701
July	.04	1.72	90.32	7.95	.639
August	.05	1.83	89.80	8.38	.643
September	.05	1.79	90.45	8.38	.643
October	.04	1.20	91.21	7.51	.584
November	.04	.83	91.85	7.30	.624
December	.04	1.04	90.11	8.30	.624
1910.					
January	.03	.92	90.23	8.25	.607
February	.05	.98	91.48	7.46	.619
March	.05	.90	90.30	7.33	.571
April	—	.94	91.58	7.49	.644
May	—	.84	91.34	7.82	.647
June	—	.95	90.61	8.13	.684
July	—	1.07	90.55	8.38	.664
August	—	1.48	90.07	8.48	.656
September	—	1.32	90.28	8.80	.685
October	—	1.01	90.48	8.58	.690

CHAPTER II.

PIG IRONS AND FRACTURE GRADING PIG AND SCRAP IRONS.

Classification of Pig Irons.—Irons are designated by the fuel used in smelting the ores, thus: An iron smelted from its ores with charcoal and a cold-blast is called cold-blast charcoal iron; that smelted with charcoal and a hot blast, hot-blast charcoal iron; iron smelted with coke, coke iron, and that smelted with anthracite, anthracite iron. All coke and anthracite furnaces are hot-blast furnaces, and the iron from them hot-blast iron.

Charcoal Irons.—The charcoal irons, cold and hot blast, are comparatively free from the impurities found in coke and anthracite irons, imparted to them from the fuel with which they are smelted, and present the characteristics of greater strength than either of these latter products. Charcoal irons are cast into long slender pigs, with a V-shaped groove in them on each side to facilitate breaking the pig into four pieces. The pigs are broken with difficulty, even when grooved in this manner, and a two-handled sledge, weighing from 20 to 30 pounds, handled by two men, is frequently required to break them. When broken, the fracture presents a rough, torn appearance, with a sharp-pointed crystal that jags the fingers when pressed upon them. They are graded Nos. 1, 2, 3 and 4. The No. 1 is a soft iron; No. 2 a grade harder; No. 3 a mottled iron, and No. 4 a white iron.

Cold-blast iron was the first iron ever made in this country, and was used in the manufacture of all kinds of castings, even for stove plate, which was not made so thin many years ago as at the present time. The No. 1 is high in combined carbon, and its tendency to chill when cast into light work is so great that it runs white on thin edges, and at any great distance from the gate, in light castings. The writer, when visiting an old foundry in Maryland at which stoves were made from this iron, many years ago, learned that only the softest No. 1 pig had been used in their manufacture, and that the gates and scrap from the work were not remelted, but were thrown into the dump, and only pig melted to insure soft castings. A dump was pointed out that was said to contain many tons of gates and scrap from this foundry.

The cold-blast iron was used in the manufacture of gear wheels, cranks, and all parts of machinery requiring great strength, and before the introduction of the steel hammer into rolling mills, and the age of steel, was the iron exclusively used in making large shafts for steam boats, mills, etc.

Many amusing stories are told by old foundrymen about casting these shafts. One recalled to mind is the casting of shafts on end and making them double the length required, that the pressure of iron in the upper end of the mold might make the iron in the lower end more dense or close, only the lower end being used for the finished shaft. This is said to have been a common practice in foundries having a high reputation for good shafts. The founders do not appear to have known that a close iron might have been obtained by using the lower grades of pig, or mixing the lower with the higher grades, and casting the shaft of its proper length. All the iron cannon used in the War of the Rebellion in this country, 1861–65, were made of this iron; hundreds of them were cast at the foundry of the Fort Pitt Works, Pittsburg, Pa., and the writer saw many of them when being finished at the lathe at these works. The iron cut like wrought iron, and many turnings from 20 to 30 feet long, were hung up around the lathe room to show its quality.

This iron, owing to its high price and chilling tendency in light work, is at the present time only used by founders for special work, such as malleable iron, car wheels, cylinders, etc. In malleables it gives a stronger and smoother iron than any other, and, in fact, is the only material from which first-class malleable iron can be produced. In car wheels it makes a strong wheel, and gives a chill of any desired depth when the different grades of it are properly mixed.

In cylinders it makes a strong, clean, close iron, free from grit, that polishes like steel, and does not wear rapidly or cut the piston head or packing ring.

For car wheels and cylinders, it may be mixed with coke or anthracite irons, and has been used to some extent in this way, and good results obtained. But it must be remembered that the characteristics of a charcoal iron decrease in proportion to the amount of these irons that are added to it in a mixture, and its good qualities may be entirely lost if too large a percentage of other iron is used.

No rule can be given for mixing, as the percentage must necessarily vary with the quality of iron used and the resulting quality desired.

Attempts have been made to produce by chemical analysis an iron from coke or anthracite irons having the characteristics of a cold-blast charcoal iron, and some success is said to have been met with in malleable iron and car-wheel works. But oleomargarine does not possess all the qualities of a good butter, and the imitation cold-blast charcoal iron will no doubt be found to be deficient in some of the characteristics of the genuine article.

Hot-blast Charcoal Iron.—Hot-blast charcoal iron presents all the characteristics of the cold-blast except its chilling tendency, which is lessened to a considerable extent by the reduced amount or per cent. of combined carbon and increased per cent. of graphite carbon contained in the iron.

A deep chill cannot be obtained from the No. 1, but a chill of any desired depth may be obtained from a mixture of the lower grades. This mixture, however, does not give a chilling iron equal to the cold-blast for car wheels.

The Nos. 1 and 2, when mixed in proper proportions, run very fluid and soft in light castings, such as stove plate, hollow-ware, bench work, pulley rims, etc., and they are the very best foundry irons for light castings requiring softness and strength.

No other iron than this was for many years used for this kind of castings, and even after the introduction of coke and anthracite irons, at a very much reduced price compared with that of charcoal iron, was for years worked by many foundrymen, and is still used exclusively by some of the old founders in localities where it can be procured at a moderate advance over the other irons.

Some of the best known and most famous brands of this iron were those of the Hanging Rock region, a mountainous district, on the Ohio River, in the vicinity of the town of Hanging Rock, Ohio. The mountains or hills in this vicinity furnished wood for charcoal for many small furnaces that for many years supplied the entire Ohio Valley from Pittsburg to the Mississippi River with foundry iron. Some of these furnaces are still in blast, but most of them have been abandoned, owing to the scarcity of wood, and the production of this iron has also been much reduced in other localities for the same reason.

One of the tricks of founders after the introduction of coke and anthracite irons was to keep a pile of the charcoal iron in the yard to show customers the quality of iron used in their castings. When a customer desired a very strong iron in his castings, he was taken into the yard and a pig of this iron broken after numerous blows with a heavy sledge. This test generally satisfied the customer, who believed he was getting an extra quality of iron, while the pig broken was likely the only one that went into many tons of his castings, the latter being made from the cheaper grades of iron.

Coke Iron.—This is probably the best known of all the foundry irons, for it is used in a large majority of the foundries of this country making a general line of castings such as stove plate, hollowware, bench work, light and heavy machinery castings, etc.

The characteristics of this iron vary to some extent, owing to the quality of the ore from which it is smelted. That made from some of the Lake Superior ores is very strong. The No. 1 presents a sharp-pointed crystal in the fresh fracture, runs soft and strong in moderately heavy castings, but very hard in stove plate and other light castings. That made from some of the southern ores is very weak, the No. 1 presenting a dull flat crystal in the fresh fracture, and running very soft in light as well as heavy castings. The best iron for light castings is that having these two characteristics in combination, and such a product is turned out by furnacemen making a specialty of foundry irons from a mixture of different ores.

These characteristics should be remembered when ordering irons, and one suitable for the work to be cast be selected.

Coke iron was first graded No. 1, No. 2 mottled, and white iron. Later, it was graded Nos. 1, 2, 3, 4, 5, 6 and 7, with the addition of No. 1 A, No. 2 A, or No. 1 X or No. 2 X. This fine grading was designed to accurately indicate the quality of iron and enable the foundrymen to order exactly the quality best suited for the work to be cast.

An effort is now being made by furnacemen in some localities to do away with grading by fracture, and to grade from chemical analysis, which is said to more accurately indicate the characteristics of the iron and enable the foundrymen to select the one exactly suited for his work.

This grading is to a large extent based upon the per cent. of silicon contained in the iron. A high silicon, a soft iron. A low silicon, a hard iron. Silicon is placed in the iron in any desired per cent. by the grade of ores smelted, and irons are made to correspond with the numbers formerly used in grading. Thus, a 3 per cent. silicon iron presents similar characteristics to an iron formerly graded No. 1; a 2 per cent. silicon those of No. 2, and so on.

Coke irons are cast into short, thick pigs, as compared with those of charcoal irons. These heavy pigs, which are almost double the thickness of the charcoal pig, are broken more readily than the slender grooved pigs of that iron. Even the strongest of the best grades in no way compares with charcoal pig for strength.

The strength of the iron is indicated to some extent by the color, as well as shape, of the crystal. A dark bluish cast in the fresh fracture indicates a stronger iron than a light or silvery cast. The No. 2 iron runs stronger in heavy and moderately heavy castings than the No. 1, but weaker in light castings, in which it is to some extent chilled by sudden cooling.

For light castings the best results may be obtained by mixing the No. 1 and No. 2 in the proportions of one-half of each, or two-thirds of No. 1 and one-third of No. 2. A mixture of about these proportions generally makes an iron that runs softer and more even in light castings than all No. 1.

The No. 3 grade is seldom used, except for very heavy castings; it is then generally mixed with the No. 2, and is employed in the mixture for the purpose of giving strength to the castings.

Anthracite Iron.—The furnaces producing this iron are principally located in Eastern Pennsylvania, New Jersey, Maryland and New York, and were the source from which these sections of the country derived their supply of foundry irons for many years.

The furnaces were generally small ones and, with anthracite coal, which smelted the ores very slowly, produced but a limited amount of iron. After the improvements in the manufacture of coke, it was found that these furnaces could be made to produce two or three times more iron with coke fuel than with anthracite fuel. This, together with the decrease in the price of coke, as improvements were made in its manufacture, induced the anthracite furnacemen to change their furnaces to coke furnaces. This change has taken place to so great an extent that very few anthracite furnaces are in existence at the present time. Even the anthracite furnaces in the Lehigh Valley, the very centre of the anthracite coal field, have changed to coke. The iron as a foundry iron was far superior to coke iron in the early stages of the manufacture of the latter; but with the advancement in the manufacture of coke, and consequent improvement in coke-iron, the two products presented very similar characteristics as foundry irons. The pigs of the irons are cast about the same size and shape, and it would be difficult, or impossible, to determine an anthracite from a coke iron by the fracture. The two products present a similar appearance and, as foundry iron, are so near alike that it would be useless to describe anthracite iron in detail after having described coke iron.

Silver Gray Iron.—Silver gray iron is a foundry iron sometimes produced by furnaces when overheated, and has been called a burned iron. It never was a regular furnace product, but a chance product, and generally sold at a very much reduced price from the regular or standard iron of the furnace. It was occasionally seen in foundry yards some 25 years ago, but was never sufficiently plentiful to come into general use.

The writer has not seen it or learned of its being used for many years, and since the improvements in blast furnace practice, it may not be made.

The fresh fracture of this iron in the pigs was very similar in appearance to that of a white iron, and was only distinguished from the latter by the silvery gray cast from which it derives its name.

It was very soft, ran fluid, and presented many of the characteristics of high silicon iron of the present time. It was very weak and unsuitable for castings when melted alone, and was used as softener when melting the lower grades of pig or scrap iron.

High Silicon Iron.—Silicon is an element that enters freely into combination with iron. It is found combined in large proportions with iron in its native state, and may be added to iron in the blast furnace. Great beds of iron ore containing this element in large proportions that are very accessible have been found in this country, and by reason of the softness and brittleness imparted to the ore by the silicon, it is easily mined and broken up, and a cheaper iron is made from it than from many others.

The iron produced from this ore is of an inferior quality. Rolling-mill men and the manufacturers of steel have no use for it, and it is being pushed forward as a foundry iron.

The only requisite quality this iron possesses as a foundry iron is weight, and this quality is offset to a large extent by its rottenness. When cast into sash weights, or other slender weights, they must be handled with care to prevent breakage.

Silicon in large proportions imparts to iron a peculiar grit that removes the edge from a finishing tool about as rapidly as a grind-stone. It also reduces the chilling tendency of cast iron, and is claimed by the advocates of silicon iron to be a softener; but I think this is a mistake, and that carbon will yet be found to be the true softener. But this iron, as before stated, is being pushed forward as a foundry iron, and as the writer has melted many tons of it in various proportions, a few suggestions on melting and mixing it may be of value to foundrymen.

The proportion of silicon that may be used in a foundry iron without impairing its quality to any great extent varies from ½ to 3 per cent., according to the kind of casting the iron is to make; thus a mixture for heavy machine castings requiring great strength needs none of this iron. Light machinery castings to be finished may require from ½ to 1 per cent., and stove plate, bench work, and other light, thin castings, from 2 to 3 per cent. This percentage of silicon reduces the chilling tendency of the iron, and prevents to a large extent hardness on thin edges, and at a distance from the runner or gate.

To distribute this per cent. of silicon evenly throughout the castings when a high silicon iron is used in a mixture with a low grade of pig or scrap, requires very nice cupola practice.

The aim must be to get the small per cent. of high silicon iron evenly distributed throughout the large per cent. of other irons when in the molten state. This can only be done by careful charging and tapping.

When all pig is melted with only the foundry scrap, the high silicon iron should be broken in pieces that will admit of it being mixed with the other pig; and when charged, care should be taken not to place the silicon iron all together, but to distribute it evenly throughout the other pig, so that when melted it may have the opportunity to mix with the other iron in its descent through the fuel to the bottom of the cupola, and be more evenly distributed in the molten mass at the bottom. The iron should be melted very hot and the cupola not tapped close, or a small tap hole should be made and a considerable body of iron permitted to remain in the bottom of the cupola, when a continuous stream is drawn. It will also be found of advantage to place a large ladle holding from 500 to 1,000 pounds on trestles in front of the cupola and pour the iron from this ladle into hand or other small ladles for light work.

When melting heavy scrap or high silicon pig, the same precaution should be observed to secure a homogeneous iron.

When melting light scrap and high silicon pig, such as that recommended to carry 90 per cent. of scrap, the silicon iron should be broken in very small pieces and mixed with the scrap in charging in a way that will insure the pig and scrap melting at the same time, and mixing as they descend, and also in the bottom of the cupola.

This would not be the case if the pig were all charged on the fuel with the light scrap on top of it, unless the entire charge was melted before a tap was made. When melting this grade of irons the precaution should always be taken to mix the iron in a large ladle as well as in the cupola.

Pig irons are now being made for foundry work that contain from ½ to 3 or 4 per cent. of silicon, and foundrymen will secure a more homogenous iron for their castings by purchasing an iron that contains the amount of silicon said to be necessary for their grade of castings than by buying an iron very high in silicon and mixing it with one very low in silcon, or free from it.

When castings are deficient in strength, and breakage is heavy in the tumbling barrels, or in the handling, the silicon should at once be reduced by increasing the proportion of irons low in silicon in the mixture.

When in finishing work the iron leaves the tool of a lathe or planer like particles of half dried sand and readily crumbles into small particles, the silicon is too high. Such iron generally takes the edge off of tools very rapidly, is difficult to finish smoothly, and if finished for small shafts, cuts out bearings very rapidly, or if finished for bearings, cuts the shaft.

Scotch Pig.—This is the common name by which numerous brands of pig iron imported from Scotland are known in this country.

Thirty or forty years ago this iron was extensively used as a foundry iron, and many founders believed they could not make soft castings without Scotch pig. At the present time its use is restricted almost entirely to seaport cities and towns, to which it is brought by vessels as ballast, and sold at a less price than American foundry irons.

The iron is cast into short, thick pigs, the fresh fracture of which is of a dark bluish cast, with the large crystal called an open iron. It is high in graphite or free carbon, and when broken small flakes of graphite frequently fall from the fracture. The iron is deficient in strength and the large pigs are easily broken with the sledge. The qualities of the different brands of Scotch iron vary to a considerable extent, and the price varies from one to two dollars per ton, according to the quality and reputation of the brands.

The best brands run very soft and clean in light work, and some years ago were the only irons used for stove plate and hollowware, but they have generally been replaced for this work by the stronger soft brands of domestic irons.

Some of the poorer brands run soft but so kishy that it is difficult to make perfect castings from them, the kish collecting in spots on the surface of the castings, making thin spots or holes, and in heavy work collecting in short angles or edges, causing rounded and uneven corners or edges. Other brands run very dirty, as well as hard, and are only fit for weights or very common castings.

NOTE.—Kish is a name given by founders to a soft, dark substance resembling black lead, that is forced out of a very soft iron when in a molten state and when cooling. In thin castings it runs before the iron in the mold and causes rounded edges or corners, similar to those made by blacking, dusted on too heavy, and washed before the iron. In heavy casting it collects on the surface in spots, and around the edges. It adheres firmly to the casting, but is soft and easily broken off, leaving a smooth surface. Kish is only found in very soft iron, in which the softness is due to graphite or free carbon, and comes from an excess of this element in the iron. It is not found in foundry irons used at the present time to the same extent it was in those used some years ago, and many of the younger founders have probably never heard the term.

American-Scotch Pig.—When the Scotch pig craze was at its height a number of furnacemen in this country, with the usual American inventive genius, conceived the idea of imitating Scotch pig, and a number of brands of iron were made and put on the market called American-Scotch pig.

These irons, in many cases, were far superior as foundry irons to the genuine Scotch, and in numerous cases soon replaced it in foundries making light work, for which it was claimed only Scotch pig could be used.

Among the brands of American-Scotch that attained a high reputation were Briar Hill and Cherry Valley. The writer has melted many tons of these irons for light as well as heavy castings and found them to run as soft as any brand of Scotch pig he ever melted, and far superior to them in cleanliness and strength.

There were many other brands of American-Scotch in different sections of this country that attained a high reputation, and are still in the market as foundry irons; but as Scotch pig is not in demand to the extent it was some years ago, furnacemen have generally dropped the term American-Scotch, and the irons are known only by their local or furnace names.

Pig Iron.—Iron when smelted from its ores in a blast-furnace is know as cast iron and when drawn from the furnace and cast into short bars or slabs as pig iron, which is frequently designated as foundry pig, mill pig, and Bessemer pig, these terms indicating the purpose for which the iron is best suited. Pig iron is also designated from the mold in which it is cast as sand pig, chill-pig and sandless pig. Since the introduction of these new methods of casting, the term pig, or pig iron has become general, and the iron is frequently designated, according to the purpose for which it is to be used or the manner of casting.

Sand Pig.—Probably ever since the beginning of the manufacture of pig iron it has been cast in open sand moulds in the floor of the furnace casting house. In preparing the moulds perfectly level beds of sand are made, and in these the pigs are moulded, a sufficient distance apart, to prevent the sand between them from being washed or forced away by the pressure of molten iron, and the pigs from running together. At the end of each row or bed of pigs a perfectly level runner or sow pig, as it is called, is moulded. This sow pig is connected with the end of each pig, and one end of it is connected with an inclined runner, constructed of sand, from the tap-hole of the furnace. Through this runner the iron is permitted to flow first to the pig bed at the greatest distance from the furnace. When the moulds in this bed are filled an iron gate or spade coated with clay is forced into the sand of the runner in such a way as to stop off the flow of metal, and another opening is made in the side of the runner by removing a shovelful of sand, which permits iron to flow into the sow of the next pig bed. When this one is filled the runner is again shut off at the next sow, and another opening made, and so on until all the iron in the furnace is cast. This mode of casting requires considerable labor in preparing the moulds for each cast, and to save this expense and obtain an iron free from sand, a cast iron pig mould or chill has been devised.

Chilled Pig.—The molds for this pig are made in a cast-iron plate or block of iron from six to eight inches thick, and of a size sufficient for four or six pigs with sow pig attached to them in each block. Two or more of these blocks are imbedded in the floor of the casting-house to form a pig bed and the moulds are filled from a runner in the same manner as the sand mould. Iron cast in the moulds is known as chilled pig, from being cast in iron moulds and having a slight chill on the surface that comes in contact with the mould. On account of the chill this iron never became popular with founders and has only been used to a very limited extent for foundry work, although the chill entirely disappears when the iron is remelted and no trace of it can be found in the castings.

Sandless Pig.—After the introduction of chemistry into blast-furnace practice, it was discovered that iron cast in sand and chill moulds was not of an even quality throughout the cast or pig. Analysis showed different qualities of iron in different parts of the same cast and in opposite ends of the same pig. This unevenness in the quality of the product was attributed to iron smelted from different ores not having been thoroughly mixed before casting. To overcome this difficulty and produce an even grade of iron a plan for mixing the iron before casting was devised. This was done by drawing the iron from the furnace into a large ladle capable of holding the cast and to mix it before casting. From this ladle it is poured directly into the pig moulds that are only about one-half the length of the ordinary sand pig. The moulds for these pigs are made of thin wrought iron or soft steel, so that they may be quickly heated by the molten metal. The chilling tendency upon the iron is thus far less than that of the heavy chill used in casting chilled pig, and to still further reduce the chilling tendency they are coated with a carbon deposit or silicon wash. These moulds are placed upon a revolving table, upon which they are brought under the ladle to be filled and removed, to be emptied when the iron has sufficiently cooled to allow of this being done. They have also been placed upon traveling belts or chains which carry them under the ladle to be filled, and to any desired distance from the furnace to be dumped in the yard or upon iron cars for shipment, this mode of casting being thus not only a labor-saving device in moulding the pigs, but also in removing the iron from the casting-house.

Since the introduction of sandless pig into foundry practice extravagant claims have been made for its superiority over sand

and chilled pig as a foundry iron. This pig is generally cooled to a considerable extent by water thrown upon it and shows a closer iron than sand pig, and while an analysis of the iron has shown a more even quality throughout the pig and cast, this is probably due more to the even temperature at which it is cast and the manner of cooling it than to mixing it in a ladle before casting. The extravagant claims made for superiority of sandless pig do not appear to have been realized, for no better castings have been made from it than from either of the other pigs when properly mixed in melting. All cast iron assumes its normal state when melted, and the chill on chilled pig, the closeness of sandless pig, all disappear when the iron is melted and do not appear again in it except from the cause that originally produced them in the pig. The manner of casting is therefore a matter of furnace practice and has nothing to do with the quality of a pig iron; it does not change its quality any more than the shape of the casting and manner of casting changes the quality of an iron when cast in a foundry. Foundrymen should therefore select their irons by quality and not by the shape or mode of casting the pig. This may now be done by analysis, and an iron of a desired quality be thus obtained with more certainty than from the appearance of the iron.

Fracture Grading of Pig Iron—Iron when smelted from its ore in blast furnaces, even when smelted from the same quality of ores and with the same quality of fuel, acquires different degrees of hardness and softness. This is due to the temperature of the furnace, or, as it is termed, "the furnace is working hot or cold," and a furnace may produce soft iron one cast and a harder iron the next, or may make soft iron for some length of time and then very hard iron. This is said to be due to the scaffolding or hanging up of the stock in the furnace. This unevenness in the iron made it necessary to have some means of determining and indicating its quality before putting it upon the market. This is done by breaking a few pigs of each cast when cold, and determining its quality by the indications of the crystalline structure in the first break. A large crystal indicates a soft iron. This is designated No. 1; a small crystal, a harder iron than No. 1. This is graded No. 2. A still smaller crystal with a white thread-like streak winding through among the crystals indicates a mottled iron and one with scarcely any perceptible crystalline structure, a white iron. Only four grades were made; of these Nos. 1 and 2 were called foundry irons, and the mottled and white irons, mill-irons. With the improvement in furnaces, a more accurate grading was desired and iron was graded up to Nos. 1, 2, 3, 4, 5, 6, 7. No. 1 indicated a soft iron, and the iron gradually grew harder until No. 7 was reached, which was extremely hard. In addition to this grading, the softer irons were sometimes graded No. 1 and No. 1 A, and No. 2 and No. 2 A, or No. 1 and No. 1 X, No. 2 and No. 2 X, which indicated that they were very soft irons suitable for very light castings. This mode of grading was termed fracture-grading, and was the only means of grading employed by furnace men for several hundred years. It as accurately indicates the quality of an iron, when the grader is an expert, as does chemical analysis, and the quality of the castings produced from the remelted iron is indicated by the grade or number of the latter. But irons melted from different ores present different characteristics, and when such irons are brought together in remelting they do not always produce the quality indicated by the grade number of one or both. When founders received their supply of iron from one furnace or from a number of furnaces using the same or about the same quality of ore, this mode of grading answered every purpose. But when founders endeavored to use in their mixtures irons made from widely different ores, they frequently found the resulting product far below that indicated by the grade number, and only founders who were fracture experts were able to use such iron in their mixtures. These experts, however, were few and far between, and foundrymen did not care to take the risk of losing a heat of casting by using an iron the characteristics of which they were not familiar with. This forced furnacemen making irons in isolated districts to devise a new method of grading that, in order to find a new market for them, would enable the founder to use them with a certainty of results. Recourse was had to chemistry, which has made it possible for the furnaceman not only to determine the exact characteristics of his own iron, but also of irons with which it might be mixed in remelting, and to determine to some extent the characteristics of the resultant mixture. This mode of grading has now been adopted by all furnaces seeking a foreign market for their iron, and to some extent by those having a local or home market. However, there are many furnacemen grading by fracture, and the practice of placing iron upon the market by number of grading is so universal that a standard analysis for No. 1 and No. 2 foundry irons has been established.

Fracture Indications in Foundry Irons.—By this is meant the quality of iron as indicated by its appearance in the fresh break or fracture of the iron when cold. The term applies to all foundry irons, such as pig, scrap irons, castings, etc. The fracture indicates to the expert the quality of an iron, either pig or scrap, as accurately as analysis. But unfortunately few foundrymen have the faculty of becoming experts and in the writer's contact with hundreds of them he has never met more than a dozen real fracture experts. These men could read the quality of an iron in the fracture and indicate two or more irons that could be melted together to give a product of any desired quality, with more certainty than has yet been done by analysis alone. However, all practical foundrymen have more or less knowledge of fracture indication; in fact it would be practically impossible to manage a foundry without such a knowledge.

The general indications of fracture are as follows: A large crystal and dark bluish color indicate a No. 1 soft iron; a large crystal and light or silvery color, a No. 1 soft but weak iron; a smaller crystal and dark color, a No. 2 soft, strong iron, suitable for mixing with either of the above irons for soft light castings or by itself for light machinery castings; a small crystal with a dark color, a No. 3 strong iron that will run hard in light castings and soft in heavy ones and is suitable for mixing with No. 2 for light and heavy machinery castings; a very small crystal and dark color, with a thread-like white streak between the crystals, a No. 4 or mottled iron. This iron is only used in foundries in mixtures to give closeness and strength to large castings. An extremely small white crystal indicates a hard iron. This iron is used in mixture with No. 2 or No. 3 iron for castings requiring a very close hard iron, or chilled surface. A silvery gray color, almost devoid of crystalline structure, indicates a soft but very weak iron. It is used in mixtures as a softener of other irons. A large crystal and dark color, with spots or patches of very small crystals indicate an uneven iron. These spots may disappear in melting but generally cause hard spots in light and thin castings.

The methods of casting and cooling the pig change these indications to some extent, a small crystal and dark color may prove to be a soft iron, as is frequently the case in sandless pig, but a light-colored small crystal always indicates a close or hard iron when remelted. A sharp-pointed crystal indicates a strong iron regardless of the size of the crystal.

In coke and anthracite irons the crystals are larger, more diamond-shaped and duller in all grades than in the same grade of charcoal iron. In the latter the crystals are sharp-pointed, ragged, and have the appearance of having been drawn apart rather than broken apart as in the coke and anthracite irons. This appearance always indicates a strong iron but is never seen in coke and anthracite irons to the same extent as in charcoal iron.

The breaking of pig iron also indicates to some extent its characteristics.

Pig that is difficult to break, indicates a strong iron. If a coke or anthracite iron it runs strong in heavy work, but generally runs hard in light or thin castings. Pig that breaks easily, if soft iron, is generally high in silicon and by itself may be used for light work, or as a softener with a soft iron.

Pig that breaks easily, if hard iron, is generally of a poorer quality that should only be used for an inferior class of castings.

Charcoal pig whether hot or cold blast, hard or soft iron, is always difficult to break and presents a sharp-pointed drawn-out crystal except in very hard white iron.

These points can only be determined by an experienced breaker, for all pig iron is hard to break by an inexperienced hand.

Pig iron is now generally sold by analysis and these indications are not of such great importance as they were when pig iron was sold entirely by fracture. If, however, the founder has no knowledge of them whatever he cannot manipulate his irons after he has them in the foundry yard, and should the irons become mixed, or there be an uncertainty as to the quality of those in various piles, he would be liable to charge a hard iron for soft work, or soft iron for hard work.

Fracture Indications in Scrap Iron.—Fracture indications apply to scrap as well as pig. In this iron the size of crystal varies with the thickness or size of castings, and does not indicate its quality to so great an extent as in pig. The principal indication in this iron is the color, a crystalline structure and dark color indicating a soft iron; a light color a hard or close one, and a very small white crystal, a very hard one.

The size or color of the crystal in burned iron, even if only slightly so, affords no fracture indication of the quality of the iron that may be obtained from it when melted. The quality of the product from light scrap heavily coated with rust can also not be determined by fracture indications unless the rust be removed previous to melting.

Shape of Scrap.—The shape of scrap castings and a knowledge of the quality of iron used for different lines of them is the most common guide in selecting scrap. It is only when there is a doubt as to the quality of iron from which work is cast that fracture indications are looked for, because scrap generally produces the same grade of iron when remelted as that from which it was cast, but a shade harder, and may be brought up to the original standard by the addition of soft pig, when remelted.

Heavy machinery scrap is a soft strong iron for heavy work; light machinery scrap, a soft strong iron for light machinery work; stove plate, a soft strong iron for thin castings. This scrap when remelted produces a much harder iron than that from which it was cast, and only by the addition of a large per cent. of softer pig, can it be used for the same line of work.

Promiscuous scrap, the quality of iron in which is not indicated by the shape of the casting, should always be broken and selected for remelting by indication of fracture.

Small scrap is always hardened to a greater extent when remelting than large scrap, and requires a larger per cent. of softener pig than large scrap.

Cast steel scrap when melted with cast iron has a hardening effect upon the latter and frequently causes hard spots in castings.

Burned Scrap.—Burned cast iron presents the most varied, as well as the most deceptive, fracture of all the irons the founder has to deal with. The variations are due to the extent to which the iron is burned, and also to the conditions under which it was burned. The deception is due to the changes effected in the crystallization of the iron by frequent or prolonged heating.

In a grate bar, we may find near the center a small crystal of a light bluish cast, and near the ends a large crystal with a dark blue cast. This is due to the center having been subjected to a greater heat than the ends. In heavy retorts, etc., we find a large crystal and open iron, presenting many of the characteristics of fracture in a very soft No. 1 pig iron. And in fact, in all burned iron, not burned in contact with fuel, we find in the fracture the characteristics of a soft iron.

The mistake commonly made by founders and melters is in judging this iron by the fracture, which in reality indicates nothing as to the quality of iron that may be melted from it. Grate bars are frequently broken and the center condemned and thrown in the dump, while the ends are melted, simply because the fracture near the end indicates a soft iron. Pieces of retorts and other burned castings that should be thrown away are for the same reason melted.

All burned iron should be judged by the external general appearance, and not by fracture. By general appearance is meant the entire casting should be considered and not certain parts of it, as is too frequently done.

In burning away the surface of a grate bar near the center, the ends are subject to a prolonged heat, of a degree lower than in the center, but sufficient to destroy the iron, although none of it may have been burned away near the ends and the external appearance gives no indication of the iron having been injured. The same rule applies to a greater or less extent to all castings, parts of which show indications of having been burned.

This principle is frequently better understood by junk dealers than by founders, and in sorting scrap unprincipled dealers break off parts of castings showing external evidence of having been burned, throwing it in the burned iron pile, while that showing no evidence of being burned is thrown in the good scrap to be sold to founders, who judge scrap by fracture only. Retorts, pipes, salt kettles, etc., are broken into plates, slabs or pieces to destroy their identity, and thrown in a pile to rust before being placed with good scrap, a few pieces to the ton, to be sold as good scrap. This is one of the tricks of trade that founders have to look out for to avoid unknowingly melting burned iron for their castings.

Burned cast iron, when melted in a cupola, produces in all cases a hard iron. The degree of hardness depends upon the extent to which the iron has been burned; from that only slightly burned, a hard gray or mottled iron may be obtained; from that burned to a greater extent, a white iron; and from that burned to a still greater extent, a very small per cent. of white iron, with an excessive amount of slag. These three grades may be found in a promiscuous lot or pile of burned iron, and when melted alone the product is generally a white iron, with a large amount of slag. The slag may boil in the cupola and stop melting, or may flow from the tap-hole with the iron, and in some cases cannot be distinguished from it until it has cooled to a considerable extent.

CHAPTER III.

SCRAP IRONS.

Cast Scrap Iron.—Iron that has been cast into various shapes and forms which are no longer wanted for the purpose for which they were cast, is designated scrap-iron or cast scrap. This iron unlike pig iron, is not graded by fracture or analysis, but is classified as machinery, car wheel, stove plate, plow and plow point, burnt iron drillings and turnings, malleable, and promiscuous scrap. This classification is designed to take the place of grading, and indicates the quality of iron from which the castings were made and the grade of iron that may be found when remelted. It also indicates changes that have been effected in the iron after casting in the process of finishing, or by the use to which the castings had been put before becoming scrap.

Machinery Scrap.—Machinery is cast from a good grade of soft, strong iron. No change is effected in the quality of the iron in finishing the castings, or by the use to which the latter are put when finished, and the same quality of iron is therefore found in this scrap as in the castings when first cast. While such are the general characteristics of machinery scrap, there are some exceptions, for all machinery castings are not made of soft iron. Gear wheels, etc., are cast from a close fine-grained iron and there are other lines of work, such as brick machinery, crushers, grinding mills, etc., parts of which are cast from a white or chilled iron that gives the same grade when remelted. The founder soon learns to designate the quality of iron in his scrap pile, by the shape of the castings and if there is any doubt, by breaking them. Close scrap is thrown aside for this line of work, as white or chilled iron is for another line.

Machinery scrap is regarded as the very best grade of scrap for general foundry castings, and sells at the highest price. In some cases, when very select, it sells at as high a price as the best brands of pig iron, because when mixed with pig it produces a stronger and better casting for some lines than all pig, and is eagerly sought for by founders doing engine work, and other lines requiring good strong castings.

Car Wheel Scrap.—Car wheels, like machinery are cast from a good grade of iron, that is not changed in finishing or by the use to which the wheels are put before being consigned to the scrap pile. This scrap being of the same quality of iron from which the wheels are cast, is of value in mixtures for wheels and is also used by founders in mixtures for castings requiring a close fine-grained iron, or chilled surface. Scrap wheels are most extensively used by car wheel founders, who are generally required by the Railroad Companies to take a certain number of old wheels in part payment for new ones. When placed upon the market, this scrap, like machinery scrap, commands a good price.

Stove Plate Scrap.—This scrap is cast from an excellent grade of iron the chief characteristics of which are softness, fluidity, and strength, exposing when run into thin plates, a very large surface to the chilling tendency of a damp mould. The characteristics of this iron are not at all changed in finishing, but are radically changed by the use to which the castings are put, some of them being exposed to so great a degree of heat, and repeated heating and cooling, as almost entirely to destroy the iron; others are exposed to oxidation, and when consigned to the scrap pile such a large surface is exposed to oxidation or rust, that the quality of the iron is greatly deteriorated. We do not find in this scrap when remelted anywhere near the quality of iron from which the castings were made. Only a limited amount of this scrap can be used in mixtures for stove plate, and it is never sought for by stove-plate founders. It is considered an inferior quality of scrap, sells at a much lower price than machinery scrap, and is principally melted in mixtures for an inferior class of castings.

Plow and Plow-point Scrap.—Plows and plow-points are generally cast from a hard iron with a tendency to chill, but not to so great an extent as that of car-wheel iron. This iron is not at all changed by the use to which it is put, and when remelted the resulting product is of the same quality, only a grade harder. This scrap is so widely distributed that it is only classified at foundry centers surrounded by a large farming district. It commands a fair price for this kind of castings.

Promiscuous Scrap.—In all large cities and at foundry centers scrap is generally handled by junk or old iron dealers, who sort it and prepare for market the various grades previously described. When the character of the scrap is not clearly indicated by the shape of the casting, or there is not sufficient of it to market it separately, it is thrown into a pile that is designated promiscuous scrap. This scrap is generally small, of an inferior quality, and sells at a lower price than graded scrap. It is used by founders for a class of castings upon which there is little finishing to be done and in which the quality of iron is not of any great importance. In foundry districts where there are no junk or old iron dealers, scrap is bought direct from the collectors and is of an entirely different character. It frequently comprises not only all the various grades of cast scrap, but also steel and wrought-iron scrap. The founder generally sorts this scrap and throws it into separate piles, or sorts it as he melts it, using the different grades in his mixtures for different classes of work. When only one line of castings is made at a foundry very little of this scrap is purchased, and when it is, the undesirable iron has to be thrown aside and sold again.

Steel Casting Scrap.—Of late years the use of steel castings for a large variety of purposes has become so extensive that this scrap constitutes an important factor in the mixing of foundry irons. Many of the smaller pieces of it are steel malleables and their effect in foundry mixtures is similar to that of malleable scrap, producing in soft iron mixtures a hard or spotted casting, and for this reason should be carefully excluded from such mixtures. It may, however, be used to good advantage in semi-steel mixtures, and also in heavy castings requiring strength and closeness. The per cent. of steel-casting scrap that can be used in these mixtures depends upon the quality of iron or metal desired in the casting, and also upon the per cent. of silicon the pig used in the mixture may contain, and varies from 10 to 50 per cent., the higher silicon, as in semi-steel, carrying the higher per cent. of scrap in producing a soft workable casting.

Scrap of steel castings is generally sold together with that of cast iron with which the castings have been incorporated in machines for which they were designed, and as these machines are generally painted, it is difficult to detect a steel casting in a lot of scrap. This is more especially the case in agricultural machinery scrap, where the steel castings are small, and in agricultural districts many founders making only soft castings have ceased to use scrap on this account.

The only practical way to detect steel in such scrap is for the sorter to break each piece until he has become familiar with the shape of the steel castings that may be found in the scrap of his district.

Malleable Scrap.—This is the name given to condemned castings made from a very strong grade of white iron. They are very hard when first cast, but are converted into a soft strong iron by a process of annealing that extracts the carbon from the iron. In this process of annealing the characteristics of the iron are completely changed and it resembles a wrought iron more than a cast iron. This iron when remelted with foundry irons does not impart to the latter the characteristics acquired in annealing, but goes back to its original state of a hard iron, and has a hardening effect upon iron with which it is melted. A large per cent. of this scrap is said by founders to be burned up or lost in melting, but we have never been able to learn of an entire heat of it having been made to accurately determine what per cent. of it was lost. This conclusion has probably been reached from the fact that it partakes of the nature of wrought iron, and the loss in the latter when melted in a cupola is very heavy. Founders using gray iron do not desire it in their mixtures of soft iron, and when found in the scrap pile it is thrown aside for castings in which an inferior grade of iron may be used. In foundries making malleable iron such scrap is melted in limited quantities in their regular mixtures, but they do not care for it, and generally confine themselves to that made in their own plant, such as condemned and broken castings. Old malleable scrap generally goes to rolling mills, as do also the old annealing pots, and from it is made the very strongest and toughest of wrought iron by what is known as the dry puddling process.

Wrought Iron Scrap.—This scrap is not used to any great extent by founders, although it may be added to certain grades of foundry iron with good results in increasing strength. Patents were taken out in England, in 1846, by Mr. Sterling, for toughening cast iron by adding wrought iron to it in melting. In his experiments he found that the exact percentage of wrought scrap that could be added to a cast iron depended upon the quality of the latter to begin with. With 10 per cent. of wrought iron added, the strength was increased 2 per cent; with 20 per cent. wrought iron, 30 per cent; with 30 per cent. wrought iron, *increased strength* 60 per cent; with 40 per cent. wrought iron only 33 per cent. It would therefore appear that his best results were obtained from a mixture of 30 per cent. wrought and 70 per cent. cast iron. He states in his published reports that the per cent. of increase in strength varied with different irons, and the above is probably the best results he was able to attain with the most favorable brands or grades tested. Although it is now more than 60 years since Mr. Sterling's patents were taken out, and the patents have long since expired, the strengthening of cast-iron by the addition of wrought iron has not been adopted either in this country or England even by foundrymen requiring very strong iron in their castings. This is probably due to the fact, as stated by Mr. Sterling in his reports, that the increase in strength varies with different irons, and the difficulty of finding an iron that could be depended upon to give the highest strength, and also to to the fact that it is very difficult to obtain solid castings from a mixture of cast and wrought iron.

A series of small heats of wrought scrap and pig were melted by the writer a number of years ago, for a large foundry requiring a very strong iron.

In these heats different brands and grades of pig were melted with various per cents. of wrought scrap, light and heavy. In each heat, the iron was accurately weighed when charged, and after being melted, to ascertain the loss in melting. The loss was found to vary from a little less than 10 per cent. to a trifle over 20 per cent., the heaviest being found with the light scrap. We did not obtain from any of our mixtures an increase in strength anywhere near that claimed by Mr. Sterling. The strength as well as the hardness varied with the different grades, the strongest iron being obtained with No. 2 Pig, but with a high strength the iron was generally too hard for the castings. Trouble was also experienced in getting sound castings for the iron cooled rapidly in the ladle and when not poured very hot, the castings frequently contained small blow holes and dirt. An extra amount of coke was required to melt the iron hot, and altogether the results were so unsatisfactory that this means of strengthening iron was never adopted at this foundry.

Over-Iron.—At the last of a heat the iron is dull or melts so slow that it becomes too dull to pour the work before the ladle is filled, and it is the practice to charge a few hundred weight more than is actually required for castings to insure a hot iron for the last work to be poured. In well-regulated foundries this extra iron is poured into beds provided for the purpose near the cupola, while in others it is poured into the sand heaps or permitted to run from the spout upon the floor. This iron is called over-iron, foundry-pig, remelt, etc. It is of the same quality as that in the castings if made from the regular mixture and can be used in the mixture again, the same as gates and other remelt scrap. If made from refuse scrap thrown in to get rid of it upon the scaffold, or about the foundry, as is sometimes the case, it should only be remelted for an inferior grade of castings, or with a softener for soft castings, for it is generally too hard to be melted in the regular mixture.

Shot-Iron.—There are numerous small particles of molten iron which fall from the cupola spout to the floor when tapping out, stopping up, and changing ladles. Iron is spilled from ladles in the gangways by careless moulders when carrying them, small particles are frequently spilled on top of moulds when pouring, and many of them fall from the cupola when the bottom is dropped. This iron, when collected, is designated in different foundries as shot-iron, gangway-scrap, foundry-scrap, cupola-scrap, tumbling-barrel scrap, etc. In describing it, we shall designate it by its most common name, shot-iron, and include in it, all very small scrap from the foundry such as shot, fins, vents, shells from runners, ladles, skulls, etc.

Old Methods of Collecting This Iron.—Some founders considered this iron of so little value that they threw away the entire cupola dump, gangway cleanings, etc., without any attempt to recover the iron, others picked the larger pieces of it, melted and unmelted, from the dump, and threw away the dump and gangway cleanings, while others again picked out the larger pieces from the dump, threw the remainder into a tumbling barrel, from which the very small particles escaped through the cracks between the staves, passed the gangway refuse through a number-two riddle, and only recovered the larger pieces of iron. The latter is no doubt the most economical practice as it recovers considerable iron that is of value. That this iron has a hardening effect upon that with which it is remelted is well known to practical foundrymen, and this was the reason that many years ago, when there were no softeners and it was sometimes difficult to get an iron soft enough for the work, no pains were taken to recover all the small particles. To prevent or reduce this hardening effect only a few bucketfuls of water were sometimes thrown upon the dump to avoid chilling the iron, and gangway scrap was thrown upon the hot dump to anneal over night. It is doubtful if this prevented hardening; at any rate it never became the general practice. To prevent this iron from hardening other irons, various plans have been devised for melting it, such as melting of shot at the end of a heat and running it into pigs to be melted with other iron in the regular heat. A device, patented a number of years ago, for melting shot, consisted of a cast-iron pot or tube with a contrivance for tightly closing the end with a cover to exclude the blast of the cupola. It has also been melted in open pots, tight wooden boxes and inclosed in iron by placing it in pig moulds and pouring molten iron upon it in such a way as to inclose or imbed it in the pig.

It has been found that the quality of shot-iron is not improved but is deteriorated, by melting it at the end of a heat, or by a separate heat and running it into pigs, and in the latter form does not mix with other iron as well as when in its original state. This is more especially the case when the iron is melted separately for the reason that some time and, perhaps months, is required to collect a sufficient quantity of it for a heat. During this time it becomes heavily covered with rust, which greatly deteriorates the quality, as well as the quantity, of iron in the shot before melting; the product being an inferior quality of iron to that obtained from new shot free from rust.

Modern Ways of Recovering This Iron.—Of late years a number of devices have been introduced for recovering all of this iron at a moderate cost, such as water-tight tumbling barrels, magnetic separators, screen separators, etc. These devices recover every particle of iron no matter how small, and at very little, if any greater, cost than by the old method. It is a very much disputed question among practical foundrymen whether it pays to recover such iron or not, but all agree that it is not worth the cost of the mixture from which it was made, and founders who have given particular attention to the matter only estimate it at 50 per cent. of this cost in figuring that of their mixture in which it is remelted, while many doubt if it is even worth this amount. In melting this iron many of the smaller particles are without doubt entirely burned up and lost, as in melting turnings and borings, and as the oxidizing action of the blast upon the larger shot has a hardening effect upon the iron melted with it, a softer grade of pig has to be used if a very soft iron is required for the casting. I have never melted an entire heat of this shot in order to determine the loss in melting or the quality of iron obtained from it, nor have I been able to learn of such a heat having been melted. However, the loss caused by burning up, and the hardening action due to the oxidizing effect of the very small shot and particles of iron thus recovered, are no doubt greater than with the larger shot collected by the old method. In a number of heats I recently melted for light castings, in which the shot was charged with each charge of iron, no bad effect of it was observed in the casting. But in these heats an extra amount of very soft iron was used, and this is probably the best way of melting this iron; but to obtain the best results all the shot recovered from each heat should be melted in the next heat and not permitted to accumulate. The small particles of this iron may be entirely destroyed, and the larger ones to a greater or less extent, by oxidation or rusting, and when melted after rusting the loss is greater, the iron harder, and it does not mix so readily with soft iron. A large pile of this iron that had become badly rusted was recently offered to a sash-weight founder at three dollars per ton, when pig was selling at twenty dollars per ton. The founder declined to take it even at this low price, giving as a reason that he would not get sufficient iron out of a ton to pay for melting it.

Melting Cast Iron Turnings and Borings.—Many tons of cast iron turnings, planings and borings are made by machine shops in finishing castings. The market value of this iron, when new and clean, is only about one-fourth that of the foundry iron from which it was made, and in many sections of the country is not always salable even at this low price.

Founders having machine shops in connection with their foundries have reasoned that this iron came from soft castings and was therefore a soft iron, and available for melting and running into soft castings again. Many attempts have been made and plans devised for utilizing it in this way, all of which have, to a greater or less extent, proved failures, so far as obtaining a satisfactory soft casting from it was concerned.

Fine iron filings may be burned in a flame of a candle and nothing but a black oxide of iron be left. When this iron is charged into a cupola in small quantities through a heat, it is probably all converted into an oxide and consumed in the cupola, as no bad effect from it upon castings has been noticed when melted in this way, and probably no iron is obtained from it. The oxidizing action of the blast upon the small particles of this iron is so great that it can only be melted in a considerable body, and even then the iron obtained from it is white and only suitable for weights or work requiring such an iron. With a view of utilizing this iron for warming ladles and preparing it for future use, it has been charged upon the bed and poured into pigs after warming the ladles, but it was found the quality of iron was not improved by running it into pig, and melting of the heat was greatly retarded by placing it on the bed.

When charged at the end of a heat with a view of running it into pig, very little iron is obtained, and the greater part of the turnings, etc., are found in a more or less oxidized condition in the slag and cinder adhering to the lining, or in the dump.

To prevent oxidation of this iron in melting, it has been tightly rammed into cast iron pots, closed with a cast iron cover, and luted to exclude the cupola blast and melted alone, and also with other iron. This plan proved a failure, as it was found the quality of iron obtained was not improved to a sufficient extent to justify the expense of the pots and labor in preparing them.

A number of plans have been devised to form this iron into a solid mass in pots, and also in molds without pots, by adding to it some material to make it stick together when rammed into a solid mass. For this purpose sal ammoniac water, molasses water, etc., have been used and the iron left for a few days after being rammed into a pig mold or other device, to rust into a solid mass before melting.

This plan worked very nicely so far as forming the iron into a solid mass was concerned, but it was found when melted that it was not softened by preparing it in this way for melting.

Of all the plans devised for melting this iron in a cupola, probably the best one yet found is to place it in tight wooden boxes holding from 100 to 200 lbs. By this plan it is held together until it reaches the melting zone, when the boxes are consumed, leaving the iron in a compact mass to be melted. In this way an entire heat may be melted by placing the boxes in the cupola a little distance apart and putting coke between them to keep the cupola working open and free. By this means the oxidizing effect of the blast is reduced to a considerable extent, and a larger per cent. of iron obtained than when thrown in loose. But oxidation is not reduced to a sufficient extent to admit of a soft iron being obtained, and the iron melted is always white and hard. This fact should be remembered when melting this iron with other irons, as the resultant mixture is similar to that produced when melting hard pig or scrap with soft pig. If the cupola is tapped close and iron drawn into small ladles, soft iron may be poured from one ladle while hard iron may be poured from another.

The melting of this iron in boxes in a heat with other iron in the proportion of 5 to 10 per cent., has been known to give satisfactory results in heavy work, for which the iron was drawn in ladles holding a number of tons, and given an opportunity to enter into combination with the soft iron in the ladle before pouring.

But, even when treated in this way, and poured into a heavy casting, it has in some instances been found not to thoroughly unite with other iron, and to produce hard spots in the casting, and also excessive shrinkage in parts of it, sometimes causing it to crack at a point least expected and at which the least strain on the casting should have taken place.

The uncertainty of results of melting this iron with other iron, either for light or heavy castings, is so great that I have never known of a founder continuing to melt it after he had experimented with it a sufficient length of time to learn of its fallacies. The melting of this iron in ladles has also been tried, but results have generally been unsatisfactory, as only a limited amount of it can be melted in this way even when the iron is very hot, and when not very hot it may be carried unmelted with the iron into a casting, causing hard spots.

This may occur when the fine iron is thrown into the molten iron with the hand in small quantities. When placed in the molten iron from a shovel in quantities, it balls up and melts very slowly. When placed in the ladle before tapping, it forms into a solid mass in the bottom of the ladle and a layer of one inch in thickness may not be melted during an entire heat. It also causes small blow-holes in castings when placed in molten iron.

In sections of the country where there is no market for this iron, it may be used for sidewalks, yard gangways, scrap-heap floors, etc. When used for such purposes a foundation of from 10 to 12 inches of ashes or cinder should be put down to prevent it being affected by frost. The iron, when clean and free from rust, should be thoroughly wet with a strong solution of sal ammoniac and placed upon the ash-bed three to four inches in thickness, evenly rammed down and left for a few days to dry before using. In a short time the iron will be found to have rusted into a solid plate of iron.

When the turnings are heavily coated with rust, they will not form a solid mass when treated in this way, and should be mixed with a thin cement, which will hold them in a solid mass and make an excellent walk or floor.

Melting Wrought Iron and Steel Turnings and Borings.—The melting of these turnings and borings in a cupola is more difficult and less profitable than the melting of cast iron ones. For when melted loose in small quantities, they almost or entirely burn up. When melted in pots or boxes they ball up into a solid mass which it is almost impossible to melt, and bung up a cupola very rapidly.

When melted in quantities in bulk they form into a solid mass through which the blast does not penetrate except in spots, and in the only heat of them we ever melted in this way it was necessary to remove the lining before the cupola could again be placed in a proper condition for melting.

In a series of tests made in melting this scrap, the per cent. of metal obtained for that charged was very small and the quality of metal very inferior. In fact, it did not make a good solid sash weight, while it was entirely too hard and brittle for any other casting.

We should not advise the melting of this metal in a cupola, as from our experience we think it will be found more profitable to sell it, and in localities where there is no market for it to rather throw it in the dump, than to undertake to melt it in a cupola.

New Methods of Melting Turnings and Borings.—Mr. Louis Baden, Foundry Superintendent of the Niles Tool Works Foundry, Hamilton, Ohio, reports the successful melting of this iron by mixing it with a sufficient amount of Portland cement to hold the turnings together when it has set. The cement is wet and mixed with the turnings. The mass is then rammed into an iron pig mould from which it is readily removed when the cement has set and formed the iron into a solid mass. The pigs are then piled to dry for a few days, and when dry, are charged into the cupola with the regular mixture of iron for the heat. Mr. Baden reports very satisfactory results with 10 per cent. of this iron in their regular mixture for soft machine tool castings; a harder iron with 20 per cent.; a still harder one with 30 per cent.; and one too hard to be machined with 40 per cent.; two bags of cement are said to be sufficient for a ton of borings.

Mr. David Spence, Foundry Superintendent of the Dayton Motor Works Foundry, North Dayton, Ohio, obtained results similar to those of Mr. Baden, in melting this iron a number of years ago, by mixing it with cement and plaster of paris and forming it into pigs in the same way as Mr. Baden, but did not continue to prepare and melt the iron in this way for any length of time, and was not doing so at the Dayton plant.

Briquetting Cast Iron Borings.—The use of cast iron borings in the cupola has always involved great difficulty, in view of the fact, that the heats rarely ever show that any of the material so charged has been recovered. This either indicates that the borings have been blown out of the cupola by the blast, or that they have been oxidized and carried away with the slag. Various methods of charging the borings have been tried, but it seems that briquetting this material gives the most satisfactory results. A mold for these briquettes made from ordinary lumber, tapering from 13x7 inches at the top, to 12x6 inches at the bottom, will form briquettes weighing from 50 to 55 pounds each. A tapered mold is preferred, as the briquettes can more easily be removed from the boxes. The material is mixed with a briquetting compound, or binder, manufactured by the S. Obermayer Co., Cincinnati, which is thoroughly mixed in a dry state and sufficient water is added to temper the mixture, in practically the same way that an ordinary core mixture is prepared. The borings mixed with the compound are then compressed in the mold, by the use of either compressed air, or a hand press, and a jarr-ramming or squeezer molding machine can likewise be used for this work. Approximately 50 pounds of the briquetting compound are used per ton of borings. Briquettes, before using, should be permitted to remain in a temperature ranging from 75 to 80 degrees Fahr. for a period of 48 hours, when they are ready for use. When charging the briquettes they should not be placed on the coke bed, but should be included in the subsequent charges. The borings should be charged on top of the scrap before the coke is added. Approximately 10 to 15 per cent. of borings may be used to each cupola charge.—*The Foundry.*

German Method of Briquetting of Iron and Metal Turnings and Chips.—A machine shop handling about 3000 tons of iron castings a year, has from 200 to 250 tons of scrap iron and steel turnings which it can sell to the foundry for briquetting. Some foundries bought the scrap and tried to melt it in cast iron pipes, pots or boxes, but gave it up, as it was too expensive.

The same was true in those foundries using wooden vessels, as the price of lumber forbade that practice.

Briquetting the scrap was also tried, but it was found that to do this a binding material was used which was high in cost, and had an injurious effect on the casting.

For use in cupolas briquets of the following properties only can be used:

1. They must consist of pure iron and steel chips.
2. They must have sufficient firmness.
3. They must remain firm till they are melted.
4. They must be low in cost.

All of these requirements are met by the briquets made by the Ronay process. In this process the chips are dumped into bins and then are conveyed by belt conveyors and elevators to the magnetic separator, where dirt and scale are removed, and last of all they go to a blast, where the last traces of dust are blown out. They are then delivered to the press, where they undergo varying pressures, going up by steps and ending with pressures from 23,000 to 30,000 pounds.

By this process and the special air-removal process which removes the latent air out of the briquets, a product is obtained which contains a minimum percentage of air, practically no air, and has very great firmness.

The presses are hydraulic rotary presses of special design. The various sorts of material used are steel, cast iron, gray iron, cylinder iron, and scrap in general. These are worked and treated in separate bins, so that the composition of the different briquets can be varied at will. This is especially useful for foundries without laboratories, as the foundry manager can always figure out the composition needed, and get just what he wants.

Tests have shown that in the iron and briquet combination used in the cupola, the carbon percentage is very low. This loss is explained in the following way: The structure of the briquets, though very compact, is not completely so, and is porous to a certain extent. It is porous enough to allow gases from the furnace to penetrate through the mass. When this takes place, the carbon in the briquets, which is there in the form of graphite, is burned. As the process goes on, the decarbonized iron takes up fresh carbon, but the time in which this is done is so short that the iron cannot take up sufficient carbon to make up the loss. We get, therefore, iron with a low carbon percentage, which is, however, very strong and gives a good grain to the casting. The carbon percentage can also be lowered by the addition of 5.15 per cent. of steel, but usually there is so little silicon in the iron that the castings become hard and difficult to machine and finish, in which case a low carbonized special iron must be added.

With the use of briquets such special iron is not needed. With the right briquetting proportions the most sensitive parts can be cast, and locomotive and pump cylinders, etc. This combination iron can also be used for castings of great strength where thin walls are necessary, or castings making sudden changes of cross section, as gear teeth and wheels. In machine and lathe castings, where fine grain is wanted, this iron will be found useful. In practice the combination of iron with 20 to 40 per cent. of briquets has proved efficient.

Briquetting of metal chips is important, as it saves money, and is much more economical than the ordinary process of melting metal in crucibles. The briquets can also be used with other metals in cupolas, or else can be used separately and will give good castings. On account of the uniform weight they are easily controlled in the stock room, and the loss in conveying suffered from loose metal chips is entirely eliminated. The process can be used for brass, copper, aluminum, white-metal, and other metals.—*Giesserei Zeitung.*

Melting Borings and Turnings in the Cupola.—A process of charging and melting borings, turnings, etc., in the cupola to insure the melting of this material with the regular pig and scrap charges, and to prevent these same particles from being blown out of the furnace by the blast, has been patented by Walter F. Prince, who is in charge of the foundry department of the International Steam Pump Co., Elizabeth, N. J. The material, consisting of borings, drillings or any other small particles of iron, is charged in wrought iron pipes, preferably Nos. 18 to 24 gauge, and varying in length from 3 to 4 feet. The casings may be open end cylinders, or they can be closed at one end so as to hold the borings independently of stacking the casings. The transmission of heat through the pigs brings the borings into condition to readily melt down with the rest of the cupola charge. The entire charge of material in the furnace, therefore, settles down uniformly, and as the charging on top is continued, casings are added and are filled with borings or drillings as desired. The first section of pipe containing borings or drillings is charged on the coke bed, and other sections are added as the charging continues. While only one stack of casings is referred to, any number of stacks may be used in the cupola, according to the results desired.—*The Foundry.*

Mr. Prince's Patented Process of Melting Borings appears to give better results in melting this iron than any other, as Mr. Prince was able to show an analysis that indicated no change in the composition of the mixture from that in which borings were not melted, and test-bars showed greater strength with, than without, the borings.

In this process, a pipe made of light iron or steel the length of a stove pipe is used, and for small cupolas, ordinary stove pipe may be employed. The pipe is set upon the bed of coke and filled to the charging door with borings, and the regular charges of coke and iron are put in around it. When melting begins, the borings melt from the end of the pipe, and the latter melts away, and settles with the other stock in the cupola. As it settles another length of pipe is put on, and filled with borings, and so on throughout the heat. At the Worthington plant of the International Steam Plant Co., Harrison, N. J., where this process is regularly used, an extra charging door has been put in, the bottom of which is on the level with the top of the regular door, and a platform has been erected for charging the borings into the pipe.

A twelve-inch pipe is used in their large cupola and this pipe is kept filled throughout the heat. The advantage claimed for this process is that the pipe protects the borings from the action of the blast upon them. More heat is required to melt the steel pipe than the borings, and hence, only the borings in the end of the pipe come in contact with the fuel and blast before being melted. The cost for pipe used at this plant is $1.25 per ton of borings melted. A small royalty is charged for the use of this patent.

These new processes of melting this iron show up very well, as various other processes have on the start, but were finally abandoned for the reasons before stated, and unless they overcome these objectionable features, namely, hard and spotted iron, excessive shrinkage in parts, etc., they too will soon be abandoned.

Steel Turnings.—Steel turnings are melted more rapidly in a ladle than either cast or wrought iron turnings, and have a decidedly hardening and strengthening effect upon the iron for gear wheels and other castings requiring a close, strong iron without chilling. The long thin clean turnings of soft steel that melt quickly are used, and they are dropped into the molten iron in such small quantities as will not admit of their balling up, and thoroughly stirred into the iron with a bar that has previously been heated to avoid chilling the molten metal. Results in this case as in all others, in which a different metal is added to cast iron, depend to a large extent upon the quality of the cast iron to which the turnings are added; and iron low in silicon will be hardened to a greater extent than one high in silicon. I have never learned of these turnings being melted alone in a cupola, but the result would probably be similar to that of wrought iron turnings, and very little metal be obtained from them.

Mr. Prince claimed that with his process these turnings are melted with the cast iron turnings, but an excess of them would no doubt have a semi-steel effect upon the iron.

W. J. Keep's Method of Melting Borings.—Mr. Keep, in answer to an inquiry as to the best method of melting borings writes in *The Foundry*, as follows: "I would advise spreading the borings over the sand bottom before the kindling is put into the cupola, which should be spread approximately 1 or 2 inches thick. This charge of borings will be melted by the first iron that comes down and will not injure the mixture. By experimenting, you can soon ascertain how thick a layer of borings can be used."

This method is new to me, and I have never seen or heard of it being tried, but should think the results would be similar to that of placing borings in the bottom of a ladle and tapping iron upon them, in which case they cake up and are not melted with the ladle in constant use during a heat.

Melting Cast Iron Borings in the Cupola.—In answer to the inquiry made in the January issue of *The Foundry*, regarding the best method of melting cast iron borings in the cupola, Mr. T. Shaw says: "I have a suggestion to offer that has given me excellent results in the past. When charging the cupola, I usually lay about 200 pounds of small scrap evenly on the bed of coke, and on top of this layer I charge from 100 to 200 pounds of borings. I then complete the charging of the furnace in the usual way, the weight of the pig iron being sufficient to prevent the borings from being blown out of the stack. Some of the borings are, of course, lost in this way, but the speed of the blower can be regulated and the blast can be kept down to eight or ten ounces.

"Before bedding in the last two charges, it is advisable to reduce the speed of the blower about one-half, as the greater loss will occur at this time, if the furnace is not properly controlled.

"Another method that has given good results provides for the charging of the borings when the furnace is running low and after the molds have all been poured. The entire charge of borings can be made, amounting to 2,000 pounds, and can be melted with a small amount of coke, as the furnace is hot enough at this time to almost melt these small particles of iron. This iron will be suitable to run in the pig bed. The borings can also be thrown unto the pigs while still in a molten state, and it will be found that a considerable quantity will be absorbed and held in this way."

This method amounts to charging the borings loose in the cupola with the regular heat, and has been tried and proved a failure many times.

Use of Borings for Annealing Scale.—Dr. Richard Moldenke offers in "The Foundry" the following remarks on the subject: "A number of years ago the custom of adding cast or steel borings to the scale used for packing about castings to be annealed came into vogue, and has continued more or less to the present time. The object at the time this was being introduced was first to get rid of a drug on the iron market, and second to take up the burning effects of any stray air that might get into a pot and thus save the sharp edges of the castings.

"A correspondent asks about the quantity to be used. First of all it is better to prevent the trouble than to correct it; that is, to lute up the pots properly, so that small currents of air cannot enter and circulate about the castings, which should be packed so tightly in scale that no openings are left between them. This will obviate the use of any borings.

"However, if it is an economic question, that is, if the borings cannot be sold, the supply that comes from the machine shop can be scattered on the scale piles every day in any quantity up to the amount which will not be oxidized in the first anneal. That is, if so large a quantity of the borings is used that when dumping the pots a large amount has remained unoxidized, or only partly so, more has been put in than was necessary to accomplish the object desired. Reduce the amount accordingly.

"As a general rule there is seldom more than a fraction of a per cent. of the annealing scale used daily, from borings made in the machine shop of a malleable works, and hence the question is not a very live one. If a good price can be obtained for the borings, it is better to sell than to add them to the scale."

CHAPTER IV.

MIXING IRONS.

Mixtures of Iron.—Mixtures are made of the various brands and grades of foundry irons for castings, for the following reasons: It has been found practically impossible to procure a single brand or grade of iron that can be depended upon to give the quality of metal desired in any one line of castings. Two or more lines of them are frequently made in a foundry, each requiring a different grade of iron. Irons made from different ores in different furnaces are generally considered to make a stronger and better casting, when mixed, than those from one furnace. A cheaper metal, suitable for the line of work to be cast, can frequently be obtained by mixing high- and low-priced irons than from any one iron. Pig and old scrap generally make a stronger casting than all pig. Silvery irons cannot be used except in mixtures, for by themselves they are generally too weak for castings, but they give softness and strength to iron that by itself is too hard for castings. Products from three or four furnaces generally give the best grade of iron in castings, this number enabling the founder to produce an iron of any desired quality by varying the percent. of different brands and grades in his mixture. In making mixtures neither fracture indication or analysis indicates to the average foundryman the quality of iron that may be obtained from a mixture of two or more irons, and to enable him to make a mixture with any degree of certainty, he must first acquire a thorough knowledge of his irons by an actual test in melting them together. This is sometimes a very expensive operation, for an entire heat of castings may be lost through the iron being unsuitable for the line of work to be cast. To reduce such losses to a minimum in trying new iron, only a small per cent. of it is melted, in one charge or part of a heat. Should this prove satisfactory the per cent. is gradually increased until the desired amount is used in a mixture. After a satisfactory mixture has been attained in a foundry, it is carefully guarded to prevent other foundries from getting hold of it, and at some foundries where special lines of work are made, precaution is taken to not even let the foreman or cupola men know the mixtures. This is done by not permitting them to learn the names of the irons used, and when piled in the yard, giving to each brand or grade a number, letter, or other mark by which it is to be known in the mixture, the latter being always made in the office and given to the foreman or melter.

A mixture made by one founder is only of value to another one who has or may obtain the same brands of iron, and is therefore only of local interest. We have at hand a number of mixtures made at different foundries for the various classes of work. In all these mixtures local brands of iron are used that are only obtainable in certain districts, and as each founder must depend upon the brands obtainable in his market, at a reasonable price, these mixtures would be of so little value that no space will be given to them in this work, which will probably reach all sections of this, as well as of other, countries, but we shall endeavor to give a general outline of how mixtures are made for different classes of castings.

Stove Plate Mixtures.—Stove-plate founders only work No. 1 and No. 2 plain or No. 1 and No. 2 X irons, and from two to four brands of each number, although we have known of as high as seventeen different irons having been used in this mixture. A pig known as a softener is also generally carried in the yard. This pig contains from 4 to 6 per cent. silicon; it is very weak and is only used in a mixture when the other irons run too hard for the castings. In making mixtures the No. 1 is known as the soft, and the No. 2 as the strong, iron. These irons are mixed in about even proportions. Should the resulting metal prove too hard, the proportion of No. 1 is increased, and if soft, but weak, that of No. 2. If it is hard and strong, the softener is added and in this way an iron of the desired quality is obtained. The mixture is also sometimes improved by using a larger per cent. of one brand than of another, or all No. 1 of one brand and all No. 2 of another, and so on. In this way the mixture is varied from day to day till the best results that can be obtained from the irons entering into the mixtures are determined. This is effected by means of test-bars, which indicate strength, softness and shrinkage. Bench and all very light casting foundries use about the same grades of irons as stove foundries and mix them in about the same way. The remelt in these foundries is so heavy that old scrap is seldom used in the mixtures.

Machinery Mixtures.—For very light machinery about the same brands and grades of iron are worked as for stove plate, but a larger per cent. of No. 2 is generally used in the mixtures.

For heavy machinery irons from different furnaces than those from which the stove plate founders receive their supply are generally used. These irons are stronger, and grades from Nos. 1 to 4 are employed. In making mixtures for light soft work, Nos. 1 and 2 are used, for heavy work, Nos. 1, 2 and 3, and for heavy work requiring a very strong close iron, mixtures are made of Nos. 2 and 3 or Nos. 2, 3 and 4. In making these mixtures the same practice is followed as in the stove plate foundries, and the suitability of the iron for the work to be cast is determined by means of test bars before an entire heat of iron for a special casting is melted.

All foundries have one or more brands of iron which they know from experience they can depend upon for hardness, softness, strength or chilling properties, and these are regarded as their standard irons that can be relied upon to give either of these characteristics desired, and in making mixtures, other irons are added to them to increase or decrease hardness, softness, strength, or chill, as may be desired in the casting.

No practical founder would undertake to melt, even by analysis, an entire heat of pig he knew nothing about, except for the more common grades of castings.

Mixtures of Pig and Scrap.—It is well known among practical foundrymen that a mixture of pig and scrap, of a good quality, produces a stronger, cleaner and better casting than a mixture of all pig, and it is the practice when good scrap can be obtained to use a large per cent. of it in mixtures for strong castings. Founders making a special line of work, only purchase a grade of scrap that experience has taught them to be suitable for their castings. The iron in the scrap is about what they desire in their castings, and, in making a mixture, only sufficient soft strong pig is used to offset the hardening effect of remelting the scrap. Founders making lines of work for which different grades of iron are required, purchase several grades of scrap for the various lines of castings, and mix them with pig such as tests have shown to prevent hardening and to increase the desired quality of iron in the castings. Jobbing foundries purchase promiscuous scrap and sort it to suit their work, and in this way are able produce an iron of almost any desired quality with only a limited variety and grade of pig.

For soft strong castings a soft machinery scrap and No. 1 pig are used at the rate of 25 to 50 per cent. pig; for a hard or close iron a close scrap with a small per cent. of No. 1 pig, or an open scrap with a No. 2 pig, in various proportions to suit the work; for hard castings, stove plate and other small scrap, alone, or with No. 2 pig; for chilled castings, a hard scrap with a No. 2 or 3 pig having a tendency to chill.

Mixtures are also made with scrap and high silicon iron as a softener. These mixtures are used for various classes of castings, the per cent. of pig in them depending upon the per cent. of silicon it contains, and varying from 15 to 50 per cent. When making this mixture, the pig should be broken in short pieces and mixed with the scrap when charging, to insure its mixing with the iron of the scrap when melting.

In all cases, pig should be broken in pieces to correspond to the size of the scrap and charged in a way that will insure the mixing of the irons in melting and their dropping to the bottom of the cupola.

Remelt Iron.—Remelt is the term by which all iron is known that is to be remelted; this comprises bad castings, gates, runners, sink heads, over-iron, etc. This iron is of the same quality from which the mixture was made, only a shade harder, and it is the practice to melt a sufficient quantity of it in each charge of iron, so that all of it is melted in succeeding heats. As there is always about the same per cent. of this iron to be melted, it is considered as part of the regular mixture, and a quality of pig that will render it sufficiently soft for the castings is melted with it. In many foundries the remelt is so light that little attention need be given to it, but in stove and bench work foundries it sometimes amounts to as high as 50 per cent. of the heat melted, and then becomes a matter of importance in making mixtures.

Locomotive Cylinder Mixtures.—The following mixtures are recommended by Mr. Paul R. Ramp for locomotive cylinders. Mr. Ramp has had a wide experience in this line of castings, and the mixtures are no doubt good ones when the brands of iron named can be obtained:

No. 1.	Pounds.
Longdale pig iron	700
Cylinder scrap	600
Hard scrap	500
Steel scrap	200

Tensile strength 31,990 to 32,810 pounds per square inch.

No. 2.	Per cent.
No. 1 Lake Superior pig iron	50
Car wheel centers	25
Selected scrap	25

Tensile strength 2,800 pounds per square inch.

No. 3.	Per cent.
No. 2 Champion pig iron	30
No. 4 Salisbury pig iron	25
Cylinder scrap	35
Car wheel scrap	10

Tensile strength 2,400 pounds per square inch.

No. 4.	Pounds.
No. 2 Crozier pig iron	1.000
No. 2 Crane pig iron	1.000
Chilled wheels	1.500
No. 1 Cylinder scrap	1.000

Tensile strength 2,100 to 2,300 pounds per square inch.

No. 5.	Per cent.
Shelby No. 5 pig iron	10
Warwick No. 3 pig iron	25
Niagara No. 2 pig iron	25
Car wheel scrap	20
No. 1 scrap	20

Tensile strength 2,100 pounds per square inch.

No. 6.	Pounds.
Charcoal Buffalo pig iron	200
Buffalo No. 2 pig iron	200
Buffalo No. 2 plain pig iron	600
No. 1 scrap	300
Car wheel scrap	400
Steel scrap	300

Tensile strength 3,200 to 3,350 pounds per square inch.

There are several other mixtures used by concerns producing cylinder castings, but those given above are sufficient to outline latter-day practice. It is possible to duplicate a mixture, but the analysis cannot be duplicated with the same mixture in another cupola, unless the operating conditions are the same in both. For this reason uniform iron mixtures cannot be used in widely separated districts. The design of the casting is another important feature that materially affects results. A low silicon mixture with a comparatively high sulphur content can be used if the casting is designed for a uniform thickness of metal throughout.

Making Mixtures.—In the preceding pages a general outline has been given of the way in which mixtures are made for various kinds of castings requiring a certain grade of iron, the latter being a necessity, for the reason that an iron suitable for stove plate would be entirely too soft, weak, and porous for heavy machinery. A mixture for heavy machinery would be too hard and brittle for stove plate; a car-wheel mixture entirely too hard for machinery, and a machinery mixture would not give the required chill in a car wheel, the same being to a greater or less extent the case in iron for all the various grades of castings.

Mixtures were formerly made from the indications of fracture in the newly-broken pig, but since the introduction of new methods of casting and cooling pig iron, fracture indications are very deceptive, and it is only in pig cast and cooled by the old method that they can be depended upon even by fracture experts. Analyses have therefore almost entirely taken the place of fracture indications, but these also are deceptive, and the mixture has to be actually melted and cast before its exact characteristics can be determined. But mixtures by fracture indication have not been entirely abandoned and there are many founders who still adhere to this method. In a foundry recently visited, in a small town in Maryland, I met a foundryman who was making a general line of castings requiring a number of grades of iron. He also had a government contract for cylinders and other castings, the specifications for which called for a certain density, tensile and transverse strengths. He was making his mixtures for these castings entirely by fracture indications and a knowledge of the irons gained from previous experience in melting them. His method was to carefully sort his promiscuous scrap and melt each grade or quality with a pig suitable to it. In this way he had no trouble in filling all the requirements of a government specification, and not a single casting had been condemned on account of falling short of these specifications. At another foundry in Wisconsin, a foundry superintendent was met who was making a general line of soft castings, and also a large line of crusher work requiring a hard, deep chill. For this work he was mixing from blast furnace analysis, fracture indication and a knowledge of the irons gained in previously melting them. Irons of extremely varying grades, such as a soft, strong iron, one with a half-inch white chill, a two- and three-inch white chill, and a two- and three-inch mottled chill, were melted in the same heat and satisfactory results in the castings obtained.

In the mixing of irons a practical knowledge of their characteristics gained by melting them is absolutely necessary to insure success, no matter whether they are mixed by a chemist and accurate analysis, or by the founder from blast furnace analysis, or no analysis at all. To gain this knowledge an accurate account of the irons and proportions of each in the mixture should be kept, as well as their analysis, and after the resultant iron has been tested, a note should be made of its quality or suitability for work cast. Such an account not only serves as a guide in keeping the mixture up to the desired standard, but is a great help in making new mixtures and trying new brands of iron.

CHAPTER V.

Loss and Gain of Iron in Melting.

Loss of Iron in Melting.—It is a very difficult matter to determine the per cent. actually lost in melting iron, owing to the carelessness of cupola men in weighing the iron that goes into the cupola, and in the practice in distributing molten iron, collecting castings, over-iron, recovering iron from dump, etc. In more than a hundred heats, melted by the writer, in different foundries for various classes of work, to determine the loss in melting for these classes of work, the results were found to vary from a gain of three per cent. to a loss of twenty per cent. on the regular foundry mixture. This would no doubt be the experience of a majority of founders to-day, if they were to attempt to ascertain their loss in melting and trusting to the weights of cupola men and others. Full fifty per cent. of these heats were manifestly incorrect, and it was only by correcting the system of weighing and collecting iron in castings and remelt, and trying again, that any conclusion could be reached. From these heats, it was concluded, that the loss in melting for different classes of work, was about as follows:

Pig and remelt for heavy machinery castings 3 per cent.

Pig and remelt scrap for light machinery and jobbing work 4 per cent.

Pig and remelt for stove-plate and bench-work 5 to 6 per cent.

The increase in loss is due to the increase in light remelt scrap, which varied, in stove and bench foundries in which the tests were made, to from 30 to 50 per cent. of the heat. These tests were made from the regular foundry mixture for the class of work indicated. And the loss, which is almost double in stove and bench work foundries, is due to the heavy remelt of small gates and scrap. The following estimate of loss upon pig and old scrap, were made for the various lines of castings with the average mixture and remelt for such work.

Pig and heavy machinery scrap for heavy work 3 per cent.

Pig and small machinery scrap for light machinery 5 per cent.

Pig and promiscuous scrap for jobbing work 7 per cent.

Pig and old stove plate, plain work, 9 per cent.

These losses indicate those on an entire heat of these irons, and, as all these mixtures are frequently melted in one heat in jobbing foundries, show the average loss to be 6 per cent. This loss will vary to some extent to the amount of each grade of scrap in the mixture melted. It also varies with the size of heat melted, and in all cases is greater in light heats than in heavy ones due to a larger per cent. of shot iron and cupola waste. These losses were determined before the new methods of recovering all the shot and small pieces of iron were introduced. But as these small particles that were formerly thrown away are probably all burned up in melting, a test in which they are melted with the regular mixture will probably show about the same loss.

Loss in Melting Machinery Scrap.—The loss in melting machinery scrap varies with its quality. With a heavy clean scrap, it is not any greater than that of pig iron. And with light scrap, rusted and dirty, it varies according to the size of the scrap, and runs as high as 7 per cent.

Loss in Melting Old Stove Plate Scrap.—In a number of heats of all old stove plate, melted in different foundries to determine the loss in melting, it was found to be from 10 to 15 per cent., it varying with the extent to which the plate was rusted and the care with which it was picked over. This was the actual loss in melting and does not cover the total loss on this iron. This scrap when piled in the yard, and exposed to the weather oxidizes very rapidly, iron being thus lost. Many small pieces are lost in the yard in breaking up the stoves, and the latter frequently contain ashes and dirt, which have been weighed as iron. Badly burned pieces, such as grates, fire-plates, covers, cross-pieces, etc., are generally thrown out, all of which increase the loss on weight of iron purchased. Taking all these losses into consideration, practical foundrymen figure the loss on this scrap at from 12 to 20 per cent. New plate from the foundry is considered at 6 per cent. loss.

Loss in Melting Plow Point Scrap.—In a number of heats melted at Albany, N. Y., of scrap selected from a promiscuous pile to determine the loss on the different scraps, it was found that plow points showed the smallest loss in melting of any of the small scraps. This loss as indicated by a number of heats was 4 per cent.

Loss in Melting Shot Iron.—The writer has made many curious tests to determine the loss in melting this iron. Among them was one made at the foundry of the Perry Stove Works, Albany, N. Y. They had a lot of shot-iron that had become mixed with small anthracite coal and it was determined to burn the coal under the boilers, and in this way melt the iron and permit it to drop into the ash-pit, from which all the ashes had been removed and a hole arranged in the center into which the iron would run and form a solid mass. A good hot fire was prepared under the boilers, and a thick layer of shot and coal spread over it. The ash pit doors were then tightly closed and a blast turned into the ash pit. Mica had previously been put into the furnace doors so that the effect of the heat upon the iron might be seen. When the iron upon the surface came near the melting point, the small shot threw off beautiful bright stars of all colors and shapes, presenting the appearance of fire works. In these stars all the small particles of iron were converted into the black oxide of iron. The iron under the surface must have gone the same way, for none of it was found in the ash pit or upon the grate bars, although fully 300 lbs. were placed in the furnace. This seems to indicate that in melting this iron it should be excluded from the air as much as possible and melted quickly to reduce loss.

In a heat of one ton of shot put up in wooden boxes and melted at the same foundry the loss was 20 per cent. This shot was to some extent composed of vents, rods, fins, etc., which had been recovered from the sand heaps and was considerably rusted. The iron obtained was very hard, although the shot had been made from very soft stove-plate iron.

In a heat melted at a stove works in Louisville, Ky., in which 1000 pounds of shot were charged loose on the bed and the regular heat for stove plate melted with it, the loss on the entire heat of five tons was 8 per cent. The cupola melted slower than usual, which was probably due to the slag and dirt from the shot covering the bed and clogging the cupola.

In a heat melted at the Baldwin Locomotive Works, Philadelphia, Pa., in 1874, the loss was 15 per cent., with the shot put up in wooden boxes, and the iron obtained was very hard.

In a heat melted at the Fort Pitt Foundry, Pittsburg, Pa., the loss was 18 per cent. The shot was smaller than that at the Baldwin works, and was put up in wooden boxes and melted in the same way; iron very hard and unfit for anything but weights.

Rust increases the loss on this iron, and also the hardness. It should never be permitted to accumulate about a foundry.

Loss in Melting Burned Iron.—When managing a malleable iron foundry in 1873, we accumulated quite a lot of old annealing boxes for which there was no market, and it was decided to try melting them in a cupola and running the iron into boxes or pig for use in our regular mixture. Some of these boxes were cast from white iron, and others from grey iron. The grey iron boxes, which were heavier than the white iron ones, were tried first. We obtained from them about 40 per cent. of very hard iron, with a large amount of slag, which was so mixed with the iron that it could not be separated from it until cooled. The white iron boxes produced about 50 per cent. of iron, which was also combined with the slag; and they required more fuel to melt than the grey iron boxes.

In a heat I melted at the American Stove and Hollow Ware Co., Philadelphia, Pa., in 1874, of annealing pots that had been used in annealing hollow ware, the loss was 30 per cent., with so large a per cent. of slag that the iron could not be run into the castings for which it was melted.

These pots were 2 inches thick and had not been subjected to so great a heat as the malleable annealing boxes.

In a heat, melted at Norfolk, Va., of the ends of grate bars that had not been in the fire and showed but little signs of having been heated, the fracture indicating a soft iron, the loss in melting was 18 per cent. The iron was white, hard and brittle, but slag was not excessive and separated readily from the molten iron. These bars were cast at a locomotive works from soft iron.

In a heat melted at the foundry of Noyes & Co., Buffalo, N. Y., of hot-blast pipe that had been used in heating blast for drying purposes, the loss was 25 per cent. This pipe had not been heated to a very high temperature and showed but little indications of having been burned.

The iron obtained from burned iron is only fit for weights, and probably the best way to melt the latter for this purpose is to mix it in small quantities with other scrap. The slag then acts as a flux for the cupola.

Loss and Gain in Melting Pig and Scrap Iron.—The following tables show the loss and gain in melting pig iron, and the loss in melting scrap iron.

Gain in melting 100 net tons of pig iron bought in gross tons of 2,240 lbs., and castings sold in net tons or pounds. 100 gross tons are equal to 112 net tons, and, therefore, there is a gain in iron on all losses under 12 per cent.

Iron.	Per cent. lost in melting.	Iron lost.	Iron gained.	Castings.
100 Tons.	3	3 Tons.	9 Tons.	109 Tons.
100 "	4	4 "	8 "	108 "
100 "	5	5 "	7 "	107 "
100 "	6	6 "	6 "	106 "
100 "	7	7 "	5 "	105 "
100 "	8	8 "	4 "	104 "
100 "	9	9 "	3 "	103 "
100 "	10	10 "	2 "	102 "
100 "	11	11 "	1 "	101 "
100 "	12	12 "	0 "	100 "

Loss in melting 100 tons of scrap iron bought in net tons and sold as net tons or pounds:

Iron.	Per cent. lost in melting.	Iron lost.	Castings.
100 Tons.	3	3 Tons.	97 Tons.
100 "	4	4 "	96 "
100 "	5	5 "	95 "
100 "	6	6 "	94 "
100 "	7	7 "	93 "
100 "	8	8 "	92 "
100 "	9	9 "	91 "
100 "	10	10 "	90 "
100 "	11	11 "	89 "
100 "	12	12 "	88 "

A comparison of these two tables shows that there is a gain of 12 tons of castings in favor of the pig iron against the scrap, when the percentage of loss in melting each is the same, while only in the melting of heavy machinery scrap the loss is the same as that of pig iron, it being heavier in all other grades of scrap until old stove plate is reached with which it may be 15 per cent. In this case only 85 tons of castings could be produced from 100 tons of scrap. Pig iron should, and can be, melted in a well-managed cupola with a loss not to exceed 3 per cent. for heavy castings, where the remelt is light and the remelt scrap comparatively heavy. By allowing 5 per cent. loss in melting pig and 7 per cent. loss on light scrap there is a difference of 14 tons of castings in favor of pig, and a still greater difference as the scrap becomes smaller and poorer. These figures and tables should convince any founder that the price at which scrap is now being sold is entirely too high in comparison with the price of pig. In some foundry districts scrap is sold in gross tons of 2240 lbs., but even in these districts the price is too high to be profitable to the founder, for at least 2 to 3 per cent. more iron is lost in melting, and more labor is required to handle scrap, because one man can load and deliver two to three barrows or trucks full of pig, while another one is loading and delivering one of small scrap, a greater expense for labor being thus incurred.

These matters should all be taken into consideration and investigated in figuring cost of castings. When this has been done the price of scrap will no doubt come down on a par with that paid in the days of rule of thumb foundry practice, when founders evidently knew more about the value of scrap in founding than the scientific founders of to-day.

No more than $12 per ton is at the present time paid for rolled-plate steel scrap by the manufacturers of steel, and the ratio of difference in price should exist between that of pig and scrap as between that of steel and scrap steel.

Stove Foundry Melting.—The following tables show statements of melting per cent. of castings, remelt, fuel and gain in iron,which were furnished by four of the leading stove foundries of Albany and Troy, N. Y., and published in my work, the "Founding of Metals" in 1877; they represent the melting and output of these foundries for the year 1876. At that time Albany and Troy were the leading stove centers of this country. Stove founders have always been noted for better cupola practice than machinery and jobbing founders. These reports show more accurately and completely what may be done in cupola practice than any reports I have ever seen published:

FIRST FOUNDRY.

	Tons.	Lbs.
Gross amount of iron melted	2,049	1,087
Amount of pig melted	1,300	1,860
Amount of clean castings net	1,344	919
Percentage of cleaned castings produced to total iron melted		57.70
Percentage of coal used in melting		15.55

SECOND FOUNDRY.

	Tons.	Lbs.
Gross amount of iron melted	2,817	1,420
Amount of pig iron melted	1,842	1,871
Percentage of cleaned castings produced to total iron melted		62.12
Percentage of fuel used in melting		14.51

THIRD FOUNDRY.

	Tons.	Lbs.
Gross amount of iron melted	3,328	84
Amount of pig iron melted	2,118	521
Amount of cleaned castings net	2,216	987
Percentage of cleaned castings produced to total iron melted .		56.35
Percentage of coal used in melting		16.12

The following statement was received from the largest stove foundry in the United States at the time it was made:

	Tons.	Lbs.
Gross amount of iron melted	6,695	1,197
Amount of pig iron melted	4,276	1,042
Amount of cleaned castings net	4,433	975
Net gain of castings over gross tons of pig iron	157	
Percentage of cleaned castings produced to total iron melted .		58.41
Percentage of coal used in melting		15.08

This last table shows the melting done and results obtained at the Perry Stove Works, Albany, N. Y., for the year 1876, and was prepared by Mr. John S. Perry, the great pioneer of modern stove and range designs and construction, and the most accurate figurer of foundry cost this country or any other has ever produced. But Mr. Perry died a poor man, while his competitors grew rich, which very clearly indicates that success in foundry practice does not all depend upon an accurate cost of production system.

This report, leaving off the odd pounds or fraction of a ton, shows that 4,276 gross tons of iron were melted. Reducing this amount to net tons, the same as cleaned castings, there is a gain of 513 tons in pig, making a total of 4,789 tons of pig melted; deduct from this the weight of cleaned castings, 4,433 tons, and there is a loss of 356 tons of iron in melting or 7.43 per cent. on the pig. Take from the 4,433 tons of castings, the 4,276 gross tons of pig, or the 356 tons lost in melting from the 513 net tons gained in reducing 4,276 gross tons to net, and there is to the founder a gain in iron of 157 tons in castings in the melting and casting of 4,276 gross tons of pig. The total amount melted was 6,695 tons, or 906 tons more than the net tons of pig. No old scrap was melted and this amount represents the remelt, which was 41.59 per cent. of the total amount melted in each heat. The loss on total amount melted, 6,695 tons, was 356 tons, the same as on the pig, but shows a per cent. loss of 5.31 as against 7.43 on the pig, or 2.12 less than the pig.

This heavier loss on the pig was due to the remelt of 41.59 per cent., or 906 tons, which had to be melted twice before it was put into castings. These figures of per cent. of loss in melting show the fallacy of figuring the loss in melting on a test heat to determine that in melting, for the pig or scrap purchased and paid for is the only iron on which the loss is sustained.

These heats were all melted with anthracite coal as fuel, but little used for the purpose at the present time, and show the per cent. of this fuel required to melt iron sufficiently hot for light stove plate. The figures given are the per cent. of fuel consumed in melting 100 pounds of iron, and not pounds of iron melted to the pound of fuel.

Determining Actual Loss of Iron.—It is interesting and of value to know the actual loss of iron in melting in a well-managed cupola. Such a knowledge serves to keep down the loss from excessive blast, scanty fuel, carelessness in recovering iron from dumps, gangways, etc. But loss in melting by no means indicates the loss of iron that the founder is liable to. In soft foundry yards a great deal of iron may be lost by sinking into the ground in wet weather. I visited a foundry at Hartford, Conn., some years ago, to which an addition was being built over the iron yard. In digging the trench for the foundation for this addition, twenty bars of pig iron were recovered, and had the entire yard been dug over, many tons of iron would no doubt have been found. Many small pieces of iron are lost in breaking scrap in these yards, and two or three feet in depth of almost solid iron may be found in yards where scrap has been broken for years. Iron is buried in the foundry in sand and refuse. Bad castings have been buried and thrown in ponds or rivers by moulders to conceal poor moulding and loss of castings, and there are many other ways in which iron may be lost. The best method, therefore, of determining loss of iron is not to depend upon the cupola report for it, but to reduce gross tons of iron to net tons or pounds and compare this with pounds of castings sold or on hand, and visible stock of iron on hand, because all stock not visible is lost, whether it has gone up the cupola stack or lost in some of the many other ways in which it may disappear from view.

CHAPTER VI.

CASTINGS BY DIRECT PROCESS.

In the early days of founding, castings were cast with molten iron taken direct from the furnace in which the ore was smelted and the iron made. In those days the remelting of iron for castings was not practiced, and all castings, light and heavy, were cast direct from the furnace. The iron from many of the ores smelted was not suitable for castings, and this prevented many of the furnacemen from engaging in the business, while those having ores that produced a suitable grade of iron for castings met with such difficulty and uncertainty in obtaining the grade of iron desired, owing to the lack of knowledge in controlling the furnace, that the business was not very profitable. This led to the invention of the cupola and to the remelting of iron found suitable by fracture-indication for the work to be cast, and to the separation of the casting industry from that of the blast furnace, and the establishment of foundry practice as a separate and distinct branch. For many years no castings were made at blast furnaces except plain ones for their own use or for rolling mills with which they were connected. But since the improvements in the mixing of ores and blast-furnace practice, some furnacemen have again engaged in the casting business. This is now known as the direct casting process. Even with the improvements in blast-furnace practice and the aid of chemistry in mixing ores, the furnacemen are not always able to control the quality of iron or produce a grade suitable for castings the molds for which have been made. Before the quality of the metal can be determined the work is cast, and the castings have to be broken up in case the iron proves unsatisfactory, and the latter has to be run into pigs, sometimes for several days, before the furnace gets back into its normal working condition and produces a soft even iron. But for certain lines of heavy castings, such as steel ingot molds, the direct process has proven a success, and these molds are regularly cast at furnaces. Aside from the liability of the iron to run too hard for the castings, is the trouble caused by kish * found in iron high in graphite, such as soft high-grade iron. This substance in appearance resembles flakes of black lead or plumbago, and is the same flaky carbon material so often found separating the crystals of pig iron and falling out when the pig is broken. It frequently separates from a cast of soft foundry or Bessemer iron, and floats off in the air in such large quantities as to cover the floor of the casting house. It appears to separate to a far greater extent when the iron is caught in ladles than when it runs through a runner direct to the pig beds in the floor of the casting house. All the excess of it is thrown out of the iron before cooling and does not appear when the iron is remelted, except in rare instances. But in casting by the direct process kish is a great annoyance. It forms cold shots, spongy porous spots in the castings, and floats upon the surface of the molten iron as it fills the mold, and gives to the top of the casting a rough, ragged appearance that often condemns the latter. Kish cannot be skimmed from the surface of the iron before pouring, and a number of gates devised to prevent it entering the casting and to collect it in the runner or gate have proved a failure, for the kish is in combination with the iron when it enters the mold and separates as the latter fills and the iron cools. For this reason it may be said that iron possessing much kish is unfit for pouring small or fine castings to be machined and finished. Kish seldom appears in iron with silicon at or below 1.5 per cent. and sulphur above 0.30 per cent., and good sound castings can be made with such iron by the direct process. But iron with such a low content of silicon is too hard for light soft castings and can only be used

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* Kish thrown off from iron in direct casting, has been analyzed and found not to be black-lead or plumbago, although in appearance it resembles it very closely.

for castings an inch or more in thickness. This has been the experience at many of the furnaces at which the direct process has been tried, but some of them appear to have had less trouble with kish than others, and turned out satisfactory small castings. That castings can be made cheaper by the direct process than the founder can remelt the iron and produce them is undisputed, and quite a number of ingot-mould foundries have been compelled to look for other work, due to direct process competition. In some sections foundries have refused to buy pig from furnaces making castings by the direct process, claiming they only want to sell the iron they can not use in the production of castings and in cutting of prices. But such a course would seem to be unnecessary as owing to the uncertainty of the quality or grade of iron a furnace may from day to day produce and the presence of kish in iron suitable for soft castings, the furnace men are not likely to engage in the general casting business.

Oxidized Iron.—This term is applied to iron that has been changed from its normal condition by the action of the elements or by heat, and in plain terms, as applied to foundry irons, means rusted and burned iron. Thin sheets of iron, such as tinned plate, from which the tinning has been removed, stove pipe, etc., may in a very short time be completely destroyed by rust if placed out of doors or in a damp place. Cast iron is destroyed in the same way, though not so rapidly as wrought iron or steel, but when exposed to the elements it becomes heavily coated with rust, and it too is in time completely destroyed, and the greater the surface exposed the more rapid the destruction. Rust does not affect cast iron beyond the depth or scale of it, and when this is removed the iron is found to be perfectly solid and not at all deteriorated. When cast iron heavily coated with rust is heated, the action of the latter upon it is similar to that of rusted iron scale used for annealing in malleable works, and extracts carbon from the iron, rendering it harder when melted. This hardening effect of the oxide can be prevented by removing the rust, which can readily be effected with small scrap, by placing the latter in tumbling barrels and tumbling it for a short time. This cannot be so readily done with larger scrap, and besides the iron is not hardened to so great an extent as is the case with small scrap, which exposes a greater surface, in proportion to the body of iron, to oxidation than heavy scrap. That the value of cast iron is decreased by rusting is well known, and pig iron that has for years lain in storage yards to be sold upon the warrant system, is sold at a lower price than new iron of the same grade. The value of scrap is to a still greater extent deteriorated by rusting than pig iron, for a far greater area of surface, in proportion to the body or weight of iron, is exposed to the action of the elements. For this reason scrap should be kept upon a dry floor under cover and not be permitted to lay upon the ground in the foundry yard, and it should be melted as soon as possible after being received at the foundry. Small iron more especially should not be permitted to rust, for the latter not only diminishes the quantity of this iron, but also the quality, for when melted with a heavy coating of rust upon it, its characteristics are changed to so great an extent that it does not mix with the same grade of iron from which it was cast to make a homogeneous metal. The quality of this iron is not at all improved by running into pigs and remelting.

Oxidation of iron by heat differs from that by rust in the entire body of iron being deteriorated or destroyed without a decrease in size or an indication in the fresh fracture of the change that has been effected. This oxidation is caused by a prolonged heat, or repeated heating and cooling, as well as by the action of the atmosphere and products of combustion upon the iron, and may take place when the iron is enclosed in a furnace, as, for instance, as retorts, or heated in the open air as grate bars. In either case the oxidation of the iron is complete if the heating is sufficiently prolonged. This form of oxidation cannot be removed the same as rust so that a good quality of iron is still left, but the iron has to be melted in combination with its oxide. The effect of the oxide is to destroy the strength and softness of the iron, the latter when separated from it by melting being always hard and brittle. The extent to which the strength and softness of the iron are affected varies with the extent to which it has been oxidized, as does also its action when melted. A very badly burned iron when melted in a cupola produces a very fluid slag which flows from the tap hole like iron and in combination with the iron the oxide contained. As the slag cools the excess of iron it is not able to hold, the latter separates and sinks to the bottom, and the more slowly the slag is cooled the greater the per cent. of iron recovered from it will be. The greater the per cent. of iron the burned iron contains the more readily it will separate from the slag, and when not too badly burned may separate from it in the cupola or be skimmed from the ladle, the slag retaining but a very small per cent. of iron, and the iron cannot be poured into castings if the oxide is in excess. That an iron has been oxidized by heat is not always indicated in the fresh fracture. In fact, the latter almost invariably indicates a fine grade of soft iron; nor is the outward appearance always an evidence of oxidation by heat, and it is frequently only by the shape of the casting, or a knowledge of the use to which it has been put, that an iron oxidized by heat can be detected. Oxidized iron when remelted always produces a harder and weaker iron than that from which it was cast, and in extreme cases of oxidation a very hard, brittle iron that does not mix readily with others so as to make a homogeneous metal. Such iron should not be mixed with others for soft castings, and it is only fit for an inferior grade of castings even when but slightly oxidized, and for weights when badly oxidized.

Sandwiched Hard Spots.—The writer first met with this iron at Albany, N. Y., in 1876. At that time the stove foundries in that city and vicinity were melting Lehigh Valley irons, which for a long time had been their leading stock and given good satisfaction in their plate. However, without any change whatever in fracture indications or general appearance, the iron, although still soft and strong, began to run hard in spots. Upon investigation he found that the hard spots were not those of ordinary hard iron, extending through the casting, but that the hard iron was inside of the soft iron with a well-defined line between the two. In very light plate the hard iron was found in a thin plate between two thicker plates of soft iron on the outside, and he gave it the name of sandwiched iron from the hard iron lying between the plates of soft iron without being in any way combined with them. In the lugs and thicker parts of the casting it was sometimes found in small globules or oblong pieces the shape of the casting. This was the form it took in door lugs and hinges, where it was found in drilling, but never in all the lugs upon the same casting. This indicated that it was not distributed throughout the iron, but appeared to float in the molten iron in small globules, which were carried into the mould with the iron and left where they chanced to be when the latter set. When the iron flowed into light plate these globules were carried into it and spread out in a thin plate, and when it ran into lugs they retained their globular shape to a greater extent, but never united with the soft iron by extending fibers into it; they frequently dropped out of the soft iron when it was broken. These spots appeared when only pig and remelt scrap were melted and none of the scrap was rusted.

A curious feature was that the hard spots were more numerous when all No. 1 pig was melted and entirely disappeared when all No. 2 pig of the same brands was melted. These spots were afterwards traced by the furnacemen to a New Jersey ore they were using in their mixture to make a cheap iron, and when this ore was left out of their mixture the spots entirely disappeared from the iron. Chemists were not then employed by blast furnacemen, and the writer is not aware that the element or metalloid in the ore that caused the hard spots has ever been determined, but they were probably due to a small per cent. of titanium. Since that time he has frequently met with these spots in castings, but has never been able to trace them to the pig melted, although in some cases the fresh fracture of the pig was badly spotted with patches of very small light-colored crystals indicating a harder iron than the main body. These spots never appeared in the castings as a separate iron, and either disappeared when the iron was melted or appeared throughout the castings as a harder iron, or as hard spots extending through the casting and connected by fibres to the softer iron. In other cases where they were found they were traced to scrap melted with the pig, and the writer has produced spots in stove plate exactly like those found at Albany, by melting badly burned iron with soft stove-plate pig, and has also produced them by melting badly rusted shot-iron with this pig. Attempts made to produce them with wrought iron and steel scrap failed, these metals hardening the iron throughout or appearing in hard spots combined with the soft iron. Sandwiched spots are never found when a close or hard iron is melted with burned iron or rusted shot, but they appear when it is melted with a high-carbon soft iron, and they are probably due to the failure of the oxidized iron of the burned and rusted shot to mix with this iron.

Sandwiched hard spots differ from other hard spots in being separate and distinct from the soft iron in which they are enclosed, while in other hard spots the hard and soft iron blend together and may be due to uneven pig, wrought iron, steel, or other scrap in the mixture that does not mix well with the pig or other irons with which they are melted. They may also be due to wet sand, uneven and hard ramming, chill, etc.

Sash Weight Metal.—The only properties required in sash weights are weight and sufficient strength to stand shipment and handling. They may be cast as over iron at the last of a heat or from any old scrap thrown into the cupola at the latter end of a heat as is frequently done. But in regular sash weight foundries, they are cast from any old metal that can be purchased at a low price, such as blast furnace scrap, pig that has been condemned for any other casting, old cast-scrap, burned iron, shot iron, malleable scrap, wrought scrap, steel scrap, tin scrap, steel wire, sheet iron, tin cans, gas pipe, galvanized iron, tin roofing, horse shoes, and, in fact, any old metal that is of little or no use for anything else. These metals are mixed so as not to get a sufficient quantity of any one kind that is more difficult to melt than another in one place or charge and clog the cupola, and a little cast iron, if at hand, is distributed through the heat. This melts more rapidly than the other metals, tends to keep the cupola working more open and free, and also to give life to the other metals when melted. This metal sets very rapidly after being drawn from the cupola and therefore requires to be melted very hot, and handled very quickly to run the weights. It is the practice to use large gates and runners, or construct a basin, and dump the metal right in so that the mold may be filled as quickly as possible.

This metal may be melted in any ordinary cupola and is sometimes melted after the regular heat of cast-iron has been melted without any bad effect upon the iron in this or the following heat. But as the metal is very hard, separate ladles should be used for it or the ladles newly daubed throughout for every heat to prevent small particles of iron from adhering to the ladle and hardening the soft iron. An extra amount of fuel is required to melt this metal hot, and the average melting is about three pounds of metal to one of fuel. To increase the fuel the weight of the charges of it should be permitted to remain the same as for cast iron, and the weight of the metal in each charge be decreased until a hot metal is secured.

Sash weight metal of this kind is neither a cast iron, wrought iron, or steel, but a mixture of all of them, and a product that is very hard and brittle and inferior to any one of the metals in the mixture from which it is cast.

Temper in Cast Iron.—The melting and casting of iron impart to the casting or iron when cold a certain degree of elasticity which may be called temper, but the drawing of this temper by heating after the casting has become cold reduces the elasticity of the iron and renders it more rigid and readily broken. This may be illustrated by the light oven plates of cooking stoves, ranges, etc. When new these plates, if warped or twisted, are readily sprung into place by the mounter, but after they have been heated to the degree required for baking in the oven, which is not even a dull red heat, become rigid and devoid of elasticity. This is the case with all soft cast iron, and the higher the temperature of the iron when cast and the more rapidly it sets in the mold up to a certain point, the higher the temper and greater the elasticity, as may be seen in the deflection of test bars. But the reverse is the case with a hard or chilled iron in which elasticity is increased by annealing. This temper exists in all soft cast iron, but is more apparent in a charcoal iron than in a coke iron, and in a close or fine-grained iron than in an open one. For many lines of castings, temper in iron is of no consequence whatever, but for others it is of great importance, and the drawing of it by heating or annealing renders the casting useless for the purpose for which it is designed. This is the case in all castings requiring a certain amount of elasticity or spring, such as that required in steam cylinder packing rings. To draw the temper from cast iron does not require a high or prolonged heat, as in annealing to soften or remove shrinkage strain, but it may be drawn by heating in turning up a light casting in a lathe with a high speed tool steel, or a dull low speed tool. This has been repeatedly shown to be the case in turning up cylinders from which small light automobile packing rings were to be cut. In this case the rings cut from the end of the cylinder, at which the sharp tool was started, had the desired elasticity and spring, while those from the other end, which had become heated by a high speed or dull tool, possessed no spring whatever, and were perfectly useless as packing rings. When the temper in cast iron has once been drawn, it cannot be returned to it by any known process, except that of remelting and casting, for it is imparted to the iron by the formation of the crystalline structure when it sets and cools. The heating of it changes the formation of the crystals to the extent of removing the strain upon them, that gives to the iron the desired temper or spring.

Automobile Cylinder Packing Rings.—One of the most difficult irons to produce is a satisfactory one for automobile cylinder packing rings, and probably more experimenting has been done in the production of this iron than in that for any other casting made in recent years. These rings are very light and require a certain amount of spring that is difficult to procure in turned and finished cast iron. Probably every brand of iron in this country known to possess peculiar characteristics has been tried, and irons have been imported from other countries for these castings with no better results than with the home product. Besides the various irons possessing distinct characteristics and mixtures of them, all the known elements in metal that give to iron elasticity and spring have been added to molten iron in the ladle in endeavors to obtain a satisfactory ring. One of the most expensive of these elements or metals to be tried was vanadium. This metal has been added to iron to the extent of the cost of forty dollars per ton of iron with very satisfactory results in the ring obtained from this alloy, but with no more certainty of results than from mixtures of iron without the vanadium, for it has been found that only under certain undetermined conditions does vanadium enter into combination with cast-iron to give to it this desired characteristic. The work done in this direction has therefore been largely experimental, and I am not aware that this metal or alloy has been adopted by any of the automobile foundries for these rings. The metal generally used for them is a mixture of strong Lake Superior iron, ten to twenty per cent. steel, and in some cases, ten to twenty per cent. charcoal iron. This mixture, which is the same as that made for the cylinders, gives, when containing the proper amount of silicon and carbon to insure its being soft, the required amount of elasticity and strength for the rings, provided the temper is not drawn from the casting by heating in turning and finishing.

CHAPTER VII.

FOUNDRY CHEMISTRY.

Historical Data—There appears to be no record of the first introduction of foundry chemistry, which is probably due to the fact that the first attempts in this direction were experimental and more or less of a failure. But the writer knows of these attempts having been made as early as 1877, the first work in this line having been done by car-wheel foundries with a view of getting a more satisfactory chill on their wheels. In 1878, Doctor Dudley, the chemist of the Pennsylvania Railroad Company, took up the subject and made a number of analyses of the pig used in the car-wheel foundry of the railroad in Altoona, Pa., as well as of the car wheels made therefrom.

For some time prior to this date, cold-blast charcoal iron, from which car wheels had long been made, was becoming scarce, and a mixture of anthracite and coke irons with steel had been substituted for it for car wheels at many of the car-wheel plants. The employment of chemists was for the purpose of determining the suitability of this mixture for wheels, and also the per cent. of steel that should be used with various brands and grades of pig. For this work, chemists who had had some experience in steel works were generally employed. In 1879 some of the larger foundries fitted up laboratories for general foundry work, and employed chemists who had been engaged in blast furnace work, so that the chemistry of foundry irons may be said to date from this year, and to have now been practiced about 31 years. From 1879 on, progress was so slow that it was not until 1882 that the prediction was made in print that the time was coming when pig iron would be sold by chemical analysis instead of by fracture, the method in vogue at that time, and it was not until 1890 that this prediction was realized, and not until 1895 that chemists were to any great extent employed by foundrymen. About 1900, the American and various local foundrymen's associations took up the matter and every facility was afforded to chemists to make foundry chemistry a success. That the results obtained from these opportunities afforded have been a disappointment to the founder is undisputed, for castings made from anthracite and coke-smelted irons possess no greater transverse or tensile strength than those made from them before chemistry was introduced, and work is cast with no more certainty, as to hardness, softness, or strength of castings than was formerly done by fracture indications, or may be done at the present time from blast furnace analysis, furnished with each car of iron from the furnace, or from fracture indications. While the car-wheel founder may have derived some benefit from chemistry in making mixtures of steel and cast iron for car wheels, the soft-iron foundry may be said to have gained nothing. The blast furnace chemist by analysis of ores before smelting them has been able to predict the quality of iron these ores will produce when mixed and smelted in certain proportions with the furnace working in its normal condition, and by analysis of fuel and fluxes has been able to produce this condition in a furnace to a far greater extent than formerly. The steel chemist has been able to produce from coal- and coke-smelted irons a steel equal to that obtained from charcoal-smelted iron, and for many purposes one superior to it. But the foundry chemist has not been able to produce from these irons one having the well-known and desirable characteristics of a hot-blast charcoal iron for light soft castings, nor one having the strength and desirable characteristics of a cold-blast charcoal iron for cylinders, etc., or one having the strength and chilling properties of this iron for car wheels. Thus the chemistry of foundry irons would be of little interest to the founder were it not that blast-furnace chemistry has made such progress that foundry irons are generally sold by analysis and foundry mixtures are to a greater or less extent made by these analyses in almost every foundry. New discoveries of metalloids and their effect upon cast iron are being from time to time made, and the chemist may yet develop a means of improving the quality of foundry irons.

The Metalloid Theory.—The chemistry of foundry iron when first introduced, and up to the present time, is based upon a knowledge of the per cent. of the various metalloids cast iron may contain, and the ways or formulas for mixing iron containing a known per cent. of various metalloids to produce a desired quantity of iron for work to be cast. This theory, while it may be correct, has not yet been carried far enough to prove it so or to be of any great advantage to the founder. If the metalloid theory is correct, it is no doubt due to the fact that all the metalloids that may be contained in a cast iron are not yet known and their effect upon the iron and upon each other, when melted together in mixtures of the various brands and grades of cast iron, has not yet been determined, and probably for this reason, all the theories of the effect of the known metalloids upon cast iron have been contradicted in actual practice. Many metalloids have been analyzed for and found in cast iron, but only five of them have been deemed of sufficient importance to be considered in formulating a standard analysis for the sale of foundry irons. These are: Silicon, carbon, manganese, phosphorus and sulphur. Silicon is said to be a softener and controller of carbon in iron, and to increase the free carbon and its softening effect; manganese to have a hardening and strengthening effect; phosphorous to give fluidity; and sulphur to be a deteriorator in all irons. A mixture of coke irons for stove plate requires from 2.50 to 3.00 per cent. silicon to produce a soft plate, yet a softer and stronger plate can be made from hot blast charcoal iron containing only 1.50 per cent. silicon, and a cold blast charcoal iron is well known to be a superior metal as regards strength to a coke iron containing a less, equal, or greater per cent. of silicon, which would seem to indicate that carbon, and not silicon, is the true softener and also strengthener of cast iron.

Irons are generally considered to lose from 0.25 to 1.00 per cent. of their silicon depending upon the per cent. of it they may contain, when melted in a cupola, yet it has been proved by numerous tests that the silicon actually increased in iron when melted in this way. Manganese, which is claimed by chemists to have a hardening and strengthening effect upon cast iron, and is extensively employed by car wheel foundries to harden their car wheel mixtures and increase depth of chill, is also used by soft iron founders in ladles and cupolas to produce an exactly opposite effect, *i. e.*, for softening and strengthening their iron. The fluidity-giving property of phosphorus is in charcoal iron almost entirely replaced by carbon, as very little of this element is found in it, and it may be run into the lightest of castings. Sulphur which in any proportion is generally considered to have an injurious effect upon iron has been used and desired in mixtures to as high as one per cent. in the castings.

The writer's attention was recently called to a mixture made by a practical foundry chemist in charge of a foundry in which all these five important elements were determined and a mixture made by analysis for soft castings, but all of them were found to be too hard to be machined. An investigation showed that a new brand of iron placed in the mixture contained titanium in sufficient quantities to harden the entire mixture. It may thus readily be seen that the results indicated by analysis may be entirely destroyed by the presence of known metalloids not analyzed for, or by metalloids, the presence and effect of which have not yet been determined as in the case of high sulphur producing a desirable casting. That the metalloid theory has not yet been developed to a sufficient extent to give a certainty in resultant mixtures of various brands and grades of iron is very evident from the many failures to produce iron of a desired quality from mixtures by analysis alone. Whether this can be done with certainty and at such a cost, which must necessarily be greater than at present, as will warrant the founder in adopting chemistry as his sole guide, has yet to be shown. The low silicon and greater transverse and tensile strengths in hot and cold blast charcoal irons as compared with coke irons, is undoubtedly due to the different form carbon has assumed in the charcoal iron, while the reverse effect of manganese in car wheel and soft mixtures is probably caused by the presence of charcoal iron and steel in the car wheel mixtures and change of the form of carbon in the mixture by these metals.

Can the metalloid theory effect this change in the carbon of an iron either in the blast furnace or cupola and increase the strength and other desired qualities in a cast iron? It has not yet succeeded in doing so, and at the present time gives no indication of being able to raise the standard of cast iron above that which it had reached before the introduction of blast furnace or foundry chemistry. With our present knowledge of metalloids the limit appears to have been reached on the metalloid theory, and before any improvement can be made with a certainty of results in the quality of cast iron or even in that of the various brands and grades mixed, more metalloids must be sought for and their effect upon the iron accurately determined. If this cannot be done then resort must be had to the furnace, as in the manufacture of steel, before the standard of cast iron can be raised or it can be cast with a certainty of quality desired.

Furnaces.—In making mixtures upon the metalloid theory, the cupola furnace should answer the purpose equally as well as the blast furnace in producing iron of the desired quality when smelted with its ores, for this furnace melts iron rapidly and does not remove from or place metalloids in the iron when melted with a proper fuel within the melting zone. If it is only a question of manipulation of metalloids to obtain an iron of the desired quality probably no better furnace could be designed then the cupola, and if the theory is correct the desired results will be obtained from this furnace when the effects of various metalloids are more fully understood, so that the failure to obtain results indicated by analysis cannot be attributed to cupola melting. But if metalloids are to be added to, or taken from, the iron, this furnace is not at all suitable, for the iron melts so quickly, and when melted drops to the bottom so rapidly, that it cannot be changed during this process. After melting, the metal in the bottom of the furnace is so inaccessible for any treatment whatever in a molten state that mettalloids can neither be added to nor taken from it. The only means suggested for effecting the change in the quality of iron in this furnace is by charging the blast with various chemicals or elements. This has been repeatedly tried, but the volume of blast required to melt iron in a cupola is so great that it is impossible to charge it to a sufficient extent to effect a change in the iron, and in every instance where this has been tried it has proved a failure and been abandoned. Another means suggested for improving the quality of iron by adding to or taking from it metalloids is the use of the tank or reservoir cupola. This has also been tried; but before the desired change can be effected the molten iron becomes too dull to run the work and no means have as yet been devised of keeping it hot or superheating it in the reservoir. So that if a change in the quality of an iron is to be effected during the process of melting, or while the iron is in a molten state, an entirely new furnace must be designed that will admit of these changes being accomplished at a moderate cost.

Steel Furnaces.—In the manufacture of steel and steel castings a number of furnaces and converters of different designs are used in which metalloids may be removed from the iron, and replaced by others to produce the quality of steel desired. Some of these furnaces have been tried by founders for improving the quality of iron, but in every instance that has come under the writer's notice, the foundry has either drifted into a steel foundry, or the furnace been abandoned as not practical, or too expensive for cast iron, so that nothing has yet been accomplished in this direction in the way of improving the quality of foundry iron. That ordinary cast iron is superior to steel for many purposes, is shown by the well-known fact that cast iron pipe lasts much longer under ground than steel pipe, that steel street railway crossings and turnouts have to be braced with cast iron to make them lasting, and that cast iron columns and plates are now being used for foundations and basement work in steel structural building, where dampness may exist, etc. A superior quality of cast iron would extend the usefulness of this material to many purposes for which steel is now employed, and even at an increased cost, prove better and cheaper in the long run. With a suitable furnace such an iron could no doubt be produced by removing certain metalloids and replacing them with others, as is done with steel, only to a less extent and at a less cost. Until such a furnace is designed and a process discovered for improving cast iron at a moderate cost upon a system similar to that by which steel is made, there is little prospect of a radical improvement in foundry iron.

CHAPTER VIII.

ELEMENTS AND METALLOIDS.

Silicon.—This is a non-metallic infusible substance which forms the basis of silica, of which quartz is an example. It is, next to oxygen, the most abundant element in the solid part of the earth's crust, but it does not exist in a free or separate state in nature and, although so abundant, the process of obtaining it pure is too expensive to admit of its being used in the arts and it is only seen as a rare curiosity in the laboratory or museum. Silicon is contained in all iron ores, and in the ashes of all fuels as an oxide of silica. Therefore more or less of it is found in all cast iron and may be alloyed with it up to 20 per cent. in the smelting of ores in a blast furnace and up to 95 per cent., it is claimed, in electric and other special furnaces. Iron alloyed with it to an excess loses its characteristics as such and the alloy may be crushed and ground to a powder and presents more the characteristics of quartz than of cast iron. The presence of a small proportion of silicon impairs the strength of cast iron and that of large proportions renders it so brittle that even pig iron has to be handled with care to avoid breaking, as exemplified in what is known as silvery and silver-gray pig. It is claimed that with the increase or decrease of the per cent. of silicon in cast iron, the free or combined carbon increases or decreases, and the presence of silicon is necessary if the iron is to be used for ordinary casting purposes as these two elements give it its fluidity and without them it could not be cast. This theory is correct only up to a certain point. A white-hard iron contains only from one-half to one per cent. of silicon, sets very quickly in a ladle, and it is only when it is very hot that it can be poured from the ladle to leave a clean skull.

With an increase of silicon in an iron the free carbon or graphite increases and with up to from 3 to 4 per cent. silicon, molten iron becomes more fluid and holds its life longer. After this point is reached the fluidity of the iron and also its strength decrease as silicon is increased, and a 10 per cent. silicon iron does not hold its life any longer than with one-half to one per cent. and can only be run into castings when very hot. So that this theory is only correct up to a certain point, and this point should not be exceeded in castings when making mixtures. Silicon is so unevenly distributed in pig iron that it is almost impossible to obtain exactly the same analysis from different parts of the same pig or cast of pig, and it is only by making a number of determinations and taking the average that the per cent. of silicon the iron may contain can approximately be determined. By this method anthracite and coke foundry pigs have been found to contain about the following per cent. of silicon in the various grades:

No. 5 White Iron, 0.50 per cent.
No. 4 White Iron, 1.00 per cent.
No. 3 Mottled Iron, 1.50 per cent.
No. 2 Plain Iron, 2.25 per cent.
No. 1 Plain Iron, 2.50 per cent.
No. 2 X Iron, 3.00 per cent.
No. 1 X Iron, 3.50 per cent.
Silvery Pig Iron, 4 to 6 per cent.
Ferro-Silicon Iron, 6 to 10 per cent.

In making mixtures of these irons by analysis, the founder should aim to get about the following per cent. of silicon in his irons for the various grades of castings: Heavy machinery castings requiring to be strong and dense, 0.50 to 1 per cent.; light machinery castings 2 to 2.50 per cent.; stove plate, bench work, etc., 2.50 to 3 per cent. This represents the amount of silicon in castings that has been found by actual test best suited for the various grades. In making mixtures to obtain these results, an allowance of one-quarter of one per cent. in the low silicon irons to one-half of one per cent. in the high silicon irons should be made for loss of silicon in melting. The two or three grades of iron containing nearest the amount of silicon desired in a casting should be used in the mixture, for this gives a more even quality of iron in the castings than the melting together of the extremely high and low silicon irons to obtain the desired per cent. of silicon.

Charcoal Pig.—The following table shows the average per cent. of silicon found in the various grades of charcoal pig, which is much lower than in the same grades of anthracite and coke pigs, and the iron is correspondingly cleaner and stronger.

No. 5 White Iron, 0.22 per cent.
No. 4 Mottled Iron, 0.35 per cent.
No. 3 Close Iron, 0.55 per cent.
No. 2 Soft Iron, 0.95 per cent.
No. 1 Soft Iron, 1.95 per cent.

These irons are graded up as far as No. 8; the silicon in the the higher grades varies from a mere trace to 0.20 per cent., and the iron is very hard, solid, and strong, while the very low anthracite and coke silicon irons are frequently honey-combed, hard, and brittle, and only fit to be put back into the furnace to have their silicon increased.

The higher grades of charcoal irons are used in mixtures for car wheels, chilled plows, and other chilled castings to give the desired depth of chill and strength to the castings, in mixtures with scrap and coke irons, and also for malleable castings to give the desired quality of iron and per cent. of silicon for annealing. In making mixtures for heavy machinery castings Nos. 3 and 4 irons are used; for light machinery castings Nos. 2 and 3, and for stove plate, bench work, and light castings, Nos. 1 and 2. But these irons are so scarce at the present time that they are seldom used by themselves for anything but special castings and are generally mixed with anthracite and coke irons to give strength or chilling properties to them. In such case special mixtures are made with local brands of pig or scrap that have been found by actual test to give the desired quality of iron in the castings, and as the per cent. of silicon varies with the purpose for which the castings are designed no special amount of silicon or mixture of irons can be given.

Silicon Lost in Melting.—When pig iron is melted in a cupola it becomes a harder iron even when cast into pigs of the original size, and every time it is remelted it becomes still harder, this hardening being due to the burning-out of silicon and graphite carbon, and the combining of carbon with the iron. The per cent. of silicon lost or removed from the iron each time it is melted varies with the per cent. of silicon the iron may contain before melting. This loss has been found by actual test in cupola practice to vary from one-fourth of one per cent. in a one per-cent. silicon pig to one per cent. in a six per-cent. silicon pig, when the iron is properly melted within the melting zone. But this loss may be greatly increased by improper melting, and the writer has known of as high as one and a-half per cent. of silicon being lost from a three and a-half per-cent. silicon iron in the process of melting. This heavy loss was occasioned by the use of too large a quantity of fuel, and by the iron being held upon the upper edge of the melting zone at a temperature just below the melting point until the excess of fuel was burned away to a sufficient extent to permit the iron to come within the melting zone and be melted. The iron when melted came down slow and hot, but did not hold its life very long, and was too hard for the work to be cast, although the mixture charged should have produced a very soft iron. Analysis showed a loss of one and a-half per cent. of silicon and a corresponding loss of graphite carbon. This same mixture, when properly melted with less fuel, produced an iron too soft for the work, and scrap had to be added to take up the excess of silicon in the pig. The average loss of silicon in melting a three per-cent. silicon pig together with the daily remelt from the foundry or with old scrap when the remelt is not heavy, has been estimated to be from one-half to one per cent. The common practice is to determine the per cent. of silicon which will give the desired degree of hardness or softness in the casting, and make a mixture that will give this amount after allowing one-half of one per cent. for loss in melting. With the low-silicon pig one-fourth of one per cent. is allowed. Very high-silicon pig is so seldom melted by itself, or with its own remelt scrap, that no accurate determination has been made of the loss of silicon in melting, but it has been estimated to be from one to three per cent. In melting this iron as a softener, with promiscuous old scrap, so little can be determined as to the per cent. of silicon in the scrap that no estimate can be made of the loss of silicon, and as regards the per cent. of high-silicon pig he should use in his mixture the founder must be guided by results as indicated in his castings.

Silicon as a Flux.—Silicon acts as a flux upon cast iron when absorbed by it and well distributed in it up to about 3.50 per cent.; a little beyond this point it begins to make molten iron look thick and mushy, although it frequently flows more fluid than its appearance would indicate to the experienced founder. But as the silicon increases, the fluidity of the iron decreases and a very high silicon iron has no more life than a white iron, and only when very hot can it be run into light castings. Numerous attempts have been made to use silicon in its native forms as a cupola flux and softener, but it has not been found practicable to have the iron take up silicon in a cupola from fluxes and fuel as is done in blast furnace practice. In numerous experiments made in this direction by the writer no practical results were obtained although the charges of fuel and iron were varied to correspond as nearly as possible to the increased and decreased burden in furnace practice, and the volume of blast was also varied. In these experiments some little increase was effected in the silicon and a softer and more fluid iron was produced, but as the same results could, at a less expense, be obtained by melting the low silicon iron used in the experiments with a higher silicon iron, the process used was not practical. Ferro-silicon has to a considerable extent been tried as a cupola flux and softener, but this also has proved a failure, owing to the fact that the iron did not absorb a sufficient quantity of silicon to justify the expense of the ferro-silicon. Up to the present time the only silicon found practicable to use as a cupola flux, is that in combination with the carbonates of lime, such as limestone, shells, etc., and these are of more benefit in keeping the cupola working open and free in long heats than in improving the quality of iron.

Ferro-silicon as a Softener in Ladles.—Ferro-silicon has been recommended for use in ladles as a softener of iron and quite extensively sold for this purpose. When first introduced it was in the shape of small lumps or gravel, but it was slow to melt, and before it was melted and absorbed by the iron the latter frequently became too dull for pouring. To overcome this difficulty, the ferro-silicon was ground to a course powder. In this shape it was more rapidly melted and the silicon taken up by the iron, but it still required considerable time and heat from the iron to melt it. It has been found that only a limited amount of silicon can in this way be added to iron before the iron becomes too dull for pouring, or assimilates the silicon to give an even, sound casting. But with very hot iron and a good-sized ladle of it, a sufficient amount of silicon has by the use of ferro-silicon been placed in it to soften it to a considerable extent, but not sufficiently so for making.a soft iron out of a white hard iron. Of course no founder desires to depend upon this method of obtaining a soft iron for his entire heat, but when a few castings are to be made that require to be softer than the iron of the regular heat, this method of softening answers very well, and many founders keep ferro-silicon on hand for this purpose. The quantity of ferro-silicon that gives the best results in a ladle is a matter that has probably never been determined, and while one manufacturer of the material claims that a 50 per cent. ferro-silicon gives the best results, another claims a 90 per cent. ferro-silicon to be the best for this purpose. The per cent. of the silicon that may be taken up by the iron from either of these ferro-silicons depends first upon the heat of the iron in the ladle, for a hot iron will absorb more than a dull iron, and secondly upon the tendency of the iron to absorb silicon, so that no definite amount can be stated.

Carbon in Iron.—Carbon is an element of great importance and very extensively diffused in nature. It exists in large quantities in the mineral kingdom and is the most abundant constituent of animal and vegetable matter. In the crystallized state it constitutes the diamond and, more or less pure, it forms the substances called plumbago, graphite, blacklead, anthracite and bituminous coal, coke, animal and vegetable charcoal.

Carbon is the most important element in cast iron; without it iron could not be cast into desired shapes nor the degree of softness, hardness and strength required for various castings be given to them. Other elements, such as silicon, sulphur, etc., destroy to a greater or less extent the effect of carbon upon iron, and for this reason we do not find in coke-smelted cast iron, which has taken up these elements from the fuel, the same desirable characteristics as in charcoal-smelted iron, which is more free from them. In the manufacture of steel from coal- and coke-smelted irons it is the aim of the manufacturer first to remove from them all the non-metallic elements and metalloids they may contain, and make the iron as nearly pure as possible. After this has been done, carbon is added to the iron to convert it into steel, and in quantities to give the latter the desired degree of hardness or softness for rolling, forging and tempering. Other metals are sometimes added to the steel to give it certain characteristics, but carbon constitutes the real steelmaker. With the well-known effect of carbon upon iron in the manufacture of steel, it is surprising that the chemistry of foundry irons should ever have been introduced upon the silicon basis with silicon as the true softener and the element to which all other elements in cast iron must be subservient. This was probably due to the researches of Prof. Turner, published in the year 1885, showing that the addition of silicon to a specially named white iron would change it to a gray iron, and that by varying the per cent. of it the softness and grayness could be controlled at will. But the professor's researches failed to show the now well-known fact that silicon is a delutant in cast iron, and while it renders it softer and more fluid, up to a certain point, it also impairs its strength and other desirable qualities to such an extent that a 6 per-cent. silicon iron is not fit for casting, and a 75 per cent. silicon iron, from which all the carbon has been removed by the silicon, presents no more of the characteristics of cast iron than a piece of rock.

Our supply of iron is derived from ore, which is an oxide of iron and only in rare instances contains carbon to any great extent. In the process of smelting in a blast-furnace oxygen is removed from the ore, and the iron it contains is left in the form of a sponge exposing a very large surface, which is acted upon by the gases of the furnace from which at a high temperature carbon is absorbed into the iron before melting. Pure iron cannot be melted by the heat of a blast furnace, but by the absorption of carbon, its melting point is to so great an extent lowered that melting is readily effected, and thus carbon is the principal agent for imparting to the iron fluidity and life as a molten metal, and the greater the amount of it is absorbed the more fluid the iron will become when melted, and the longer-lived it will be. The amount of carbon iron may absorb in smelting depends upon the condition of the furnace during the smelting process. The greater the heat, the more carbon will be absorbed, and the grade of iron is controlled by varying the charges of fuel and ore to make the furnace work hot or cold; a hot furnace produces a soft foundry iron, and a cold furnace a white iron. Carbon when absorbed into the cast iron enters into combination with it up to the point of saturation which, in a charcoal-smelted iron, is about 4 per cent. and in an anthracite and coke iron 3.50 to 3.75 per cent. When iron absorbs more carbon in the furnace than it can contain, the excess is burned out upon exposure of the molten iron to the atmosphere, and a black smoke is thrown off. It is also thrown out as kish during the solidification of the iron, but this only occurs when a foreign element like silicon is present. When in a molten state, all the carbon an iron may contain is in combination with it; should it contain more carbon than it can hold in a combined state when cold, the excess is thrown out during the change from a molten to a solid state and held between the crystals of iron in thin flakes called graphite carbon. A white iron represents the extreme amount of combined carbon cast iron can hold when cold. As carbon increases the structure of the iron changes, the crystals become larger and the appearance of the fresh fracture darker, until a No. 1 iron is reached with its large crystals and dark appearance, as compared with the very small crystals and white appearance of a white iron. But this appearance can be changed to some extent by the manner of cooling. A white iron cooled slowly, presents a larger crystal and darker color than the same iron cooled rapidly. This is due to the carbon separating from the iron to a greater extent than when cooled rapidly and assuming the graphite state. The reverse is the case with the soft iron, which may be made a white iron by running it against the chill and cooling it suddenly. In this case the carbon, which is always in combination with the molten iron, has not time to separate and assume the graphite form before the iron is too cold for it to do so. However, this sudden cooling only effects the iron near the chill and for this reason we find in our car wheels a hard tread where the iron has been run against a chill, and a soft web and hub where it has been cast in the sand and the iron permitted to cool slowly.

The hardness of cast iron by chilling being due to the carbon held in combination with the iron, the latter is not rendered permanently hard by sudden cooling, and the hardness may be removed by annealing at a sufficiently high temperature to permit the combined carbon to assume the graphite state and entirely disappear when the iron is remelted. Carbon is very evenly distributed in cast iron, the extreme variation in different parts of the same pig only being about 0.12 per cent., and it is only when the iron is suddenly cooled in a mold that hard spots in castings can be attributed to carbon. This may occur when the iron is run against a chill, wet sand, or hard rammed sand, which cools the iron so suddenly that the carbon has not time to assume the graphite state, but remains in combination.

Carbon, being lighter than iron, increases the bulk of the latter when combined with it and decreases its weight, whether present in the combined or graphite state. A cubic foot of pure iron weighs 489 lbs.; one of white cast iron 474 lbs.; one of mottled iron 458 lbs.; one of gray iron 450 lbs., and one of dark gray or No. 1 foundry 425 lbs., making the difference in weight of a cubic foot of pure iron and a cubic foot of No. 1 foundry iron 64 lbs., and that between a white iron which may be cast and a No. 1 soft iron 49 lbs. It will therefore readily be seen that a casting cast from white iron will be heavier than one from the same pattern with a No. 1 soft iron, and a corresponding difference in weight will be found between castings made from the different grades of foundry irons.

In my controversy with Thomas D. West on foundry chemistry in the Iron Trade Review, some years ago, and in a circular letter issued to the foundry trade about that time, and also in a paper read before the American Foundrymen's Association, May 29, 1900, I claimed that silicon was a foreign element in cast iron and a detriment to it in any proportion and should be eliminated to the fullest possible extent; that carbon was the real softener and hardener of cast iron as in steel and the controlling element. This theory was met by the statement of chemists that carbon did not control silicon, but silicon did control carbon, and therefore was the controlling element in cast iron. Notwithstanding this statement and its adoption by chemistry, I have during the past year met quite a number of foundry chemists who have adopted the carbon theory, and do not analyze for silicon, or they give but little attention to it, and make their mixtures for hardness and softness entirely by the total carbon. This system has given better results than the silicon theory and will probably soon be generally adopted. But this does not fully cover the theory advocated by me, for it does not eliminate silicon entirely from the iron, but only as a controlling element in making mixtures.

Kish in Foundry Irons.—Kish is the name given to a form of carbon which separates from cast iron when in a molten condition, and during the process of changing from a molten or liquid state to a solid. It is a soft, dark substance resembling blacklead in appearance, but analysis shows it to differ very materially from it. It is never seen in the foundry when only charcoal irons are melted, and it is only when very soft anthracite and coke irons are melted that it makes its appearance and then only in heavy castings that cool slowly. It separates from the iron when filling a mold and floats upon the surface and is sometimes found in thin layers or streaks on the top of castings or in sharp corners, where it has been washed by the molten iron when filling the mold. It is readily removed from the casting when cleaned, and gives to the surface a ragged or streaked, and to sharp corners a rounded, appearance. It is seldom seen in the better grades of American foundry irons when remelted, but is thrown out freely from some of the brands of English and Scotch pig, imported into this country, and foundrymen melting these irons are frequently annoyed with it. The formation of kish seems to be due to the presence of silicon in the iron, for it is only thrown out from high-silicon pig when remelted. The formation of it, when melting these irons for soft castings, can be prevented by increasing the per cent. of low-silicon pig, or the per cent. of scrap in the mixture to an extent that will absorb the excess of silicon in the resultant mixture and still give a soft iron. It can also be prevented by the addition of steel scrap to the mixture and a stronger casting thus be made. But when this scrap is used the iron should be melted very hot, tapped into a large ladle and thoroughly stirred to obtain an even iron in the casting. Even when this is done hard spots may be found if the castings are light, and better results are obtained from adding low silicon-pig, or cast iron scrap. Kish does not separate to so great an extent from irons when remelted, as when castings are made by the direct process from a blast furnace. When this is done, the iron is caught direct from the furnace in ladles, holding as high as 50 tons, and a large surface of molten metal is thus exposed to the atmosphere. From this surface kish separates and floats off in the air to such an extent that it may be gathered up by the handful in the casting house and everything in a foundry is covered with it as with dust. It also separates from the castings in the molds and floats to the surface. This separation of it occurs from irons containing as low as one and a-half to two per cent. silicon, while in the foundry it is seldom seen when melting iron with less than three to three and a-half per cent silicon. This is said to be due to the iron being softer when cast by the direct process than when remelted, but is probably also somewhat due to the large surface of molten iron exposed to the atmosphere in the ladle, as kish is not seen to so great an extent when the same grade of iron is run direct from the furnace into the pig bed of the casting house.

Manganese and Iron.—Metallic manganese was discovered by Scheele and Gahn, in 1774, and is obtained from the native black oxide or ore by intense ignition with charcoal. When pure, it is of a grayish-white color, brittle and very hard, being capable of cutting glass and scratching the hardest tempered steel. It is susceptible of the most perfect polish and is not altered even in moist air at ordinary temperatures. With oxygen it forms five compounds, three regular oxides and two acids.

It is found in combination with iron in iron ores and may be alloyed with it up to 40 per cent. in the blast furnace and to 90 per cent. in the electric furnace. When in combination up to 40 per cent. the iron is called "spiegel iron" (German for mirror iron), owing to the mirror-like appearance of the fresh fracture. When alloyed above the point of spiegel it is termed ferro-manganese and the fresh fracture loses its mirror-like appearance, is more granular, softer, and is often beautifully stained with rainbow colors due to superficial oxidation.

The effect of manganese upon cast iron is to increase combined carbon, to decrease silicon, and eliminate graphite carbon and sulphur. Its tendency is, therefore, to harden cast iron, although in quantities only sufficient to eliminate sulphur it has a softening effect. Beyond this point it forms a double carbide of iron and manganese which is very hard, and when diffused through the iron, hardens it. It is also claimed that manganese strengthens iron. This claim, like that of all other metalloids added to iron, is only true up to a certain point; and beyond this point, it has a weakening effect. With a low manganese and high sulphur iron, the effect of added manganese, either in the cupola or ladle, is a softening one due to the elimination of sulphur, but when this has been accomplished, any excess of manganese added has a hardening effect due to its tendency to increase combined carbon. If the iron is low in sulphur at the start, the first addition of manganese will harden it. It will thus readily be seen that such a fine line has to be drawn between the hardening and softening effects of manganese that this metalloid is not available as a softener, or as a preventative of sulphur being taken up by iron from coke in melting for soft work. The strengthening effect of manganese is also offset by its tendency to convert graphite into combined carbon and, when added to soft iron, to harden it when remelted, the only manganese available in iron for soft castings being that alloyed with it in the blast furnace in combination with other desirable elements. Greater claims are made for manganese as a hardener and strengthener than as a softener. These two properties are subject to well-defined lines for foundry irons, and it is only when in combination in certain proportions with other desirable elements that manganese gives either of them to the iron. When thrown out of these proportions by the addition of manganese when remelted, the effect of the latter is so varying that it cannot be depended upon to give the desired degree of hardness or strength. It is only when the per cent. of other elements is well known, and there is a deficiency of manganese in the alloy, that it can be added with any degree of certainty as to results. The presence of these elements may be learned from analysis or from practical experience, as in melting an even grade of scrap, such as old car wheels, and determining by depth of chill the per cent. of manganese that should be added. Up to a certain per cent., determined by the presence of other elements, manganese increases the depth of chill with the chilled fibres extending well into the softer iron. Beyond this per cent. the chill tends to separate with a well-defined line between the chilled and soft iron. Owing to these uncertainties many car-wheel founders refuse to add manganese or ferro-manganese to their mixtures, and it is only when a large per cent. of old wheels is melted in the mixture that it is used to any great extent. In these cases a manganese ore or ferro-manganese is generally melted with the iron in the cupola.

Manganese used in a ladle to add chilling properties to iron has been known to give with the same mixture of iron and quantity of manganese a perfectly satisfactory chill one heat, and no chill whatever the next one. This was attributed to the iron in the latter heat containing an excess of sulphur and the manganese entering into combination with the sulphur, for which it has a greater affinity than iron.

Manganese and Ferro-manganese in a Ladle.— Ferro-manganese has to some extent been used in ladles for softening, hardening and strengthening foundry iron. For these purposes it is ground to a coarse powder and the iron drawn upon it, or after the ladle is filled it is placed upon the iron and stirred into it. In either case, so great an amount of heat is required to melt it that only a limited amount of manganese can be added to the iron before it is too dull for pouring. To overcome this difficulty, manganese has been cast into slabs or bars and heated in a forge to almost the melting point just before placing it in the iron. This method has given better results than the other, but neither one is employed to any great extent, for it has been found that manganese gives better results in a cupola than in a ladle, and car-wheel founders, who are the greatest users of it, prefer to apply it in this way. In a ladle, manganese has been found to be very uncertain in action, and according to the characteristics of the iron may harden or soften it, or should the iron be high in sulphur, form the sulphite of manganese and have no effect upon the iron whatever, except to remove sulphur from it, and in this way soften it to a limited extent. Ferromanganese or manganese can hardly be considered a softener of foundry irons beyond removing the hardness due to sulphur in the iron, for all its tendencies are to harden or strengthen iron. And it is more readily taken up by an iron with a chilling tendency than by a very soft iron.

Phosphorus in Iron.—Phosphorus is a translucent, nearly colorless substance resembling wax, without taste, but having a peculiar smell. It was discovered in 1669 by Brandt, an alchemist of Hamburg. It is extremely inflammable and should be kept under water to protect it from light. When exposed to the air it emits white fumes which are luminous in the dark. It may be obtained in two varieties, the white and red. The white in its pure state does not unite with iron, but the red combines readily with it, as does also phosphoric acid, which is to a greater or less extent found in all iron ores. Phosphorus exists in iron as iron phosphide, which has a lower melting point than iron and therefore separates from the latter in cooling, forming a network between the iron crystals. Its effect in consequence of this separation is to weaken iron when cold, and the term cold short iron as applied to wrought iron, meaning an iron that is tough and strong when hot, but brittle when cold, is said to be due to the presence of phosphorus in the iron and its separation from it in cooling. As iron has an affinity for phosphorus and exists in combination with it in ores, it is to a greater or less extent found in all cast iron, and may be alloyed with it up to 20 per cent. in the blast furnace and to 30 per cent. in electric furnaces. But these high-phosphorus irons are of little interest to the iron founder, as they cannot be used to advantage either in the cupola or ladle. The effect of phosphorus upon iron, it is claimed, is to impart life and fluidity to it when in a molten state. Attempts have been made to prove this by adding various per cents of phosphorus to wrought iron, white iron and gray iron. From these experiments there appear to be some grounds for this claim, for in making them it was found that the life of the iron was prolonged by increasing the per cent. of phosphorus, as were also the fluidity and flowing properties, and it is generally conceded that an iron for light soft castings should contain from 1 to 2 per cent. of phosphorus. All our better brands of soft foundry iron contain about this per cent. Phosphorus has a hardening effect upon iron, but this has been found to be so slight in foundry irons that no special attention need be given to it by the founder, as no increase in depth of chill is caused by it. Phosphorus also has a weakening effect upon cast iron, but this weakening effect in foundry irons appears to vary with the presence of other elements and is not apparent to any great extent in iron containing up to 2 per cent. phosphorus. But beyond this point the strength decreases rapidly, and a 5 per-cent. phosphorus iron shows only about one-half the strength in a test-bar as one with 2 per cent. or less phosphorus.

Sulphur in Iron.—Sulphur is very generally disseminated throughout the mineral kingdom; native sulphur in almost a pure state is found in greater abundance in volcanic countries and is hence called volcanic sulphur. It enters into combination with certain metals as iron, lead, mercury, antimony, copper and zinc, forming compounds called sulphurets. Many of the iron ores contain sulphur, and also to some extent, all the mineral fuels with which ores are smelted, and therefore more or less of it is found in cast iron. The effects of sulphur on cast iron are to harden and weaken it, increase shrinkage and cause blowholes when cast. These effects vary to some extent with the two forms in which sulphur exists in the iron, namely, iron sulphide and manganese sulphide. Iron sulphide melts at a lower temperature than iron and is very fluid at the solidifying point of cast iron. It is claimed that the sulphur separates at this point, forming a gas, which, in its efforts to escape from the solidifying iron, forms blow-holes, and also that the low temperature at which it becomes solid causes it to separate from the iron when solidifying and to diffuse between the crystals, causing weakness and sometimes cracks in the iron. It also promotes the formation of iron carbide and hence has a hardening effect upon the iron. Manganese sulphide melts at a temperature nearer that of cast iron and does not separate to so great an extent, but forms little globules in the iron, which have a weakening, and also a hardening, effect. This would indicate that sulphur in either form is a detriment to foundry irons, and this is the general opinion of foundrymen, who always endeavor to obtain iron as free from it as possible, and also fuel free from it, so that it may not be taken up from the latter by the iron when melted.

The writer a few years ago had a curious experience with sulphur when investigating the cause of hard irons in a foundry in which only soft irons were melted, and hardness was only found in a limited number of castings. In making this investigation it was noticed that newly-lined ladles, although thoroughly dried and no boiling of iron occurred in them, when filled with iron the first and second time threw off a strong sulphuric odor and upon investigation the castings made from this iron were found to be harder than those cast after the ladles had been filled a number of times. A clay obtained from a near-by coal mine was used for lining ladles. In making an analysis of this clay by heating a flat iron bar to a red heat and sprinkling on it a thin layer of dry clay and heating, a strong sulphuric odor was thrown off, indicating that the clay was highly impregnated with sulphur. Sulphur taken up by the iron from this clay was undoubtedly the cause of the hard iron, for when the use of it for daubing ladles was discontinued and a loam clay used, the hardness in castings entirely disappeared.

Hardening Iron with Sulphur.—Sulphur has such a hardening effect upon cast iron that iron may to a considerable extent be hardened by adding sulphur to it in the ladles. This is frequently done by founders requiring a hard or chilling iron for a few small castings, when melting only soft iron. The sulphur is placed in the bottom of the ladle and iron tapped upon it, or it may be placed upon the iron and stirred in. This method of hardening gives a very satisfactory casting when it is only desired to increase the wearing properties of the iron, as in bearings, break shoes, etc., but has not given satisfaction in castings that are subject to strain or jar, as the iron is rendered brittle by the sulphur, and the castings hardened in this way are easily broken.

Oxygen in Iron.—Oxygen is an elementary substance universally diffused throughout nature, it being a constituent of atmospheric air, water, and most of the acids, and of all bodies of the animal and vegetable kingdoms, and essential to animal and vegetable life and to combustion. It is found in combination with all iron ores as an oxide and hence exists to a greater or less extent in all cast iron and is absorbed by it when exposed to the atmosphere, forming a scale upon the surface, which is called rust, and is an oxide of iron. The tendency of iron to absorb oxygen is to so great an extent increased by moisture in the atmosphere, and also by heat, that cast or pure iron heated to a high temperature in contact with oxygen for a comparatively short length of time, or repeatedly heated and cooled in the atmosphere, loses its characteristics as an iron, and is almost entirely converted into an oxide, as exemplified in old retorts, grate-bars, fire-plates, etc. We are dependent upon the oxygen in the atmosphere for a supply of it for rapid combustion of fuel in the smelting and melting of iron, and a great deal has recently been said and written about the effects of moist and dry atmosphere in these operations, and also about those of hot and cold blast. Hot blast has been used for many years to lessen the amount of fuel required for smelting and to increase the output of iron from blast furnaces, but it is only in recent years that an attempt has been made to remove moisture from the blast for these furnaces. This has been successfully done by passing the air through a cold-storage plant to freeze out the moisture before passing it through the blast heating ovens, and a saving of considerable fuel has been effected in the process of smelting. The saving of fuel resulting from drying the blast, although said to be considerable in a blast furnace, would hardly be sufficient in a cupola to justify a foundryman in putting in a cold-storage plant to dry the blast for a cupola that is only in blast two or three hours each day, or at the utmost eight hours, out of twenty-four, this probably being the longest average time it is in blast in ordinary foundry practice. The writer has not been able to learn of any radical improvement in foundry irons having been effected in a blast furnace by drying the blast. But even if such an improvement has been effected it is doubtful if similar results could be obtained when remelting iron in a cupola, because until the iron becomes heated the blast has no more effect upon it than the atmosphere in the foundry. Iron is not heated to any great extent in a cupola until it nears the melting zone. In a cupola melting nine tons per hour the iron would probably be put in in three-ton charges and each of these charges would be melted in 20 minutes. While the first charge is melting, the second charge of fuel and iron descends gradually into the heat zone and becomes heated. The third charge is so high up when the first one is melting that its fuel is not ignited and the iron is not heated to such an extent as to absorb the oxygen, so that in a rapidly melting cupola the extreme length of time the iron would be heated to a sufficient extent before melting to absorb oxygen from the blast would not exceed forty minutes, and probably not more than one-half that length of time. Thus the amount of oxygen the iron would absorb from the blast in this short length of time would probably not be sufficient to make the removal of a few atoms of moisture from the blast by freezing a matter of any importance to the founder in the melting of his irons. The only time blast has an oxidizing effect upon iron in melting in a cupola, that can be prevented by the founder, is when too great a quantity of fuel is used for a bed and in charging, and iron is for some time held on the upper edge of the melting zone at a heat near the melting point, while the extra fuel is being burned away to a sufficient extent to permit the iron to enter the melting zone and be melted. This can be prevented by carefully studying the working of a cupola and using only a proper amount of fuel. The effect of oxygen upon cast iron is to increase the combined carbon and therefore to harden it. The only means of preventing this in melting, within reach of the founder, is in the proper management of his cupola as just described. To prevent hardening by oxidized iron care should be taken to avoid using badly oxidized material, such as burned and badly rusted iron, in the mixture. The effect of these irons upon soft iron has already been explained under the head of oxidized irons.

Nitrogen in Iron.—Nitrogen is an important elementary principle forming about four-fifths of the atmospheric air. It is a colorless, odorless and tasteless gas. It is remarkable for its inertness compared with oxygen, hydrogen, and other elements.

Nitrogen exists in iron in the form of nitrates and is said to cause weakness and brittleness. These conclusions have been reached from the fact that elements or materials that tend to eliminate nitrogen from cast iron that has been added to it invariably increase the strength of it. But no way has yet been suggested for removing this element from iron in foundry practice, and until this is done the founder will have to get along with nitrogen as he finds it in his iron.

Hydrogen in Iron.—Hydrogen is an element and is the lightest ascertained substance. It is a gas, forming one of the constituents of water, and of inflammable air. It is colorless, inodorous and tasteless. It is inflammable, but will not support combustion. It does not appear to have any native place in iron and very little has been done in adding it to iron except in electrolysis, in which it is said to make electrolytic iron brittle to such an extent as to destroy its usefulness.

CHAPTER IX.

IRON AND OTHER METALS.

Titanium in Iron.—Titanium is an extremely infusible metal and so hard as to scratch not only glass, but also crystals. In color it resembles copper. It is found in combination with iron in iron ore and may be alloyed with it up to almost any desired per cent. Its effect upon cast iron is said to be to absorb or remove oxygen and nitrogen, and thereby increase fluidity, tensile and transverse strengths, and resistance to shock. But its tendency to harden is so great that 0.2 per cent. of it renders iron too hard for light soft castings, and it is of more interest to the car-wheel and roll founders than to the soft iron founder, except for cylinders and castings requiring a close, strong iron, for which iron containing a fraction of 1 per cent. of titanium, it is said, may be used. Titanium is said to greatly increase the wearing qualities in the chill of car wheels, and car wheels made from iron containing it have been run over 200,000 miles with a wear of less than one-eighth of an inch from the tread of the wheel. This would seem to indicate that titanium-iron may be destined to become the car-wheel metal of the future. It has also been used for heavy shafts of steam vessels with very satisfactory results, and may in the near future entirely replace steel-forged shafts for this purpose. Although there are large deposits of titanium-iron ore in this country and Canada, as well as in foreign countries, titanium pig iron has not yet been produced in sufficient quantities to place it regularly upon the market, and only such a small amount of it has for test purposes been made in specially constructed furnaces that its place as a foundry iron has not yet been fully determined. But this will no doubt be done before long, if it is found by those testing it to be better suited for any class of castings than the iron now being used or available for mixture with other foundry irons.

At the present time soft iron foundries shun it, for the reason that a very small per cent. of titanium in regular foundry iron has been found to have a decidedly hardening effect when the iron is remelted and run into castings.

Ferro-titanium is now manufactured and on sale for use in steel and foundry mixtures and the following claims are made for it by the manufacturers:

Ferro-titanium in lump form is made for foundries, with 10 per cent. to 25 per cent. titanium, so as to bring its specific gravity nearer to cast iron or steel. If the percentage of titanium is above 25 per cent. in the alloy, it is very difficult to alloy with iron or steel, and great losses in titanium occur. The specific gravity of the high-percentage titanium alloys is considerably below that of iron or steel, its tendency being to float right to the top and have no effect on the molten mass; whereas the 10 per cent. to 25 per cent. titanium alloys more readily, and without a great loss. 0.05 per cent. titanium is usually added, and increases the tensile strength of iron or steel wonderfully, and also improves the general quality.

Titanium has a great affinity for nitrogen, and in removing this the steel or iron is very much purified. The physical conditions of iron are much improved. The iron becomes more liquified, the grain closer without the iron becoming harder. The iron can be worked with ease.

Especially good effects were obtained for steam cylinders, pipes, and castings for hydraulic presses. To chilled iron, an addition of titanium seems to improve the chill, so that it withstands longer wear and tear without the titanium acting as a hardener. Even the best iron is improved by the addition of a little titanium, whereas poor scrap improves 25 per cent. or more in strength.

The addition of titanium can be made in the cupola, or in the open hearth, or crucibles. The best method to introduce it, however, is to melt it with a certain amount of the scrap in a separate crucible, and add this to the bulk of the iron or steel in a molten condition in the ladle. Titanium may be added up to 0.5 per cent.

COST OF 10 PER CENT. FERRO-TITANIUM IN 100 LBS. OF MOLTEN IRON OR STEEL BASED ON COST OF FERRO-TITANIUM, $3.20 PER POUND.

Percentage of Pure Titanium.	Percentage of 10 Per Cent. Ferro-Titanium to be Used.	Quantity of 10 Per Cent. Ferro-Titanium Required for 100 Pounds of Molten Iron.	Cost Per 100 Lbs. of Iron.
0.05 per cent.	0.5 per cent.	8 ounces	16 cents.
0.10 "	1.0 "	1 pound	32 "
0.12 "	1.2 "	1 pound, 3⅕ ounces	38.4 "
0.15 "	1.5 "	1 pound, 8 ounces	48 "
0.20 "	2.0 "	2 pounds	64 "
0.25 "	2.5 "	2 pounds, 8 ounces	80 "

COST OF 20 PER CENT. FERRO-TITANIUM IN 100 LBS. OF MOLTEN IRON OR STEEL.

Percentage of Pure Titanium.	Percentage of 20 Per Cent. Ferro-Titanium to be Used.	Quantity of 20 Per Cent. Ferro-Titanium Required for 100 Pounds of Molten Iron.	Cost Per 100 Lbs. of Iron.
0.05 per cent.	0.25 per cent.	4 ounces	16 cents.
0.10 "	0.5 "	8 ounces	32 "
0.12 "	0.6 "	9⅗ ounces	38.4 "
0.15 "	0.75 "	12 ounces	48 "
0.20 "	1.0 "	1 pound	64 "
0.25 "	1.25 "	1 pound, 4 ounces	80 "

Aluminum and Cast Iron.—Aluminum is a silvery-white metal obtained from clay, is very strong and malleable, sonorous, unalterable in air and lighter than glass. The probability of its existence was demonstrated by the researches of Sir

Humphry Davy in the year 1808, but it was not fairly obtained until 1828, when Wöhler procured it in an impure state in globules about the size of a pin's head. In 1854, Deville obtained the pure metal in ingots, but it was not until about 1880 that a process was discovered which admitted of the metal being obtained in sufficient quantities, and at a price that permitted of its being used in the foundry and mechanical arts. Since that time, like all new metals, its use has been advocated for everything, and it is only within the last few years that it began to take its proper place among the useful metals.

Aluminum is not found in combination with iron in any of the iron ores or fuels with which they are smelted, and is therefore not found in cast iron. Numerous attempts have been made to put it into this iron in the blast furnace and cupola, but owing to its low specific gravity, which is only about one-third that of iron, and its low melting point, which is but one-half that of cast iron, it has been found impossible to combine it with the latter in either of these furnaces. But it has been combined with iron by melting the metals together in covered crucibles, and from these experiments it has been learned that aluminum decreases combined carbon and increases graphite carbon to such an extent that it is impossible to chill iron containing it, and it therefore acts as a softener. It also increases fluidity and strength up to about one per cent. Above this point it decreases strength, due to too great a softness. These results vary, however, with the quality of iron before the aluminum is added. Numerous attempts to obtain these results by adding aluminum to molten iron in a ladle did not prove satisfactory, owing to the aluminum being so light and having such a strong affinity for oxygen that it was not found practicable to have it taken up by the iron to a sufficient extent to produce any marked change in the latter. Ferro-aluminum has also been tried in ladles, but here, as with all other ferro-alloys, the chilling effect of the alloy upon the molten iron interfered with the success of the operation to such an extent that no practical results were obtained. At the present time aluminum seems to have no place in the manipulation of foundry irons.

Nickel in Iron.—Nickel is a white hard metal, found in a metallic state in meteorites. It is very ductile, hard and tenacious so that a wire of it will sustain a greater weight than an iron wire of the same diameter. The ores of nickel are sulphides, arsenides, silicates, carbonates, etc., but it is not found in combination with iron in any of the ores of the latter.

Nickel has been quite extensively used in the manufacture of steel, and especially in the making of armor-plate, in which it is said to greatly increase the resisting power of the plate to penetration by shot. It has been found to alloy with certain grades of foundry iron when melted with it in a cupola and may to some extent be added to it in the ladle, but it has not yet been used to a sufficient extent to accurately determine its effect upon the iron. Reports of investigations of its effect upon these irons made by two eminent chemists and metallurgists for the American Foundrymen's Association, showed almost contradictory results which may probably be due to the grade and quality of foundry iron used.

Reasoning from a theoretical knowledge of the two metals and the effect of nickel in steel, it should in iron increase the strength, density, tendency to take a high polish, and resistance to corrosion, but all these may be offset by other elements in cast iron which have been removed from it in converting it into steel, and totally different results be obtained. But even should these results be produced by the addition of nickel to iron, they must be effected by a very small per cent of it, for it is far too expensive a metal to be added to iron in large quantities for ordinary castings.

Other Metals and Cast Iron.—Very little is said or published by foundry chemists as to the effect of copper, bronze, tin, lead, zinc, and antimony upon cast iron, when alloyed with it, which is probably due to the fact that these metals have long been in the hands of foundrymen and their personal knowledge of them is such, that information regarding their chemical action or effect upon iron is not deemed necessary. The writer many years ago made a series of experiments in alloying these metals with iron in the cupola, ladle, and crucible without obtaining any very satisfactory results. In some instances the addition of these metals to iron in the ladle seemed to have a beneficial effect upon it in the castings, but this was generally offset by some other objectionable feature to such an extent that the use of the alloy was discontinued. In none of these tests was there sufficient improvement found in the quality of castings to justify the addition of any of the above mentioned metals to iron. Since making these experiments, the writer has frequently met foundrymen who had made similar experiments with the same results, so that it is quite certain that no substantial improvement can be effected in the quality of castings by adding any of these metals to iron, either in the cupola or the ladle.

Untried Metals in Iron.—Tungsten, uranium, chromium, molybdenum, calcium, magnesium, have all been tried and to some extent used in the manufacture of steel, with various results, but have not yet to the writer's knowledge been to any great extent tested in foundry irons and are not likely to be used in them as they are all rare and at the present time too expensive for this purpose in the production of the ordinary line of castings, even if found to improve their quality.

Vanadium.—The name of this element is derived from Vanadis, a surname of the Scandinavian goddess Freya. It was discovered about a century ago in a lead ore from Zimapan, Mexico, by the Mexican mineralogist Del Rio. It is of a grayish-white color, similar to that of steel, very difficult of reduction, and is not oxidized by air or water. It is a very interesting element; it belongs to the bismuth group of metals which also includes arsenic, nitrogen and phosphorus. It does not occur in a pure metallic state. Its chief ore is vanadinite or vanadate of lead. It is also found in other minerals and, in small quantities, frequently in iron ores, especially in pea-ore; it then passes into the iron and especially into the finery cinders.

Vanadium has thus far been so rare and difficult to obtain, as well as expensive, that very little is known regarding its characteristics as a useful metal. However large deposits of vanadium ores recently discovered in Colorado by Professor Hildebrand of the U. S. Geological Survey, are now extensively worked and the metal is produced in abundance at a moderate price. A use for it is now being sought and, like aluminum when it became more plenty and cheaper, it may be recommended and tried for every purpose for which metals are used and require, as aluminum did, twenty-five years to find its true place among the useful metals.

Vanadium at the present time is being extensively experimented with in the manufacture of steel to determine all the desired properties it may impart to it, and has been found to greatly increase the strength of this metal. It has also been tried to some extent in foundry irons but not sufficiently so to accurately determine if it can be used to advantage.

Dr. Moldenke reports a series of experiments in melting burned iron with vanadium whereby the strength was increased 50 per cent. and the iron also softened to a considerable extent. But burned iron can hardly be considered a foundry iron as all foundrymen aim to avoid melting it for anything but sash weights or the commonest and cheapest kind of castings, and few founders would care to remelt this iron to use vanadium in a mixture with it.

The Superintendent of the American Roll and Foundry Co., Canton, Ohio, reports having tested vanadium and found it entirely too expensive for use in their castings. Mr. Philip Smith, Sup't of the Ingersoll-Rand Co. Foundry, reports it having been used in their foundry at Phillipsburg, N. J. under the directions of an expert, with no perceptible change in the iron, either in hardness, softness, strength, or density, when used in various proportions up to a cost of $10 per ton of iron for the vanadium used.

Wilson Bros., Easton, Pa., report that they contemplated the use of vanadium in their ladles to increase the strength and wearing properties of the grinding castings in their grinding machine. However, upon investigation they found that vanadium before it was taken up by the iron rendered the latter too dull for pouring, and that it could not be used in molten iron without a furnace for superheating the iron to promote the absorption of the vanadium after adding it, and as they did not care to go to that extent as an experiment, vanadium was not tried.

The metallurgist of The Illinois Steel Co., at Joliet, Ill., added vanadium to cast iron at a cost of $30 per ton of iron, and produced an automobile cylinder packing ring that was flexible, could be readily sprung between the thumb and finger, and was superior in every way to cast iron or steel for this purpose, but he failed to obtain a superior iron for this or other purposes at a less cost per ton of iron for vanadium. Other tests of vanadium have probably been made by founders but these are the only ones that have been brought to our attention. From these it would appear that vanadium, the cost of which is now about five dollars per pound, is entirely too expensive a metal for use in foundry irons for any but particular castings for which a special price can be obtained. Ferro-vanadium has recently been placed upon the market by the Primos Chemical Co., who give the following data in regard to it.

Ferro-Vanadium.—15 to 20 per cent. and 20 to 25 per cent. As the specific gravity of vanadium is much lower than that of iron or steel, the lower percentage alloys are much preferred, as they alloy more readily and without loss, whilst those of over 25 per cent. are more difficult to introduce owing to their tendency to float on the top of the molten iron or steel. The effect of the vanadium is primarily on the oxygen and nitrogen; up to 3 per cent. vanadium is added, but usually 0.05 to 0.10 per cent. is sufficient. A small percentage of nickel can be used to advantage in connection with vanadium. Vanadium increases the tensile strength very materially, the same as titanium. Both prevent crystallization to a great extent and the castings, etc., from becoming fatigued.

COST OF 10 PER CENT. FERRO-VANADIUM IN 100 LBS. OF MOLTEN IRON OR STEEL BASED ON COST OF FERRO-VANADIUM, $4.75 PER POUND.

Percentage of Pure Vanadium.	Percentage of 10 Per Cent. Ferro-Vanadium to be Used.	Quantity of 10 Per Cent. Ferro-Vanadium Required for 100 Pounds of Molten Iron.	Cost Per 100 Lbs. of Iron.
0.05 per cent.	0.5 per cent.	8 ounces	23.75 cents.
0.10 "	1.0 "	1 pound	47.5 "
0.12 "	1.2 "	1 pound, 3⅓ ounces	57 "
0.15 "	1.5 "	1 pound, 8 ounces	71.25 "
0.20 "	2.0 "	2 pounds	95 "
0.25 "	2.5 "	2 pounds, 8 ounces	$1.1875

COST OF 20 PER CENT. FERRO-VANADIUM IN 100 LBS. OF MOLTEN IRON OR STEEL.

Percentage of Pure Vanadium.	Percentage of 10 Per Cent. Ferro-Vanadium to be Used.	Quantity of 20 Per Cent. Ferro-Vanadium Required for 100 Pounds of Molten Iron.	Cost Per 100 Lbs. of Iron.
0.05 per cent.	0.25 per cent.	4 ounces	23.75 cents.
0.10 "	0.5 "	8 ounces	47.5 "
0.12 "	0.6 "	9⅗ ounces	57 "
0.15 "	0.75 "	12 ounces	71.25 "
0.20 "	1.0 "	1 pound	95 "
0.25 "	1.25 "	1 pound, 4 ounces	$1.1875

Vanadium when melted with charcoal iron gives better results as to increase in strength than with coke iron. A low-silicon iron shows a greater increase in strength when melted with vanadium than a high-silicon iron; the lower the silicon the better the results.

Vanadium when melted in the regular foundry mixture for soft castings gives no increase in transverse or tensile strength. It is claimed to greatly increase the strength of a semi-steel mixture.

Vanadium in Cast Iron.—The element of vanadium has recently received special notice by metallurgists, but has not as yet begun to play an important part in American foundry practice.

It is suggested, however, that it may be one of the secrets behind the claim that French automobile cylinders outlast those cast in America. One of the features probably causing deterioration in automobile engines is the loss of compression due to the wearing of the cylinders. Some foreign engine castings have been superior to the general product in this particular.

The American Locomotive Automobile Company has recently been carrying on some experiments along this line. It was found that American cast cylinders soon took a polish from the piston, but that in a short time this polished surface began to check and crack, resulting in a rough condition, rapid wear, and the loss of compression.

Some imported Berliet cylinders were tried under the same conditions. These took a high polish which was practically permanent. A careful analysis showed that the French cylinders contained a considerable percentage of vanadium. It is supposed, and the assumption seems reasonable, that their success was due to the presence of this element.—*Castings.*

CHAPTER X.

GRADING IRON BY ANALYSIS.

Pig Iron Specifications.—The American Society for Testing Materials adopted in 1904 the following analysis for foundry irons as a standard: No. 1 pig Si., 2.75 per cent.; S., 0.35 per cent.; No. 2 Iron Si. 2.25 per cent.; S., 0.45 per cent. In the absence of a definite understanding a variation of 0.10 per cent. of the silicon either way is allowed. But for each 0.10 per cent. of the silicon below this a penalty of 1 per cent. in the price of pig iron should be required.

The committee who formulated this standard were evidently not practical foundrymen or had in view only a standard for No. 1 and No. 2 irons, for no founder could produce from only these two grades an iron suitable for all the various grades of castings that are made, and no blast-furnaceman could confine his furnace to the production of only two grades of iron showing this standard of analysis. At any rate this standard has not proved satisfactory to either founder or furnaceman, and the matter was taken up by the Philadelphia Foundrymen's Association, who appointed a committee on standard specifications for foundry irons. This committee made the following report at the January, 1909, meeting of the association, and the report was ordered printed and distributed:

Philadelphia Foundrymen's Association. Standard Specifications for Foundry Pig Iron.—Your committee would respectfully report that, following the instruction of your association, they have, in drawing the enclosed specifications, abandoned the buying of pig iron by number. The tables are so arranged that different qualities of pig iron can be accurately designated by their chemical content. There are three points which, perhaps, it is desirable to speak of.

First. As buying by analysis fails as to the standard for newspaper quotations, it is proposed that there shall be a grade established upon which prices can be based known as No. 2 which shall be a quality of metal similar to the foreign standard grading upon which warrants are issued, this grade to analyze as stated in the specification.

Second. So that buyers and sellers can readily express the character of metal they want, symbols have been put after each analysis, the combination of which into one word will express exactly what the buyers desire, thus saving considerable expense in telegraphing. Further, these symbols condensed into a word will be of value when warehousing iron as the word written into the certificate will accurately describe the iron that is stored.

Third. If a purchaser wishes to split the steps at which silicon varies (0.50 per cent) the tables are so arranged that he can designate silicon with a difference only of 0.25 per cent.

Your Committee believes that with these explanations the reason for the new departures will be entirely clear and that the tables are so arranged that it will be possible for any one in the foundry business to designate with precision the metal he desires.

Proposed Standard Specification for Foundry Pig Iron—Analysis.—It is recommended that all purchases be made by analysis.

Sampling.—Each car load or its equivalent shall be considered as a unit, at least one pig shall be selected from each four tons of every car load, and so chosen from different parts of the car as to represent as nearly as possible the average quality of the iron.

Drillings shall be taken so as to fairly represent the fracture surface of each pig. The sample analyzed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis.

Percentage of Elements.—Opposite each percentage of the different elements a symbol has been affixed so that buyers, by combining these symbols, can form a code word, to be used in telegraphing such inquiries as they may desire to make.

Carbon.

Total carbon not less than 3.25 per cent.

Silicon.

Per cent.	Symbol.	Per cent.	Symbol.
0.50	Ca.	2.50	Cu.
1.00	Ce.	3.00	Cy.
1.50	Ci.	3.50	Ch.
2.00	Co.	0.25 allowed variation.	

Sulphur.

0.03	Sa.	0.07	Su.
0.04	Se.	0.08	Sy.
0.05	Si.	Maxima gravimetric method.	
0.06	So.		

Phosphorus.

Less than 0.20	Pa.	1.20	Pu.
0.30	Pe.	1.50	Py.
0.60	Pi.	0.15 allowed variation.	
0.90	Po.		

Manganese.

0.40	Ma.	1.20	Mu.
0.60	Me.	1.60	My.
0.80	Mi.	0.20 allowed variation.	
1.00	Mo.		

Example.—Code word Ci-se-pi-ma represents silicon 1.50, sulphur 0.04, phosphorus 0.60, manganese 0.40. Whenever standards one-half between the standards above are desired, they will be designated by the symbol X. Thus "Cix" means 1.75 per cent. silicon, or, in trade parlance, 1.50 to 2.00 per cent. silicon, and "Cox" means 2.25 per cent. silicon, or, in trade parlance, 2.00 to 2.50 per cent. silicon. For market quotations a grade shall be assumed to be known as No. 2, analyzing silicon 2.50 per cent. and over, and sulphur 0.04 per cent. or under.

The American Foundrymen's Association Standard Specifications for Foundry Pig Iron.—At the Toronto, Canada, meeting of the American Foundrymen's Association, 1908, a committee was appointed on standard specifications for foundry pig iron, to confer with similar committees from the American Society for Testing Material, Philadelphia Foundrymen's Association, and Eastern Pig Iron Association. This committee, after conferring with the other committees, made the following report to the Cincinnati, Ohio, meeting of the American Foundrymen's Association, 1909, which was adopted after much discussion, as to whether the gravimetric or the evolution method should be used in determining the presence of sulphur. The testing laboratories and furnacemen opposed the gravimetric method, although more accurate than the evolution method, on account of the additional expense incurred in making it.

Proposed Standard Specifications for Buying Pig Iron.—It is recommended that foundry pig iron be bought by analysis, and that when so bought these standard specifications be used.

Percentages and Variations.—In order that there may be uniformity in quotations, the following percentages and variations shall be used.

(These specifications do not advise that all five elements be specified in all contracts for pig iron, but do recommend that when these elements are specified that the following percentages be used.)

Silicon.

(0.25 allowed either way.)

Per cent.	Code.	Per cent.	Code.
1.00	La.	2.50	Lo.
1.50	Le.	3.00	Lu.
2.00	Li.		

Sulphur.

(Maximum.)

Per cent.	Code.	Per cent.	Code.
0.04	Sa.	0.08	Su.
0.05	Se.	0.09	Sy.
0.06	Si.	0.10	Sh.
0.07	So.		

Total Carbon.

(Minimum.)

Per cent.	Code.	Per cent.	Code.
3.00	Ca.	3.60	Co.
3.30	Ce.	3.80	Cu.
3.40	Ci.		

Manganese.

(0.20 either way.)

Per cent.	Code.	Per cent.	Code.
0.20	Ma.	1.00	Mu.
0.40	Me.	1.25	My.
0.60	Mi.	1.50	Mh.
0.80	Mo.		

Phosphorus.

Per cent.	Code.	Per cent.	Code.
0.20	Pa.	1.00	Pu.
0.40	Pe.	1.25	Py.
0.60	Pi.	1.50	Ph.
0.80	Po.		

Percentage of any element specified one-half way between the above shall be designated by addition of letters to next lower symbol. In case of phosphorus and manganese, the percentages may be used as maximum or minimum figures, but unless so specified, they will be considered to include the variations above given.

Sampling and Analysis.—Each carload, or its equivalent, shall be considered as a unit in sampling.

One pig of machine cast, or one-half pig of sand cast iron shall be taken to every four tons in the car, and shall be so chosen from different parts of the car as to represent as nearly as possible the average quality of the iron.

Drillings shall be taken so as to fairly represent the composition of the pig as cast.

An equal weight of the drillings from each pig shall be thoroughly mixed to make up the sample for analysis.

In case of dispute, the sample and analysis shall be made by an independent chemist mutually agreed upon, if practicable at the time the contract is made.

It is recommended that the standard methods of The American Foundrymen's Association be used for analysis. Gravimetric methods shall be used for sulphur analysis, unless otherwise specified in the contract. The cost of resampling and re-analysis shall be borne by the party in error.

Base or Quoting Price.—For market quotations an iron of 2.00 per cent. in silicon (with variation of 0.25 either way) and sulphur 0.05 (maximum) shall be taken as the base.

Penalties.—In case the iron when delivered does not conform to the specifications, the buyer shall have the option of either refusing the iron or accepting it on the base shown in the above table, which must be filled out at the time the contract is made.

Allowance.—In case the furnace cannot for any good reason deliver the iron as specified at the time delivery is due, the purchaser may at his option accept any other analysis which the furnace can deliver, the price to be determined by the base table above, which must be filled out at the time the contract is made.

Base Table.—The accompanying table may be filled out, may become a part of the contract "B," or base representing the price agreed upon for a pig iron running 2.00 in silicon (with allowed variation of 0.25 either way), and under 0.05 sulphur; "C" is a constant differential to be determined at the time the contract is made.

(This table is for settling any differences which may arise in filling the contract, as explained under penalties and allowance, and may be used to regulate the price of a grade of pig iron which the purchaser desires and the seller agrees to substitute for the one originally specified.)

Silicon percentages allow 0.25 variation either way, sulphur percentages are maximum.

Sulphur	Silicon Per cent.									
Per cent.	3.25	3.00	2.75	2.50	2.25	2.00	1.75	1.50	1.25	1.00
0.04	B+6C	B+5C	B+4C	B+3C	B+2C	B+1C	B	B—1C	B—2C	B—3C
0.05	B+5C	B+4C	B+3C	B+2C	B+1C	B	B—1C	B—2C	B—3C	B—4C
0.06	B+4C	B+3C	B+2C	B+1C	B	B—1C	B—2C	B—3C	B—4C	B—5C
0.07	B+3C	B+2C	B+1C	B	B—1C	B—2C	B—3C	B—4C	B—5C	B—6C
0.08	B+2C	B+1C	B	B—1C	B—2C	B—3C	B—4C	B—5C	B—6C	B—7C
0.09	B+1C	B	B—1C	B—2C	B—3C	B—4C	B—5C	B—6C	B—7C	B—8C
0.10	B	B—1C	B—2C	B—3C	B—4C	B—5C	B—6C	B—7C	B—8C	B—9C

Note.—The specifications of The American and Philadelphia Associations have been so recently adopted that they have not been in use a sufficient length of time to test them as a standard in the buying and selling of irons, but they will no doubt answer the purpose, as they give a wide range for the various elements, and cover the old and well-known theory that all irons are good irons when properly mixed and melted, and more than one brand and grade of iron is necessary to produce castings of different degrees of hardness, softness, and strength.

Analyses of Castings.—The following analyses of castings collected from various parts of the country show those that have proved satisfactory for different lines of castings made from different brands of iron. The variations in them are due to the characteristics of the various brands of iron and also, in some instances, to the use of charcoal iron or steel scrap in the mixture.

Stove Plate, T. C. 3.33, Si. 2.80, P. 0.80, S. 0.09, M. 0.20.

Light Pulleys, T. C. 3.40, Si. 3.10, P. 0.80, M. 0.71.

Heavy Pulleys, T. C. 3.25, Si. 3, P. 0.70, S. 0.10, M. 0.75.

Auto Cylinders, Si. 2.50, P. 0.70, S. 0.50, M. 0.10.

Auto Cylinders, Si. 2.25, P. 0.08, S. 0.75, M. 0.50.

Gear Wheels, Si. 2.00, P. 0.70, S. 0.50, M. 0.70.

Gear Wheels, C. C. 0.75, G. C. 2.25, Si. 2.00, P. 0.50, M. 0.50, Tensile Strength, 36.546.

Steam Cylinders, Weight, 1.500 to 3.000 lbs., Thickness of metal, 1.25 to 1.50 inches, Si. 1.20 to 1.60, P. 0.70, M. 0.70 S. 0.50 or less.

Bedstead Joints, Si. 3.00, P. 1.00, M. 0.20, S. 0.10.

Pipe Fittings, T. C. 2.75 to 3.50, Si. 3.00, P. 1.00, M. 0.05, S. 0.10.

Small Cylinders, Si. 1.88, P. 0.50, M. 0.85, S. 0.26.

Chill Rolls, C. C. 1.10, G. C. 1.71, Si. 0.78, P. 0.50, S. 0.61, M. 0.21.

Mine Car Wheels, Si, 2.40, P. 0.50, S. 0.10, M. 0.77.

Malleable Iron, Si. 0.75 to 1.50, M. 0.60, S. 0.04.

Chills for Foundry Use, Si. 2.50, P. 0.10, S. 0.07.

Close Strong Iron for Heavy Castings, Si. 1.20 to 1.50, S. 0.10, P. 0.35 to 0.50, M. 0.50 to 0.75.

Medium Heavy Castings, Si. 1.50 to 2.00, S. 0.10, P. 0.30 to 0.50, E. 0.40 to 0.80.

Soft Light Castings, Si. 2.25, to 2.75, P. 0.70, M. 0.70, S. 0.20.

Annealing Pots, Si. 0.60 to 0.80, P. 0.10 to 0.20, M. 0.40 to 0.60, S. 0.92 to 0.03.

Car wheel mixture most commonly used is composed of about, 20 per cent. charcoal pig, 30 per cent. of 2 per. cent. manganese coke pig, 10 per cent. steel rail, and the balance remelt scrap and old wheels.

METHOD OF CALCULATING MIXTURES FOR THE CUPOLA.

Analysis of the Castings Required.

		Per cent.
Silicon		1.60
Phosphorus		0.70
Sulphur	less than	0.10
Manganese		0.50

From previous experience with the iron and coke, due consideration being given to local melting conditions, it is estimated that the approximate loss of silicon will be 0.25 per cent. and manganese 0.10 per cent., while the increase in sulphur will be approximately 0.03 per cent.

The average analysis of the iron and scrap to be charged should be as follows:

		Per cent.
Silicon		1.85
Phosphorus		0.70
Sulphur	less than	0.07
Manganese		0.60

TABULATION OF THE MATERIAL TO BE CHARGED AND METHOD OF FIGURING THE MIXTURE.

Kind of Material.	Weight in Pounds.	Analysis.				Weight of *			
		Silicon Per cent.	Sulphur Per cent.	Phosphorus Per cent.	Manganese Per cent.	Silicon.	Sulphur.	Phosphorus.	Manganese.
Steel scrap	400	0.10	0.07	0.10	0.60	0.40	0.28	0.40	2.40
Machinery scrap	2,000	1.70?	0.10?	1.00?	0.60?	34.00	2.00	20.00	12.00
High sulphur Southern.	1,600	0.70	0.10	1.50	0.30	11.20	1.60	24.00	4.80
X No. 1	1,600	3.00	0.03	0.80	1.25	48.00	0.48	12.80	20.00
No. 3 foundry........	4,000	1.75	0.07	0.30	0.60	70.00	2.80	12.00	24.00
High silicon iron	800	3.50	0.025	0.07	0.60	28.00	0.20	0.56	4.80
Total	10,400	......	.....	.....	.....	191.60	7.36	69.76	68.00
Average per cent	......	......	.....	.....	.....	1.84	0.071	0.67	0.65

* Multiply the weight of each kind of material by the per cent. of the element in it, then divide the total weight of each element by the total weight of the material which in this example is 10,400 pounds.

By the relative adjustment of the pig iron and scrap, mixtures for any desired analysis can be made.

CHAPTER XI.

CHEMICAL STANDARDS FOR IRON CASTINGS.

The following report on chemical standards for iron castings of the various grades or classes was made at the Detroit meeting of the American Foundrymen's Association by a committee appointed at a previous meeting:

Chemical Standards for Iron Castings.—Under this heading is presented what is probably the largest collection of analyses of iron castings ever gathered into one table, and it is thought that the information contained should be of considerable value and interest.

The sources of these data are three in number: first, published work; second, the private notes of the writer; third, the replies to the inquiries sent out by your committee:

Regarding this last source, which has supplied the greater number of analyses, approximately 1,000 inquiries were sent out to as many different foundries, selected largely at random from "Penton's List." These inquiries ran in substance as follows:

"At the last convention of the American Foundrymen's Association it was decided to make an attempt to formulate chemical standards for iron castings, in the belief that such standards would be of great use both to the individual foundryman and to the industry as a whole.

"The information on which these should be based could, of course, be obtained by analyzing typical castings bought in the open market. This would, however, involve much trouble and expense, and will be unnecessary if foundrymen will freely donate the information for the good of the industry.

"We urge you, therefore, to act generously in giving us the data indicated below, and since composition is but one item in the successful manufacture of castings, we feel sure that in so doing there can be no possible detriment to your personal interests. .

"Replies will, of course, be entirely confidential as regards the names of those giving information. There is desired the following information:

"Name or Class of Castings, Silicon, Sul., Phos., Mang., Comb. Carb., Graph. Carb., Total Carb."

To this letter about 10 per cent. of replies were received, the greater number of which contained more or less information.

Regarding the classification of castings, it is evidently impossible to consider as separate cases all the different patterns. Nor would this be desirable, since any foundry must itself class its castings into comparatively few groups which are each poured from one kind of iron. For example, a shop doing machine-tool work may make castings from several hundred patterns and will use not to exceed four mixtures of iron for all of these, probably dividing the work into light, medium and heavy castings, with possibly a special mixture for pulleys. It is thought, therefore, that a classification according to use or properties necessary is in the majority of cases desirable.

Thickness is, of course, taken into consideration, since this largely determines the percentage of silicon necessary, and it has been the aim to subdivide the various classes according to section wherever possible. In this respect the writer has endeavored to follow the definitions of the American Society for Testing Materials, who have grouped castings according to thickness as follows: (126).

"Castings having any section less than one-half of an inch thick shall be known as light castings."

"Castings in which no section is less than 2 inches thick shall be known as heavy castings."

"Medium castings are those not included in the above definitions."

It is unfortunately true that there is much lacking in this table, many important classes of castings being entirely missing, while others are inadequately represented by only one or two analyses. These deficiencies are due to the lack of available data in certain cases, and it is to be hoped that they may be at least partially remedied by future work.

Malleable cast iron is omitted entirely, partly because of the small amount of data obtained and partly because its manufacture is a process entirely different from those involved in the ordinary iron foundry.

Regarding arrangement, the analyses taken from published sources are preceded by a number in the first column referring to the bibliography, Part V. The last analysis under each head is preceded by the word "Sug." (abbreviated from suggested) and is the tentative standard or probable best analysis *suggested* by your committee. It should be clearly understood in this connection that while this is based on a careful study of both theory and practice, it represents only the individual opinion of the writer, and is not necessarily infallible.

Furthermore, these suggestions are incomplete in certain other respects. The most desirable percentage of silicon, for example, will depend largely on the exact thickness of the casting and the practice followed in shaking out. These factors, being in many cases undetermined, have been allowed for by giving fairly wide limits to this element. Again, the possibilities in the use of purifying alloys have not been taken into account here, although they have been discussed in the preceding parts, and the use of steel scrap has been ignored except that the "low" total carbon specified in some cases must, as a rule, be obtained in this way. Finally, in many cases, a very wide range of composition is permissible and compatible with the best results, and in such cases the question of cost will be the first element to be considered in fixing the composition.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
Acid Resisting Castings.						
7	1.00	.050	.50			3.00
42	2.30	low	.20	.41		3.60
81	.80-2.00	.02-.03	.40-.60	1.00-2.00		3.00-3.50
Sug.*	1.00-2.00	und.* .05	und. .40	1.00-1.50		3.00-3.50
Acid Stills and Eggs. See Acid Resisting Castings.						
Agricultural Machinery, Ordinary.						
64	2.20-2.80	und. .085	und. .70	und. 70		
	2.65	.050	.81	.70	.15	3.50
	2.25	.070	.70	.80	.30	3.50
	2.10	.068	.73	.45	.47	3.42
	2.00	.089	.89	.46	.50	3.39
Sug.	2.00-2.50	.06-.08	.60-.80	.60-.80		
Agricultural Machinery, Very Thin.						
	2.90	.050	.85	.70	.10	3.50
	2.50	.080	.65	.60	.30	3.50
Sug.	2.25-2.75	.06-.08	.70-.90	.50-.70		
Air Cylinders.						
64	1.20-1.50	und. .09	.35-.60	.50-.80		
	1.90	.074	.50	.65		
	1.12	.085	.40	.70	.70	3.50
	.95	.100	.30	.90	.80	3.40
	2.00	.070	.30	.60	.40	
Sug.	1.00-1.75	und. .09	.30-.50	.70-.90		3.00-3.30
Ammonia Cylinders.						
14	1.20-1.90	und. .095	und. .70	.60-.80		
Sug.	1.00-1.75	und. .09	.30-.50	.70-.90		3.00-3.30
Annealing Boxes for Malleable Casting Work.						
Sug.	.65	.05	.10-.20	.20	2.75	2.75
Annealing Boxes, Pots and Pans.						
171	1.20	.060	.10	.40		
81	1.80	.03	.70	.60		2.90
198	1.53	.04	.33	1.08	.58	3.68
Sug.	1.40-1.60	und. .06	und. .20	.60-1.00		low
Automobile Castings.						
	1.80	.030	.50	.70	.60	3.50
	1.65	.076	.45	.65	.55	
	2.35	.072	.60	.70	.40	
Sug.	1.75-2.25	und. .08	.40-.50	.60-.80		

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* "und." is abbreviated from under and "sug." from suggested.

Automobile Cylinders.

Ref.	Silicon.	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
	1.65	.076	.45	.65	.55	
19	2.31	.094	.50	.43	.51	3.35
19	2.70	.053	.46	.23	.44	3.02
19	2.45	.102	.72	.41	.41	3.47
19	2.59	.083	.57	.47	.11	3.35
19	2.55	.104	.82	.32	.09	3.04
19	2.98	.047	.89	.27	.14	3.19
19	2.67	.111	.73	.38	.10	3.24
19	2.30	.084	.81	.52	.59	3.35
19	1.60	.083	.54	.42	.66	3.75
19	3.26	.159	.93	.44	.03	2.87
19	1.72	.091	.58	.48	.62	2.52
19	1.67	.068	.44	.82	.62	3.91
19	1.38	.093	.62	.52	.76	3.61
19	1.47	.075	.13	.60		
19	1.50	.103	.86	.43		
19	1.99	.130	.65	.39	.45	3.17
19	1.89	.090	.70	.39	.77	3.34
19	2.29	.090	.83	.60	.90	4.16
Sug.*	1.75-2.00	und.* .08	.40-.50	.60-.80	.55-.65	3.00-3.25
Automobile Fly Wheels.						
	2.35	.072	.60	.70	.40	
	3.10	.045	.35	.55	.27	
Sug.	2.25-2.50	und. .07	.40-.50	.50-.70		
Balls for Ball Mills.						
196	1.00	.100	.30	.50		low
Sug.	1.00-1.25	und. .08	und. .20	.60-1.00		low
Bed Plates.						
	2.20	.090	.55	.50		
	1.32	.090	.40	.60		
	1.65		.28	.72		
	1.85	.080	.60	.55	.50	3.25-3.50
	1.80-2.20	.04-.06	.45-.55	.40-.50	.40-.50	3.40-3.60
	1.65-1.85	.070	.65-.80	.60-.75		3.85
Sug.	1.25-1.75	und. .10	.30-.50	.60-.80		

Binders. See Agricultural Machinery.

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* "und." is abbreviated from under and "sug." from suggested.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
Boiler Castings.						
194	2.50	und.* .07	und. .20	.80-1.0		
	2.25	.060	.62	.59		
Sug.*	2.00-2.50	und. .06	und. .20	.60-1.0		
Brake Shoes.						
95	1.50		low			low
64	2.00-2.50	und. .15	und. .70	und. .70		
57	2.00-2.50	und. .15	und. .70	und. .70		
	1.40-1.80	.06-.08	.50-.80	.45-.60	.40-.65	3.50
	1.86	.183	1.93	.33	1.22	3.01
Sug.	1.40-1.60	.08-.10	.30	.50-.70		low
Car Castings, Gray Iron. See also Brake Shoes and Car Wheels.						
64	2.20-2.80	und. .085	und. .70	und. .70		
	1.40-1.80	.06-.08	.50-.80	.45-.60	.40-.65	3.50
	2.25	.050	.60	.75		3.50
	1.75	.070	.85	.60		
Sug.	1.50-2.25	und. .08	.40-.60	.60-.80		
Car Wheels, Chilled.						
51	.50-.70	.05-.07	.35-.45	.30-.50	.50-.75	3.50
171	.58-.68	.05-.08	.25-.45	.15-.27	.63-1.0	
171	.73	.080	.43	.44	1.25	4.31
171	.86	.127	.35	.49	.92	3.47
126	.70	.08	.50	.40	.60	3.50
	.58	.141	.38	.48	.90	3.63
	.57	.101	.41	.42		
	.68	.188	.36	.53		
	.67	.170	.38	.81	.74	3.66
	.50-.60	.08-.10	.30-.40	.45-.55	.70-.80	3.50
Sug.	.60-.70	.08-.10	.30-.40	.50-.60	.60-.80	3.50-3.70
Car Wheels, Unchilled. See Wheels.						
Chemical Castings. See Acid Resisting Castings.						
Chilled Castings.						
135	.80-1.00	.09-.11	.50	.50		
197	1.20-1.40		low			low
69	1.00	.08	.40	.75		3.25
65	1.35	.117	.60	.54	.65	3.00
	.50	.200	.45	1.50	3.00	3.00
	1.20	.090	.30	.50	1.20	3.20
	1.20	.080	.30	1.25		3.50
	.75	.090	.30	.30	3.00	3.20
Sug.	75-1.25	.08-1.0	.20-.40	.80-1.2		

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* "und." is abbreviated from under and "sug." from suggested.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
Chills.						
105	2.07	.073	.31	.48	.23	2.64
Sug.*	1.75-2.25	und.* .07	.20-.40	.60-1.0		
Collars and Couplings for Shafting.						
	1.60	.040	.55	.55	.30	3.57
Sug.	1.75-2.00	und. .08	.40-.50	.60-.80		
Cotton Machinery. See also Machinery Castings.						
	2.20-2.30	und. .09	.70	.60	.45	3.45
Sug.	2.00-2.25	und. .08	.60-.80	.60-.80		
Crusher Jaws.						
135	.80-1.00	.09-.11	.50	.50		
69	1.00	.080	.40	.75		3.25
	.50	.20	.45	1.50	3.00	3.00
Sug.	.80-1.00	.08-.10	.20-.40	.80-1.2		
Cutting Tools, Chilled Cast Iron.						
65	1.35	.117	.60	.54	.65	3.00
Sug.	1.00-1.25	und. .08	.20-.40	.60-.80		
Cylinders. See Air Cylinders, Automobile Cylinders, Hydraulic Cylinders, Ammonia Cylinders, Gas Engine Cylinders, Locomotive Cylinders, Steam Cylinders.						
Cylinder Bushings, Locomotive. See Locomotive Castings, Heavy.						
Dies for Drop Hammers.						
171	1.40	.060	.10	.40		
	1.40	.090	.40	.70	1.00	3.20
Sug.	1.25-1.50	und. .07	und. .20	.60-.80		low
Diamond Polishing Wheels.						
105	2.70	.063	.30	.44	1.60	2.97
Dynamo and Motor Frames, Bases and Spiders, Large.						
171	1.95	.042	.40	.39	.59	3.82
	1.90	.08	.47	.60	.64	3.79
	2.15	.070	.75	.60	.55	3.80
	2.10	.070	.55	.40		3.50
Sug.	2.00-2.50	und. .08	.50-.80	.30-.40	.20-.30	low

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* "und." is abbreviated from under and "sug." from suggested.

Dynamo and Motor Frames, Bases and Spiders, Small.

Ref.	Silicon.	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
171	3.19	.075	.89	.35	.06	2.95
	2.30	.070	.55	.40		3.50
	2.50	.070	.75	.60	.55	3.95
Sug.*	2.50-3.00	* und. .08	.50-.80	.30-.40	.20-.30	low

Electrical Castings.

171	3.19	.075	.89	.35	.06	2.95
171	1.95	.042	.40	.39	.59	3.82
	1.90	.080	.47	.60	.64	3.79
	2.15	.070	.75	.60	.55	3.80
	2.50	.070	.75	.60	.55	3.95
	2.10	.070	.55	.40		3.50
	2.30	.070	.55	.40		3.50
Sug.	2.00-3.00	und. .08	.50-.80	.30.-40	.20-.30	low

Eccentric Straps. See Locomotive Castings and Machinery Castings.

Engine Castings. See Bed Plates,
Fly Wheels,
Machinery Castings,
Engine Frames,
Locomotive Castings,
Steam Cylinders.

Engine Frames. See also Machinery Castings.

	2.25	.080	.55	.60
	1.00	.090	.50	.60
	1.32	.100	.40	.60
Sug.	1.25-2.00	und. .09	.30-.50	.60.-1.0

Fans and Blowers. See Machinery Castings.

Farm Implements.

	2.00	.089	.89	.46	.50	3.39
	2.10	.068	.68	.45	.47	3.32
Sug.	2.00-2.50	.06-.08	.50-.80	.60-.80		

Fire Pots.

194	2.50	und. .07	und. .20	.80-1.0
Sug.	2.00-2.50	und. .06	und. .20	.60-1.0

Fly Wheels. See also Automobile Fly Wheels and Machinery Castings.

	2.20	.090	.55	.50
	1.50	.090	.50	.60
Sug.	1.50-2.25	und. .08	.40-.60	.50-.70

" und." is abbreviated from under and " sug." from suggested.

Ref.	Silicon.	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Friction Clutches.						
64	2.00-2.50	und.* .15	und. .70	und. .70		
Sug.*	1.75-2.00	.08-.10	und. .30	.50-.70		low
Furnace Castings.						
194	2.50	und. .07	und. .20	.80-1.0		
	2.00	.085	.35	.53		
	1.85	.090	.70	.60		
Sug.	2.00-2.50	und. .06	und. .20	.60-1.00		low
Gas Engine Cylinders.						
137	1.45			.65		
	1.98	0.90	.84	.63		
	1.21	.117	.40	.35	1.40	3.74
	1.00-1.25	.04-.08	.20-.40	.70-.80	.60-.80	3.00-3.10
Sug.	1.00-1.75	und. .08	.20-.40	.70-.90		3.00-3.30
Gears, Heavy.						
171	1.40	0.60	.10	.40		
	.94	.150	.43	.31	1.47	
	1.60	.080	.40	.60		3.50
	1.50-1.75	.080	.40-.60	.50-.70		
	1.00-1.25	.075	.40	.80-1.0		very low
	1.40-1.60	.04-.08	.30-.50	.40-.60	.50-.80	3.20-3.40
Sug.	1.00-1.50	.08-.10	.30-.50	.80-1.0		low
Gears, Medium.						
64	1.50-2.00	und. .08	.35.-.60	.50-.80		
171	1.90	.060	.10	.40		
	2.30	.060	.60	.60		3.75
	1.90	.100	.69	.58	.55	3.83
Sug.	1.50-2.00	und. .09	.40-.60	.70-.90		
Gears, Small.						
198	3.43		1.42	.90		
	2.00	.100	.50	.70		3.50
Sug.	2.00-2.50	und. .08	.50-.70	.60-.80		
Grate Bars.						
195	2.75	low	low			
	2.00	.085	.35	.53		
Sug.	2.00.-2.50	und. .06	und. .20	.60-1.0	und. .30	low

“und.” is abbreviated from under and “sug.” from suggested.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
Grinding Machinery, Chilled Castings for.						
	.50	.200	.45	1.50	3.00	3.00
Sug.*	.50-.75	.15-.20	.20-.40	1.5-2.0		
Gun Carriages.						
171	.94	.050	.44	.31	.63	3.03
171	1.00	.050	.30	.60	1.10	2.50
Sug.	1.00-1.25	und.* .06	.20-.30	.80-1.0		low
Gun Iron.						
171	1.34	.003	.08	1.00	.93	3.12
171	1.19	.055	.41	.42	1.13	3.18
171	1.53	.050	.29	.45	.42	3.43
171	.98	.06	.43	.43	.75	1.74
198	.30		.44	3.55	1.70	3.90
	1.20	.100	.30	.80	1.00	3.00
Sug.	1.00-1.25	und. .06	.20-.30		.80-1.0	low
Hangers for Shafting.						
	1.60	.040	.55	.55	.30	3.57
Sug.	1.50-2.00	und. .08	.40-.50	.60-.80		
Hardware, Light.						
198	1.84		.58	1.04		
198	2.20		.74	1.10		
198	2.50		1.21	1.16		
	2.51	.110	.62	.41	.24	3.18
	2.70	.030	.60	.50	.40	3.60
	2.50	und. .050	.60	.70		
	2.00-2.25	.050	.85	.40		3.85-4.00
Sug.	2.25-2.75	und. .08	.50-.80	.50-.70		
Heat Resistant Iron.						
171	1.20	.060	.10	.40		
171	1.67	.032	.09	.29	.43	3.87
134	2.15	.086	1.26	.41	.13	3.30
134	2.02	.070	.89	.29	.84	3.60
198	1.53	.040	.33	1.08	.58	3.68
105	2.07	.073	.31	.48	.23	2.64
81	1.80	.030	.70	.60		
195	2.75	low	low			
194	2.50	und. .07	und. .20	.80-1.0		
	1.76	.075	.63	.79	.56	3.68
	2.00	.030	.70			
Sug.	1.25-2.50	und. .06	und. .20	.60-1.00	und. .30	low

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* "und." is abbreviated from under and "sug." from suggested.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
Hollow Ware.						
	2.51	.110	.62	.41	.24	3.18
Sug.*	2.25-2.75	und.* .08	.50-.70	.50-.70		
Housings for Rolling Mills.						
	1.00-1.25	.085	.65	.75		low
Sug.	1.00-1.25	und. .08	.20-.30	.80-1.0		low
Hydraulic Cylinders, Heavy.						
171	1.00	.050	.30	.60	1.10	2.50
22	.90	.136	.39	.25	1.44	3.34
63	.80-1.50	.07-.11	.35-.50			
	1.12	.085	.40	.70	.70	3.50
	.95	.100	.30	.90	.80	3.40
	1.15	und. .08	.50	.60	1.15	
	.90-1.20	.06-.08	.30-.50	.80-1.0	.80-1.0	2.90-3.10
Sug.	.80-1.20	und. .10	.20-.40	.80-1.0		low
Hydraulic Cylinders, Medium.						
171	1.40	.060	.10	.40		
	1.90	.074	.50	.65		
	1.62	.08	.50	.60		
	1.75	.070	.40	.55	.50	
Sug.	1.20-1.60	und. .09	.30-.50	.70-.90		low
Ingot Molds and Stools.						
171	1.20	.060	.10	.40		
171	1.67	.032	.09	.29	.43	3.87
Sug.	1.25-1.50	und. .06	und. .20	.60-1.0		
Locomotive Castings, Heavy.						
57	1.40-2.00	und. .085	und. .60	und. .70		
	1.25-1.50	.06-.08	.40-.60	.45-.60	.50-.70	3.50
	1.62	.098	.40	.49		
Sug.	1.25-1.50	und. .08	.30-.50	.70-.90		
Locomotive Castings, Light.						
57	1.40 2.00	und. .085	und. .60	und. .70		
	1.50-2.00	.06-.08	.40-.60	.45-.60	.45-.55	3.50
Sug.	1.50-2.00	und. .08	.40-.60	.60-.80		

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* "und." is abbreviated from under and "sug." from suggested.

Locomotive Cylinders.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total. Carb. Per cent.
126	1.25–1.75	und.* .10	und. .90			
57	1.40–2.00	und. .085	und. .60	und. .70		
	1.25–1.50	.06–.08	.40–.60	.45–.60	.50–.70	3.50
	1.00–1.40	und. .11	.40–.90	.40–.90		
	1.41	.092	.38	.39		
	1.56	.061	.45	.78		
Sug.*	1.00–1.50	.08–.10	.30–.50	.80–1.0		

Locks and Hinges. See Hardware, Light.

Machinery Castings, Heavy.

171	1.05	.110	.54	.35	.33	2.98
178	.85	.030	.35	.92		
63	.80-1.50	.030-.050	.35-.50			
	.90-1.50	.09-1.2	.15-.40	.20-.80	.10-30	2.50-2.90
	1.85	.100	.50	.60		3.50
	1.30	.090	.40	.60		
	1.85	.120	.60	.45		3.40-3.55
	1.75	.100	.50	.70	.80	3.65
Sug.	1.00-1.50	und. .10	.30-.50	.80-1.0		low

Machinery Castings, Medium.

171	1.83	.078	.50	.31	.43	2.93
	2.25	.080	.55	.60		
	1.60	.060	.66			
	2.29	.071	.66	.49		
	1.60	.090	.50	.60		
	2.10	.110	.67	.50		3.40-3.55
	2.25	.060	.75	.55		
	2.00	.100	.75	.50	.75	3.50
	1.76	.075	.63	.79	.56	3.68
	2.00	.100	.50	.50	.50	3.60
	2.35	.075	.45	.65	.30	
	1.80	.060	.80	.50	.70	
	2.06	.075	.78	.47		3.45
	1.40	low	.20	.40		
	2.00	.030	.70			
	1.85	.08	.60	.50-.60	.50	3.25-3.50
	1.50-2.10	.08-.09	.40-.80	.20-.60	.10-.40	2.60-3.20
	1.80-2.10	und. .09	.40-.90	.40-.90		
Sug.	1.50-2.00	und. .09	.40-.60	.60-.80		

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* "und." is abbreviated from under and "sug." from suggested.

Machinery Castings, Light.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
171	2.04	.044	.58	.39	.32	3.84
	2.25	.080	.70	.50	.20	3.55
	2.76	.037	1.19		.13	3.66
	2.49	.097	.90	.42		3.40
	2.51	.084	.62	.61		3.46
	2.50	.100	.60	.70		3.50
	3.00	.060	.65	.50		3.50
	2.40	.050	.47	.59		
	2.85	.064	.67	.65		
	2.52	.062	.66	.68		
	3.15	0.50				
	2.50	.100	.70	.60		3.40-3.55
	2.20-2.80	.06-.08	.60-1.3	.20-.40	.10-.60	3.00-3.60
Sug.*	2.00-2.50	und.* .08	.50-.70	.50-.70		

Machine Tool Castings. See Machinery Castings.

Motor Frames, Bases and Spiders. See Dynamo.

Molding Machines. See Machinery Castings.

Mowers. See Agricultural Machinery.

Niter Pots. See Acid Resisting Castings and Heat Resisting Castings.

Ornamental Work.

171	4.19	.080	1.24	.67	.03	2.88
	2.51	.110	.62	.41	.24	3.18
	2.25		.60-.90			
Sug.	2.25-2.75	und. .08	.60-1.0	.50-.70		

Permanent Molds.

134	2.15	.086	1.26	.41	.13	3.30
134	2.02	.070	.89	.29	.84	3.60
Sug.	2.00-2.25	und. .07	.20-.40	.60-1.0		

Permanent Mold Castings.

93	2.00-3.00					3.00-4.00
	1.50-3.00	und. .06		und. .40		

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* "und." is abbreviated from under and "sug." from suggested.

Piano Plates.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
197	2.00	low	.40	.60		
Sug.*	2.00-2.25	und.* .07	.40-.60	.60-.80		
Pillow Blocks.						
	1.60	.040	.55	.55	.30	3.50
Sug.	1.50-1.75	und. .08	.40-.50	.60-.80		
Pipe.						
	2.00	.060	.60	.60		
	2.00	.060	1.00	.60		
Sug.	1.50-2.00	und. .10	.50-.80	.60-.80		
Pipe Fittings.						
198	2.88		.41	1.10		
	1.70	.058	.50	.73	1.16	4.18
	2.51	.110	.62	.41	.24	3.18
Sug.	1.75-2.50	und. .08	.50-.80	.60-.80		
Pipe Fittings for Superheated Steam Lines.						
75	1.72	.085	.89	.48	.17	2.45
75	1.40-1.60	.06-.09	.20-.40	.45-.75		3.00-3.25
Sug.	1.50-1.75	und. .08	.20-.40	.70-.90		low
Piston Rings.						
137	1.35			.40		
	1.60	.08	1.15	.35	.60	
	1.50-2.00	.06-.08	.40-.60	.45-.60	.45-.55	3.50
Sug.	1.50-2.00	und. .08	.30-.50	.40-.60		low
Plow Points, Chilled.						
197	1.20-1.40		low			low
	1.20	.090	.30	.50	1.20	3.20
	.75	.090	.30	.30	3.00	3.20
	1.20	.080	.30	1.25		3.50
Sug.	.75-1.25	und. .08	.20-.30	.80-1.0		

Printing Presses. See Machinery Castings.

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* "und." is abbreviated from under and "sug." from suggested.

Ref.	Silicon.	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Propeller Wheels.						
	1.15		.32	.51	.60	
	1.40	low	.20	.40		
Sug.*	1.00-1.75	und.* .10	.20-.40	.60-1.0		low
Pulleys, Heavy.						
	1.75	.040	.55	.55	.30	3.57
	2.40	.060	.60	.60		3.75
Sug.	1.75-2.25	und. .09	.50-.70	.60-.80		
Pulleys, Light.						
64	2.20-2.80	und. .08	und. .70	und. .70		
14	2.40	und. .08	.95	.70		
	2.72	.040	.50	.66		
	2.52	.075	.77	.68		3.37
	3.35	.089	.70	.47		3.42
	2.25	.040	.55	.55	.30	3.57
	2.15	.080	.70	.60	.40	3.55
Sug.	2.25-2.75	und. .08	.60-.80	.50-.70		
Pumps, Hand.						
	2.30-2.75	und. .08	.60-1.0	.30-.50		
Sug.	2.00-2.25	und. .08	.60-.80	.50-.70		
Radiators.						
	2.15	low	.80	.45	.50	3.50
	2.45	.104	.44	.40	.35	3.40
Sug.	2.00-2.25	und. .08	.60-.80	.50-.70	.50-.60	
Railroad Castings.						
64	2.20-2.80	und. .08	und. .70	und. .70		
	1.40-1.80	.06-.08	.50-.80	.45-.60	.40-.65	3.50
	2.25	.050	.60	.75		
	1.75	.070	.85	.60		
Sug.	1.50-2.25	und. .08	.40-.60	.60-.80		
Retorts. See Heat Resistant Castings.						
Rolls, Chilled.						
171	.50-1.00	.01-.06	.20-.80	.15-1.5	2.60-3.25	
171	.80	.100	.88	.16	.91	2.84
171	.71	.058	.54	.39	1.38	3.00
173	.65	.050	.25	1.50	.63	3.50
Sug.	.60-.80	.06-.08	.20-.40	1.0-1.2		3.00-3.25

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* "und." is abbreviated from under and "sug" from suggested.

Ref.	Silicon. Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
Rolls, Unchilled (sand cast).						
171	.75	.030	.25	.66	1.20	4.10
Scales.						
198	1.67		1.92	1.90		
198	2.12		.61	.80		
198	1.70		.63	1.60		
Sug.*	2.00-2.30	und.* .08	.60-1.0	.50-.70		
Slag Car Castings.						
	1.76	.075	.63	.79	.56	3.68
	2.00	.030	.70			
Sug.	1.75-2.00	und. .07	und. .30	.70-.90		
Smoke Stacks, Locomotive. See Locomotive Castings.						
Soil Pipe and Fittings.						
	2.00	.060	.100	.60		
Sug.	1.75–2.25	und. .09	.50-.80	.60-.80		
Steam Cylinders, Heavy.						
	1.41	.092	.38	.39		
	.95	.100	.30	.90	.80	3.40
	1.10	.136	.43	.33	.99	3.30
	1.00	.080	.20-.30	1.00	.75	3.00
	1.35-1.50	.080	.50	.75		3.65
	1.20-1.40	.04-.08	.40-.50	.70-.80	.70-.80	3.00-3.20
111	.90-1.20	.09-.12	.20-.40	.70-.90		und. 3.50
Sug.	1.00-1.25	und. .10	.20-.40	.80-1.0		low
Steam Cylinders, Medium.						
70	1.66	.065	.70	.90		
70	1.60	.063	.72	.85		
70	1.70	.070	.70	.75		
70	1.70	.075	.60	.92		3.50
14	1.40-2.00	.085	.70	.30-.70		
64	1.50-2.00	und. .08	.35-.60	.50-.80		
	1.40-1.60	und. .09	.40-.90	.40-.90		
	1.50-1.65	.080	.60	.60-.70		
	1.50-1.80	.070	.43	.76		

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* "und." is abbreviated from under and "sug." from suggested.

Steam Cylinders, Medium—Continued.

Ref.	Silicon Per cent.	Sulphur. Per cent.	Phos. Per cent.	Mang. Per cent.	Comb. Carb. Per cent.	Total Carb. Per cent.
	1.85	.080	.60	.50-.60	.50	3.25-3.50
	1.75	.100	.65	.55		3.40-3.55
	1.32	.136	.43	.38	.99	3.30
	1.12	.085	.40	.70	.70	3.50
	2.00	.100	.50	.70	.40	3.50
	2.00	.070	.30	.60		
	1.50	.070	.75	.70		3.50
	1.59	.109	.60	.38		3.34
	1.86		.29	.55	.52	
	1.90	.074	.50	.65		
	1.56	.061	.45	.78		
Sug.*	1.25-1.75	und.* .09	.30-.50	.70-.90		

Steam Chests. See Locomotive Castings and Machinery Castings.

Stove Plate.

Ref.	Silicon	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
198	2.90		.73	1.40		
171	2.59	.072	.62	.37	.35	3.30
171	3.19	.084	1.16	.38	.33	3.41
	2.75	.050	1.00	.80	.18	3.38
	2.79	.077	1.40	.32	.20	3.22
	2.51	.110	.62	.41	.24	3.18
	2.76	.071	.63	.63	.37	3.50
	2.76	.084	.65	.54		
	2.50	0.60	1.00	.60		
	2.60	.050	.60	.60		
	2.50-3.00	und. .10	.60-.80	.40-.60		3.00-4.00
Sug.	2.25-2.75	und. .08	.60-.90	.60-.80		

Valves, Large.

Ref.	Silicon	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
64	1.20-1.50	und. .09	.35-.60	.50-80		
136	1.00	1.00	.50	.90		
	1.67		.26	.45	.69	
Sug.	1.25-1.75	und. .09	20-.40	.80-1.0		

Valves, Small.

Ref.	Silicon	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
	1.70	.058	.50	.74	1.16	4.18
	2.23	.075	.67	.67		
Sug.	1.75-2.25	und. .08	.30-.50	.60-.80		low

Valve Bushings. See Locomotive Castings and Machinery Castings.

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* "und." is abbreviated from under and "sug." from suggested.

Water Heaters.

Ref.	Silicon.	Sulphur.	Phos.	Mang.	Comb. Carb.	Total Carb.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
	2.15	.050	.40	.50		
Sug.*	2.00-2.25	und.* .08	.30-.50	.60-.80		
Weaving Machinery. See Machinery Castings.						
Wheels, Large.						
	2.10	.040	.40	.70		
Sug.	1.50-2.00	und. .09	.30-.40	.60-.80		
Wheels, Small.						
	2.10	.050	.40	.50		
	1.60	.083	.60	.39		
Sug.	1.75-2.00	und. .08	.40-.50	.50-.70		
Wheel Centers. See Locomotive Castings.						
White Iron Castings.						
	.50	.150	.20	.17	2.90	
	.90	.250	.70	.50		2.50
Wood Working Machinery. See Machinery Castings.						

DIRECTORY OF PIG IRON BRANDS.

As an introduction to this section a brief description and discussion of the methods used for grading pig iron may be of service.

Pig iron may be classified from several points of view. According to the furnace practice it is cold, warm or hot blast iron. On the basis of the fuel used in its manufacture it is coke, anthracite, or charcoal pig. According to the method of casting it is sand, chill or machine cast. Finally, according to its chemical composition it is basic, Bessemer, malleable, foundry or forge iron. To completely describe any given brand we must classify it in all four ways; thus for example, we might say of a certain iron that it was hot blast, coke chilled, basic.

The terms used in the first three classifications hardly need definition since they are self-explanatory. With regard to the

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* "und." is abbreviated from under and "sug." from suggested.

last it may be well for the sake of completeness to define these grades.

Basic iron means primarily a low silicon iron, the standard for this grade having silicon under 1 per cent., and sulphur under .050 per cent.

Similarly, Bessemer iron means primarily phosphorus under .10 per cent. Standard Bessemer contains 1.00-1.25 per cent. silicon, with sulphur under .050 per cent., but the grade is essentially based on low phosphorus. Irons with extra low phosphorus and variable silicon sometimes go under the designation of "low phosphorus" iron.

Finally, the terms foundry and forge embrace practically everything in the way of ordinary iron, these grades being subdivided again on the basis of silicon and sulphur content. The following subclassification of foundry and forge irons has been agreed upon by the blast furnace interests of the districts indicated.

CLASSIFICATION AND GRADES OF FOUNDRY IRON.

	Silicon.	*Sulphur.*
Southern Points.		
No. 1 Foundry	2.75-3.25 per cent.	.05 per cent. and under
No. 2 "	2.25-2.75 " "	.05 " " " "
No. 3 "	1.75-2.25 " "	.06 " " " "
No. 4 "	1.25-2.00 " "	.07 " " " "
Gray Forge	1.25-1.75 " "	.08 " " " "
No. 1 Soft	3.00 and over	.05 " " " "
No. 2 Soft	2.50-3.25 per cent.	.05 " " " "
Eastern Points.		
No. 1 X	2.75 per cent. and up	.030 per cent. and under
No. 2 X	2.25-2.75 " "	.045 " " " "
No. 2 Plain	1.75-2.25 " "	.050 " " " "
No. 3 Foundry	1.25-1.75 " "	.065 " " " "
No. 2 Mill	1.25 " " and under	.065 " " " "
Gray Forge	1.50 " "	.065 " " " up
Mottled and White by Fracture		
Central West & Lake Points.		
No. 1 Foundry	2.25-2.75 per cent.	.05 per cent. and under
No. 2 "	1.75-2.25 " "	.05 " " " "
No. 3 "	1.75 " " and under	.05 " " " "
Gray Forge		.05 " " " over

	Silicon.	*Sulphur.*
Buffalo Grading.		
Scotch	3.00 per cent. and over	.05 per cent. and under
No. 1 Foundry	2.50-3.00 “ “	.05 “ “ “ “
No. 2 “	2.00-2.50 “ “	.05 “ “ “ “
No. 2 Plain	1.50-2.00 “ “	.05 “ “ “ “
No. 3 Foundry	1.50, “ “ (under)	.05 “ “ “ “
Gray Forge		.05 “ “ (over)

NOTE.—If sulphur is in excess of maximum, it is graded as lower grade, regardless of silicon.

Charcoal is not as a rule graded according to the above table, but is sold by fracture, by analysis, by chill tests, or by some special system of grading according to the custom of the maker and demand of the purchaser.

NOTE.—Analyses of numerous brands of pig iron accompanied this report, but it has been deemed best not to place them in this work.

GRADING PIG IRON, ALLOYS AND COKE.

Standard Analyses of the Various Grades of Foundry and Steel Making Irons, Ferro-alloys and Melting Fuels.

The following grading of pig iron, ferro-alloys and coke was prepared by Eliot A. Kebler, manager of sales of Matthew Addy & Co., Cincinnati, the foreign pig iron classification being furnished him by W. W. Hearne, the Philadelphia partner of the same company:

Standard Bessemer.—This iron is used principally for making acid Bessemer steel, this process burning out the impurities by blowing air through the molten Bessemer metal.

As neither this, nor the acid open-hearth, process removes any phosphorus, it must be low.

The standard specification is as follows:

Silicon	1 to 2 per cent.
Phosphorus	not over 0.10 “
Sulphur	not over 0.05 “

In the central section of this country it is sold per ton, 2,268 pounds, if sand cast, or 2,240 pounds, if chill cast, except for special purposes, where the sand iron is broken, in which case it may be sold per ton, 2,240 pounds, and a charge of 25 cents per ton may be added for breaking.

In the east and west (Chicago) it is always sold per ton, 2,240 pounds.

Malleable Bessemer or Malleable,—This is used for the manufacture of malleable castings. The usual specification is:

Phosphorus	not over 0.20	per cent
Sulphur	not over 0.05	“
Silicon as specified, usually	0.75 to 1.25	“
	or 1.25 to 1.75	“

Pigs are usually broken if sand cast, and both sand and chill cast are sold per ton, 2,240 pounds, except from a few furnaces in the central district which still sell some unbroken and also some broken malleable per ton, 2,268 pounds.

Low Phosphorus.—This is used for making acid steel extra low in phosphorus. The usual specification (sometimes called special low phosphorus) is:

Silicon	1 to 2	per cent.
Phosphorus	not over 0.035	“
Sulphur	not over 0.035	“

For baby Bessemer converters, the silicon is desired as high as possible. It is sold per ton, 2,240 pounds.

Washed Metal.—This is Bessemer iron from which a large part of the phosphorus and sulphur, and practically all the silicon and manganese have been removed from the molten metal by one of the pig washing processes. It is largely used in acid open-hearth furnaces for steel castings and fire-boxsteel, and also in making crucible steel. It is sold by analysis, the four analyses recognized being:

Phosphorus	not over 0.010	per cent.
Sulphur	not over 0.015	“
Phosphorus	not over 0.015	“
Sulphur	not over 0.020	“
Phosphorus	not over 0.020	“
Sulphur	not over 0.025	“
Phosphorus	not over 0.025	“
Sulphur	not over 0.030	“

It is cast on an iron plate, and comes in irregular pieces about 8 inches square. It is sold per ton, 2,240 pounds.

Basic.—This iron is used for making basic steel and can contain any phosphorus, as the basic flux and lining by combining with the phosphorus prevent it from entering the steel. As silicon attacks the lining and requires more flux, it is always specified under 1 per cent., and the basic pig is always sandless; that is, cast in chill molds. The sulphur is specified under 0.05. Basic iron is sold per ton, 2,240 pounds.

Iron Graded by Fracture.—This method of grading is being rapidly superseded by analysis grading.

No. 1 Foundry.—Fracture contains large crystals.

No. 2 Foundry.—This is considered the standard and contains medium-size crystals, say ⅛ inch square, with no spot larger than 1 inch diameter without crystals, although pig can be close for ¼ inch along edges.

No 3. Foundry.—Contains small crystals; fracture is close.

East of Altoona, Pa., and throughout all of New York state these grades are: No. 1X, No. 2X, No. 2 plain.

No. 1 is the highest priced, the usual differential being 50 cents a ton.

Forge has a gray fracture with practically no crystals.

Mottled shows small white spots, giving the fracture a mottled appearance. Most of the carbon is in the combined state.

White shows a white fracture, and all carbon is in the combined state.

These last two grades are usually high in sulphur and low in silicon.

In the South, iron which has a silvery fracture is graded as follows:

No. 1 soft (sold same price as No. 1 foundry).

No. 2 soft (sold same price as No. 2 foundry).

No. 4 foundry (price is between No. 3 foundry and gray forge).

Foundry pigs cast in sand are always broken, and all the furnaces outside of a few of the central district irons are now sold per ton, 2,240 pounds. These few sell 2,268 pounds to a ton, the extra 28 pounds being added to cover sand clinging to the pig.

Forge, mottled and white iron may be unbroken or broken and is sold per ton, 2,240 pounds, with the exception of some central district irons, which are sold per ton, 2,268 pounds.

All pig iron cast in chills is sold by analysis per ton, 2,240 pounds.

American Foundry and Forge Iron by Analysis.—A committee appointed by the blast furnace interests has made the following classification by analysis, and the tendency is to sell iron by analysis instead of fracture.

SOUTHERN POINTS.

	Silicon, per cent.	Sulphur, per cent.
No. 1 foundry	2.75 to 3.25	0.05 and under
No. 2 foundry	2.25 to 2.75	0.05 and under
No. 3 foundry	1.75 to 2.25	0.06 and under
No. 4 foundry	1.25 to 2.00	0.065 and under
Gray forge	1.25 to 1.75	0.07 and up
No. 1 soft	3.00 and over	0.05 and under
No. 2 soft	2.50 to 3.25	0.05 and under

EASTERN POINTS.

	Silicon, per cent.	Sulphur, per cent.
No. IX	2.75 and up	0.03 and under
No. 2X foundry	2.25 to 2.75	0.045 and under
No. 2 plain	1.57 to 2.25	0.05 and under
No. 3 foundry	1.25 to 1.75	0.065 and under
No. 2 mill	1.25 and under	0.065 and under
Gray forge	1.50 and under	0.065 and up

Note—If sulphur is in excess of maximum, the iron is graded as lower grade regardless of silicon.

CENTRAL WEST AND LAKE POINTS.

	Silicon, per cent.	Sulphur, per cent.
No. 1 foundry	2.25 to 2.75	0.05 and under
No. 2 foundry	1.75 to 2.25	0.05 and under
No. 3 foundry	1.75 and under	0.05 and under
Gray forge		0.05 and over

BUFFALO DISTRICT.

	Silicon, per cent.	Sulphur, per cent.
Scotch	3.00 and over	0.05 and under
No. 1 foundry	2.50 to 3.00	0.05 and under
No. 2 foundry*	2.00 to 2.50	0.05 and under
No. 2 plain	1.50 to 2.00	0.05 and under
No. 3 foundry	1.50 (under)	0.05 and under
Gray forge		0.05 (over).

CHICAGO POINTS.

	Silicon, per cent.	Sulphur, per cent.
No. 1 foundry	2.25 to 2.50	0.02 to 0.05
No. 2 foundry	1.75 to 2.25	0.02 to 0.05
No. 3 foundry	1.35 to 1.75	0.06 and under
Scotch	2.50 to 3.00	0.05 and under
Silvery	2.00 to 3.50	0.05 and under
Gray forge		0.06 and over.

Sampling.—The American Society for Testing Materials recommends the following method of sampling, which has been adopted by the American Foundrymen's Association:

In all contracts where pig iron is sold by chemical analysis each car load or its equivalent shall be considered as a unit. At least one pig shall be selected at random from each four tons of every carload, and so as to fairly represent it.

Drillings shall be taken so as to fairly represent the fracture surface of each pig, and the sample analyzed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis.

In case of disagreement between buyer and seller, an independent analyst, to be mutually agreed upon, shall be engaged to sample and analyze the iron. In this event each pig shall be taken to represent every two tons.

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* No. 2 foundry and No. 2X foundry are the standards, and No. 2 soft sells at the same price. No. 1 foundry or No. 1 soft sells usually 50 cents higher, and "silvery" still higher, depending on silicon contents. The other grades decrease about 50 cents a grade.

"Scotch" indicates a more fluid iron, usually higher in phosphorus and silicon than the ordinary furnace run.

In selling by analysis the tendency is to do away with the numbers and merely give the limits in silicon and sulphur.

The cost of this sampling and analysis shall be borne by the buyer if the shipment is proved up to specifications, and by the seller if otherwise.

High Silicon Irons.—*Softeners* are sold by silicon contents and run from 6 to 10 per cent. silicon, the price increasing about 50 cents per unit of silicon.

Silvery irons run from about 3½ to 5½ per cent. of silicon. This last class is sometimes divided into No. 1 Silvery, which is the higher silicon, and No. 2 Silvery, the lower.

The still higher silicon irons are shown under ferro-alloys.

In addition to this, there is a special high silicon, usually 50 per cent. silicon, although it is sometimes sold as high as 75 per cent. silicon, made in an electric furnace.

Ferro-Manganese.—This is ordinarily sold with a guarantee of 80 per cent. manganese, this being the only element which is guaranteed.

Owing to the lower phosphorus in English cokes, the English ferro-manganese ordinarily runs a little lower in phosphorus than that made in Germany.

Foreign Iron.—All pig iron is sold in England per ton, 2,240 pounds, and in France and Germany per 1,000 kilos.

In England and Europe generally, iron is not called Bessemer, as both acid and basic Bessemer converters are used.

Hematite.

Silicon	about 2.50	per cent.
Sulphur	usually about 0.035	"
Phosphorus	usually 0.035	"
It seldom running over	0.06	"

West Coast hematite shows manganese under 0.50; East Coast hematite has manganese over 0.75.

Thomas Gilchrist, or Thomas Pig Iron.—This is used in basic Bessemer converters and usually analyzes about:

Silicon	0.50	per cent.
Phosphorus	2.50	"
Manganese	2.50	"
Sulphur	up to 0.20	"

Open-hearth Basic.—There is practically no open-hearth basic in Europe or England. At Middleboro the Bells are making open-hearth basic, but their pig analyzes:

Silicon	0.75 to 1.50	per cent.
Phosphorus	1.00 to 1.65	"
Sulphur	up to 0.20	"

They use a mixer and a desulphurizing bath.

English Foundry Iron.—This is graded by fracture and no analysis is guaranteed. The rules for standard foundry pig iron issued by the London Metal Exchange are as follows, and it will be noted that instead of grading by silicon content, as in this country, sulphur seems to be the ruling element:

	Silicon, per cent.	Phosphorus, per cent.	Sulphur, per cent.
No. 1,	2½ to 3½	not over 1.00	not over 0.04
No. 2,	2½ to 3½	not over 1.25	not over 0.05
No. 3,	1 not over 3½	not over 1.65	not over 0.08
No. 4,	1 not over 3	not over 1.75	not over 0.10

The ordinary English pig irons can be divided into two groups, with

Manganese	under 0.75	per cent.
And Manganese	say 0.75 to 1.10	"

The brand and grade mostly imported into this country is:

Middlesboro, No. 3. Analysis unguaranteed, but usually shows:

Phosphorus	1.40 to 1.50	per cent.
Manganese	0.40 to 0.75	"
Silicon, usually high	say 2.50	"
Sulphur	0.02 to 0.05	"

The No. 1 has practically the same analysis, except that the sulphur is extremely low.

All Mine Pig Iron.—Analysis about as follows:

Phosphorus	0.20 to 0.70	per cent.
Sulphur	0.06 to 0.20	"
Manganese	under 0.75	"

The Scotch pig iron is also sold by fracture, a typical analysis of No. 3 being

Phosphorus	0.60 to 1.15	per cent.
Manganese	1.10 to 1.80	"
Sulphur	about 0.03	"
Silicon	about 2 to 2.50	".

American Charcoal Irons.—These irons are divided into two classes:

Cold Blast, which is made in small furnaces with a capacity of about four to eight tons a day, blown with unheated air.

Warm Blast, in which the blast is heated from 500 to 900 degrees Fahr.

Cold Blast Iron.—This iron is used principally for making chilled rolls and is graded as follows outside the Lake Superior region:

No. 1, highest silicon, lowest sulphur iron with a fracture like a No, 3 coke iron.

No. 2 has a fracture like a forge and will chill ⅛ inch when cast against an iron plate.

No. 3 shows a ¼-inch chill.

No. 4 a ⅜-inch to ¾-inch chill.

No. 5 a ¾-inch to 1½-inch chill, the face of the pig being strongly mottled.

No. 6 is white, all of the carbon being in a combined state.

Warm Blast Iron.—This iron is used principally for car-wheel work, for strengthening general machinery castings, and making rolls.

Outside of the Lake Superior region it is graded as follows:

No. 1 highest silicon, lowest sulphur iron, with a fracture like a No. 2 coke iron.

No. 2 has a fracture like a No. 3 coke iron.

No. 3 has a fracture similar to forge.

No. 4 will show a chill of about ¼ inch if cast against an iron plate.

No. 5, a chill of about ¼ inch to ¾ inch.

No. 6 will show a chill of about ¾ to 1½ inches and is mottled when cast in sand.

No. 7 has a white fracture. Carbon is all combined.

The Lake Superior charcoal irons are graded, not by fracture, but by analysis, the following classifications being most generally used.

	Silicon, per cent.			
	Average.	Min.	Max.	Chill.
A Scotch	2.50	2.38	2.62	
B Scotch	2.25	2.13	2.37	
C Scotch	2.00	1.88	2.12	
Low 1	1.75	1.63	1.87	
High 1........	1.50	1.38	1.62	
Low 2	1.25	1.13	1.37	
High 2........	1.00	.88	1.12	
Low 3	.75	.63	.87	Trace to ¼ in.
High 3........	.56	.50	.62	¼ to ⅝ in.
Low 4	.44	.38	.50	⅝ to 1 in.
High 4........	.32	.25	.38	1 to 1½ in.
Low 5	.20	.15	.25	Low Mottled.
High 5........	.10	.05	.15	White Mottled.
No. 6	.00	.00	.05	White.
Phosphorus				0.15 to 0.23
Manganese				0.30 to 0.70
Sulphur				Trace to 0.018

Coke.—This is divided into the following classes:

Foundry.—This coke is selected from ovens which have burned 72 hours. It is always made on Mondays and Tuesdays, as no work is done at the ovens on Sunday. It may be made on other days of the week by shutting down another day. It is hard and large and has a bright appearance, caused by the carbon condensing or fusing on the surface. This coke is used in cupolas for melting iron and for heavy forging work.

Furnace.—This is coke that is burned 48 hours and is used in smelting ores in blast furnaces. It is sometimes used in cupola practice.

Standard Foundry and Furnace Coke.—Sulphur under 1 per cent., the lower the better. Ash not over 13 per cent.; quality improves with the reduction in ash, until percentage is reduced to a point where structure is weakened.

Smelter coke is either of the above, running, say, over 1.20 per cent. in sulphur. While this higher sulphur renders it undesirable for smelting or melting iron, it does no harm in the smelting of most other ores.

Stock.—This coke is stocked on the oven yard instead of being loaded direct into the car. If care is used in selecting this coke when loading, it is as good as if freshly drawn, with the exception that it is somewhat broken up by the double handling and is discolored.

Soft, Heating or Jamb.—This coke is the cullings from the above classes and is made up of the backs, fronts, and coke around the oven doors. This is often incorrectly called stock coke.

Crushed Coke.—This is crushed and graded according to size into the following classes:

Egg, large stove, small stove, chestnut, ⅞-inch pea, ½-inch pea, dust. The first four grades are used for house heating, small forgings, etc., the pea coke for chemical works, etc., and the dust for packing the bottoms of soaking pits and crucible furnaces.

Ferro-Alloys.—Owing to the fact that many of the ferro-alloys have only been in use for a comparatively short time, the fixed standards have not in many cases been adopted. One company designates its material by showing the number of units of carbon by "X" and the kind of alloy by its letter symbol, thus a ferrochrome containing 9.70 carbon, it would designate 9 x C.

All foreign ferro-alloys are sold to the American consumers f. o. b. cars American seaboard, based on present duties, United States custom-house weights at seaboard to govern settlement, and upon certificate of foreign chemist of repute to be conclusive as to quality.

Ferro-aluminum is sold containing 10 per cent. aluminum. Higher percentages are also used in iron and steel, No. 1 being guaranteed over 99 per cent. pure aluminum. No. 2 is guaranteed over 90 per cent. aluminum, with no injurious impurities for alloying with iron and steel. It is sold by the pound.

S. A. M. Alloy.—This is an alloy of silicon, aluminum, manganese and iron. One partial analysis showed:

Silicon	8.01	per cent.
Aluminum	6.80	"
Manganese	8.39	"
Phosphorus	0.075	"

Ferro-chrome usually runs 60 per cent. to 68 per cent. chromium. It is graded per unit of chromium and per unit of carbon, the price increasing with the chromium and decreasing with the increase in carbon, these elements being guaranteed. If low in carbon, it is sometimes called "mild."

A typical analysis only guaranteed as above is as follows:

	Mild, per cent.	Ordinary, per cent.
Chromium	64.80	66.00
Iron	33.43	21.91
Carbon	1.21	9.90
Silicon	0.29	1.40
Phosphorus	0.027	0.07
Sulphur	0.02	0.22
Manganese	0.09	0.20
Copper	0.12	....
Aluminum	....	....

It is sold per ton, 2,240 pounds.

Ferro-mangarese contains over 40 per cent. manganese.

Standard ferro-manganese is only guaranteed to average 80 per cent. or over manganese. The English runs lower in phosphorus than that from the continent. A typical analysis, manganese only guaranteed, is as follows:

	English.	
Manganese	80.50	per cent.
Iron by dif.	11.50	"
Silicon	1.65	"
Phosphorus	0.23	"
Carbon	6.78	"
Sulphur	....	"

It is sold per ton, 2, 240 pounds.

Ferro-molybdenum is sold per pound of pure molybdenum contained, regardless of the percentage of other material. Thus, if a pound of 80 per cent. ferro-molybdenum is purchased, 1 ¼ pounds of the alloy will be received. A typical analysis, the units of molybdenum only guaranteed, is as follows:

Molybdenum	79.15	per cent.
Iron	17.55	"
Carbon	3.24	"
Phosphorus	0.028	"
Sulphur	0.021	"

Nickel.—As ordinarily used in steel this is guaranteed over 99 per cent. nickel and is sold by the pound.

Ferro-nickel is also supplied with 25, 35, 50 or 75 per cent. of nickel as specified. The balance of analysis outside of the nickel and iron runs about:

Carbon	0.85	per cent.
Silicon	0.25	"
Sulphur	0.015	"
Phosphorus	0.025	"

Ferro-phosphorus contains over 10 per cent. of phosphorus. The foreign is guaranteed 22 to 24 per cent. phosphorus.

A typical analysis of foreign, the phosphorus alone being guaranteed, is as follows:

Phosphorus	21.40	per cent.
Iron	75.03	"
Manganese	0.70	"
Silicon	1.63	"
Carbon	1.17	"

The domestic is guaranteed:

Phosphorus	18 to 22	per cent.
Sulphur	under 0.05	"
Manganese	under 0.50	"

It is sold per ton, 2,240 pounds.

Phosphor-Manganese.—A typical analysis is:

Manganese	65.00	per cent.
Phosphorus	25.00	"
Iron	7.00	"
Carbon	2.00	"
Silicon	1.00	"

Silico-Spiegel contains manganese 17 to 22 per cent. and silicon 6 to 12 per cent. The standard is guaranteed as follows:

Manganese	18 to 20	per cent.
Silicon, 9 to 11 per cent	average 10	"

A typical analysis, nothing but manganese and silicon guaranteed, is as follows:

Manganese	20.32	per cent.
Iron by dif.	68.02	"
Silicon	10.33	"
Carbon	1.26	"
Phosphorus	0.07	"
Sulphur	....	"

It is sold per ton, 2,240 pounds.

Special High Silicon contains over 40 per cent. silicon. It is guaranteed 50 per cent. silicon with an allowance of $1.75 per unit either way. The other elements are not guaranteed. A typical analysis is:

Silicon.	49.90	per cent.
Manganese	0.16	"
Carbon	0.55	"
Phosphorus.	0.075	"
Sulphur.	0.018	"

It is also guaranteed 75 per cent. silicon, with an allowance of $2.50 per unit either way. It is sold per ton, 2,240 pounds.

Bessemer Ferro-Silicon.—This runs 8 to 16 per cent. in silicon,, the price usually increasing or decreasing $1 per unit.

The "Domestic" is guaranteed silicon as specified 8 to 16 per cent.

Phosphorus.	not over 0.10	per cent.
Sulphur	not over 0.05	"

The "Foreign" is not guaranteed, but phosphorus and sulphur, while not guaranteed, run very low. It is sold per ton 2,240 pounds. For lower percentages of silicon see "High Silicon Irons."

Ferro-Sodium is usually sold with 25 per cent. metallic sodium and free from lime or excess of carbon.

Spiegel, Spiegel-Eisen or Mirror Iron contains 10 to 40 per cent. of manganese. The standard is guaranteed:

	Per cent.
Manganese, 18 to 22 per cent	average 20
Phosphorus	0.10 or under.

The silicon limits are sometimes specified, as it is desirable to know how the same will run. A typical analysis only guaranteed as above, is as follows:

Manganese	20.50	per cent.
Iron.	73.61	"
Silicon.	0.76	"
Carbon	5.18	"
Sulphur.	0.002	"
Phosphorus.	0.055	"

It is sold per ton, 2,240 pounds.

Ferro-Titanium.—The lower titanium contents is sold guaranteed only in titanium, which is 10 to 12 per cent., and is sold by the pound of alloy.

A typical analysis is:

Titanium	11.21	per cent.
Iron by dif.	87.68	"
Carbon	0.67	"
Silicon.	0.37	"
Phosphorus.	0.04	"
Sulphur	0.03	"

If higher in titanium, it is sold per pound of pure titanium contained, regardless of the percentage of other material, the titanium above being specified. A typical analysis is as follows:

Titanium	51.30	per cent.
Iron	44.18	“
Carbon	2.82	“
Manganese	0.14	“
Arsenic	1.10	“
Sulphur	0.04	“
Phosphorus	0.021	“
Aluminum	0.41	“

Ferro-Tungsten is sold per pound per unit of tungsten contained, the price increasing with the increase in tungsten and decreasing with the increase in carbon. A typical analysis, the tungsten and carbon only being guaranteed, is as follows:

Tungsten	85.47	per cent.	61.20	per cent.
Iron	13.90	“	33.02	“
Carbon	0.30	“	2.97	“
Silicon	0.13	“	0.47	“
Manganese	0.09	“	1.88	“
Aluminum	0.00	“	0.31	“
Phosphorus	0.019	“	0.03	“
Sulphur	0.025	“	0.03	“

Ferro-Vanadium is sold per pound at price per unit of vanadium contained; that is, if alloy contains 20 per cent. vanadium and selling price is five cents per unit, it would cost $1 per pound of alloy. A typical analysis as made by one foreign company, vanadium alone being guaranteed, is as follows:

Vanadium	36.0	per cent.
Manganese	0.6	“
Iron	61.0	“
Carbon	0.4	“
Silicon	0.9	“
Aluminum	0.8	“

CHAPTER XII.

ANALYSIS AND FOUNDRY CHEMISTS.

Inaccuracy of Analysis.—One of the obstacles to the success of chemistry in foundry irons has been inaccuracy in the analysis of iron. In the early stages of the employment of chemists by foundrymen, it was found that their analyses frequently differed very materially from those furnished from the furnace with the iron. This led to the declaration by foundrymen that blast furnace analysis could not be depended upon for accuracy and a counter claim by blast-furnacemen that the foundry chemist's analysis was not correct. To determine who was right in the matter, samples taken from the same pigs of three different grades of iron were sent for analysis to twenty different firms employing competent chemists. The report of analysis from these firms as read before the Pittsburg Foundrymen's Association, by Thos. D. West, March 28th, 1898 is given below.

TABLE I.

COMPARATIVE ANALYSES OF FOUNDRY IRON.

No.	Laboratory.	Sil.	Sul.	Phos.	Man.	G. C.	C. C.	T. C.
1	* A	1.95	.011	.60	.63	3.35	.48	3.83
2	B	2.00	.010	.543	.56	....	..	4.27
3	C	2.02	.0045	.615	.56	2.99	.64	3.63
4	D	2.05	.010	.59	.69	3.20	.52	3.72
5	E	2.05	.007	.59	.60	3.41	.45	3.86
6	F	2.06	.011	.617	.62	....	..	3.85
7	G	2.06	.013	.579	....	....	..	....
8	H	2.11	.011	.617	.54	3.12	.80	3.92
9	I	2.13	.006	.503	.56	3.04	.44	3.48
10	J	2.158	.018	....	....	....	..	....
11	K	2.16	.015	.612	.550	....	..	....
12	L	2.19	.012	.591	.504	3.29	.82	4.11
13	M	2.21	.008	.61	.46	2.82	.36	3.18
14	N	2.21	.018	.600	.546	3.59	.32	3.91
15	O	2.22	.020	.54	.59	3.32	.25	3.57
16	P	2.224	.018	.603	.59	3.42	.29	3.71
17	P	2.219	.019	.614	.60	3.45	.23	3.68
18	P	2.228	.017	.610	.58	3.36	.40	3.76
Greatest Variation.		.27	.0155	.114	.23	.77	.59	1.09

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* Corresponding letters in the four tables signify that analyses are from the same laboratory or firm.

TABLE II.

Comparative Analyses of Bessemer Iron.

No.	Laboratory.	Sil.	Sul.	Phos.	Man.	G. C.	C. C.	T. C.
19	A	2.12	.060	.088	.73	3.19	.75	3.94
20	C	2.15	.048	.094	.93	2.78	.85	3.63
21	D	2.20	.056	.086	.91	3.10	.64	3.74
22	F	2.21	.051	.093	.95	....	..	3.81
23	S	2.25	.058	.090	.90	....	..	...
24	E	2.29	.048	.080	1.09	3.14	.57	3.71
25	R	2.30	.051	.087	.910	3.46	.50	3.96
26	B	2.31	.056	.083	.89	....	..	3.80
27	K	2.31	.060	.0865	.890	....	..	....
28	O	2.32	.051	.086	.84	3.06	.25	3.31
29	L	2.32	.055	.111	.809	3.51	.84	4.35
30	Q	2.37	.058	.087	.83	2.92	.82	3.74
31	P	2.445	.064	.086	.93	3.15	.67	3.82
32	P	2.402	.066	.084	.98	3.20	.68	3.78
33	P	2.413	.060	.086	.96	3.12	.72	3.84
Greatest Variation.		.32	.018	.031	.36	.73	.60	1.04

TABLE III.

Comparative Analyses of Charcoal Iron.

No.	Laboratory.	Sil.	Sul.	Phos.	Man.	G. C.	C. C.	T. C.
34	D	.95	.019	.89	1.76	2.90	.78	3.68
35	A	.97	.017	.96	1.77	3.10	.88	3.98
36	L	.97	.013	.929	1.795	2.94	.91	3.85
37	E	.98	.016	.91	1.80	3.01	.79	3.80
38	R	.98	.022	.957	1.98	3.25	.60	3.85
39	C	.99	.016	.956	1.90	2.84	1.02	3.86
40	T	1.00	.016	.952	1.90	2.69	.48	3.17
41	F	1.02	.017	.948	1.93	....	..	3.95
42	B	1.04	.021	.906	1.83	....	..	3.76
43	N	1.09	.033	.932	1.768	3.30	.44	3.74
44	P	1.161	.027	.931	1.85	3.20	.56	3.76
45	P	1.152	.025	.930	1.89	3.28	.44	3.72
46	P	1.157	.024	.939	1.90	3.25	.48	3.73
Greatest Variation.		.21	.020	.067	.22	.61	.58	.30

TABLE IV.

Firms and Chemists Furnishing Comparative Analyses.

Laboratory.	Analyses.	Concerns Furnishing Analyses.
A	3 Sets.	Buffalo Furnace Co., Buffalo, N. Y., Frank Hersh, Chemist.
B	3 Sets.	Carnegie Steel Co., Cochran, Pa., J. M. Camp, Chemist.
C	3 Sets.	Tennessee Coal, Iron & Railroad Co., Birmingham, Ala. J. R. Harris, Chemist.
D	3 Sets.	Embreville Iron Co., Embreville, Tenn., F. E. Thompson, Chemist.
E	3 Sets.	Phillips Testing Laboratory, Birmingham, Ala.
F	3 Sets.	Illinois Steel Co., So. Chicago, Ill.
G	1 Set.	Spearman Iron Co., Sharpsville, Pa., W. E. Dickinson, Chemist.
H	1 Set.	Thomas Iron Co., Hokendauqua, Pa.
I	1 Set.	Everett Furnace, Everett, Pa., F. R. Bennett, Chemist.
J	1 Set.	Booth, Garrett & Blair, Philadelphia, Pa.
K	2 Sets.	Crane Iron Co., Catasauqua, Pa., H. A. Knauss, Chemist.
L	3 Sets.	Hamilton Furnace Co., Hamilton, Ontario.
M	1 Set.	James C. Foster, Sheffield, Ala.
N	2 Sets.	Warwick Iron Co., Pottstown, Pa., Wm. A. Stephan, Chemist.
O	2 Sets.	Andrews & Hitchcock Iron Co., Youngstown, Ohio.
P	9 Sets.	Dr. R. Moldenke, Met. Eng., Pittsburg, Pa.
Q	1 Set.	Bethlehem Iron Co., So. Bethlehem, Pa., A. L. Colby, Met. Eng.
R	2 Sets.	Claire Furnace Co., Sharpsville, Pa., D. K. Smith, Chemist.
S	1 Set.	Stewart Iron Co., Sharon, Pa., E. R. Sanborn, Chemist.
T	1 Set.	Superior Charcoal Iron Co., Detroit, Mich., W. P. Putnam, Chemist.

All the drillings for these analyses were taken from the same bar of pig iron and thoroughly mixed before samples of them were sent to the chemists, and should have shown precisely the same analysis. Yet no two of them show exactly the same per cent. of the various metalloids. In some cases the variation is so slight that two different irons showing these analyses would practically produce the same quality of iron in castings. But the extremes in carbon in the foundry iron, for instance, would indicate two different grades of iron that, if melted for the same grade of casting, would not give satisfactory results in each case. These analyses were made by experienced chemists in well equipped laboratories. The question naturally arises, what would have been the results had they been made by inexperienced chemists in poorly equipped laboratories with analytic material of unknown purity? It is this uncertainty of the accurracy of analysis, even when made under the most favorable conditions, that has more than anything else destroyed its value in the estimation of foundrymen. For although chemists have endeavored to attribute this variation in results to different methods of analysis and diversity in samples, they have not been able to overcome the difficulty. Founders fail to see how an iron can show totally different analyses indicating two different grades of iron, or to understand how this iron can be suitable for two grades of castings, one requiring a hard and the other a soft iron. Yet analyses of the same iron made by two different chemists have indicated this to be the case, as will be seen by reference to the above table. And even wider variations than these have been found by foundrymen when having analytical work done by different chemists.

Blast-Furnace Analysis.—It has come to be the practice for furnacemen making foundry iron to furnish to the founder with each car or shipment of iron an analysis indicating the quality of iron in each car or shipment of less than a car load. These analyses are made from a number of samples taken from different parts of each cast from the furnace and are supposed to fairly represent the per cent. of various elements or metalloids the iron of each cast contains. These casts are piled separately in the furnace-yard and numbered. The samples taken from each for analysis are correspondingly numbered and, when analyzed, the analysis is placed opposite the number in the record book. When shipments are made casts are selected from this book, the analysis of which shows the iron to contain the per cent. of various elements best suited for the grade of castings to be cast from it. The iron is sold to show the analysis which practice has show to produce the quality of iron in the castings required for them. Should the iron prove too hard or too soft, the analysis is not correct and the furnaceman has to replace the iron with another shipment, or lose his customer. The chemist must therefore be accurate in his determinations or lose his job, for he has no chance to shift the responsibility for inaccuracy. There is therefore every reason to expect that the analysis furnished with each car or shipment of iron from the furnace is accurate and has been made for every element having an effect upon the quality of iron when remelted and run into castings. There appears to be no reason why this analysis should not answer the purpose of the founder in making his mixtures equally as well as an analysis, even if accurate, by his own chemist. This is the view many foundrymen take of analysis and depend entirely upon that furnished from the furnace.

Cost of Analysis.—The cost of analysis seems to be a difficult matter to determine owing to the variation in price charged by different chemists and discount allowed for a certain amount of work given to them by the founder each month, but may be said to vary from fifty cents to three dollars for each element the foundry desires to have the iron analyzed for. At the minimum rate it would cost three dollars to have an iron analyzed for the per cent. of what are considered the six most important elements in cast iron, namely, silicon, manganese, phosphorus, sulphur, graphite, and combined carbon. Should the per cent. of other elements be desired an additional cost would be incurred. This represents the lowest price for what is termed contract work. For only an occasional analysis a higher price is charged by all chemists and with some the minimum charge is from one to three dollars for a determination for per cent of each element. The expense of a laboratory in which the founder could have his own work done, would be a suitable room for the purpose the cost of which would depend upon whether it is an available room at the plant or whether it has to be built; an outlay of $100 for laboratory apparatus, the keeping-up of this apparatus, which is quite an item as it consists to quite a large extent of glass and the breakage is considerable; supply of acid and chemicals for analysis, gas for analytical purposes, and an experienced chemist at a cost of from $5 per day up.

Testing Laboratories.—At almost every foundry center in this country, chemical laboratories have been established for doing foundry analytical work, testing etc., saving to founders the expense of fitting up and maintaining a laboratory and employing a chemist at their plants. These laboratories are known as testing laboratories. As the chemistry of foundry iron is only a manipulation of these irons with the aid of chemistry, the success of which manipulation depends to a very large extent upon a practical knowledge of the irons gained by melting and mixing them, these laboratories have an advantage over the foundry chemist in their extensive field for gaining this information, for to enable them to locate the trouble of which the founder complains, the latter must give to them the name and per cent. of each brand of iron and scrap in his mixture. The information thus obtained makes it possible for the laboratory to give this mixture to another founder, and the remedy found to correct the mixture enables it to give a satisfactory mixture to another founder who is melting the same brand of iron. As founders in any given district melt about the same brand of iron for the same class of castings, this information is of great value to the testing laboratories, and in many cases enables them to give to the founders a more satisfactory mixture than the experienced foundry chemist at their own plants, and in almost every case, a more satisfactory one than an inexperienced chemist. But this system gives away the foundry mixture of iron, a secret many foundries endeavor to guard very closely. Testing laboratories contract to do this line of work for foundries by the year at a much less cost then they can employ a competent chemist and maintain a laboratory. These laboratories are also of value to the founder, when not regularly employed by him, in settling disputes with pig iron men as to analysis of iron, and in making tests for tensile and transverse strengths of iron called for in specifications for castings, testing coke, etc.

The Foundry Chemist.—The inaccuracy of analysis and the chances of a sample taken from a few pigs in a carload of thirty to forty tons not fairly representing the per cent. of the various elements or metalloids analyzed for, which the iron of the entire carload may contain, and the uncertainty of resultant mixtures by analysis alone, have placed the chemistry of foundry irons in such bad repute among practical foundrymen, that it is only when a chemist has made himself master of the metallurgy of iron in addition to chemistry, that his services are considered to be of value by foundrymen. That the accuracy of resultant mixtures made by analysis alone can not be depended upon, is admitted by practical foundry chemists, for in visiting foundries I have met many experienced chemists who frankly admitted that they depend more upon a practical knowledge of their irons, physical tests, fracture indications of iron in gates and castings, working of the iron etc., than upon analysis, and only resort to the latter to determine whether a new shipment of iron or fuel is up to the standard, or to locate some trouble with castings that can not be determined by other means. This is not stated with a view of condemning foundry chemistry, which has no doubt done a great deal to advance foundry practice, but for the purpose of outlining the course the young chemist must pursue if he hopes to become a successful chemist of foundry irons. The laboratory training of a chemist fits him to become the most expert man on foundry irons about a foundry, for in this training he has learned the importance of accuracy and detail which fits him to do away with the rule of thumb practice so often complained of in foundry practice. In this training he learns the various metalloids and elements that enter into the composition of cast iron, and their effect in giving to this iron its various characteristics. This knowledge fits him for becoming more expert in the manipulation of foundry irons than a man who knows nothing about the metalloids of cast iron, or their effect in various per cents. upon the characteristics of the iron. But he must realize that this knowledge is only the ground work upon which to build up a more practical knowledge of foundry iron than the man who does not possess it is able to attain. Foundry business was successfully conducted for hundreds of years before the modern chemistry of foundry irons was introduced, and besides analysis there are other things to be considered in the successful manipulation of them than the application of chemistry to them. Fracture indications are a very important matter in the manipulation of these irons. Without a knowledge of these indications the chemist would not be able to indicate the different grades of iron when piled in a foundry yard and, even if he knew the location of the piles from which his sample was taken, he would, if he undertook to make a mixture of iron upon the cupola scaffold, be entirely at the mercy of the cupola men and, if they chose to deceive him as to the pile from which the iron came, he would place an entirely different iron in his mixture. He might charge one grade or number of iron for another, and even go to the extreme of charging a white iron for a number one iron. To avoid this he should at the earliest possible moment make a practical study of fracture indications, for although he may have been taught in his laboratory work that they are of little or no value in indicating the quality of an iron, they have served the purpose of the founder in selecting his iron for various grades of castings ever since the beginning of iron founding, and must ever play an important part in determining the quality of iron in pig, scrap and castings. The chemist by a careful study of fracture indications in connection with his analysis should be able not only to detect by the eye the presence of a greater per cent. of any one metalloid in one iron than in another, but he should also be able to state about the per cent. of various metalloids the iron contains almost as accurately as he can by analysis, as well as indicate the quality the iron will make when remelted and run into castings. When he has done this he can reduce his analyses actually necessary to such a small number, that he will have plenty of time for other work. Mechanical analysis is of great importance in determining the quality of iron after it is cast, and in indicating changes to be made in the mixture to obtain the desired quality of iron in castings. These are made by test bars, the shrinkage, soundness, transverse and tensile strengths of which in many cases indicate as accurately as analysis the per cent. of various metalloids the iron may contain, and also indicate whether an iron containing a greater or less per cent. of certain metalloids should be used in the mixture. Here again, the chemist has an opportunity of reducing the number of his analyses. It should be his aim to thoroughly understand this form of analysis, for by it alone can the quality of iron in castings be accurately determined, and changes made in the mixture to produce the quality required, and if he does not know what he has, his chemistry will not indicate the changes necessary to produce what he wants. Another important factor in the manipulation of foundry irons is the melting process. In this process the chemical composition of an iron may be entirely changed and the value of analysis destroyed. It should be the aim of the chemist to learn every detail of this process and he should be able to take charge of the cupola and give the cupola men instructions in every detail in making up the cupola for a heat, and the melting of iron. It will thus readily be seen that when a chemist has mastered only the analysis of foundry irons, he has only been fitted to begin to learn the manipulation of them. When the chemist has mastered these problems he is fitted to relieve the busy foundryman and his foreman of the details in manipulation of their iron, and his services are of value to the founder, while as an analytical chemist only, they are of little or no value, and he frequently becomes a disturbing element in the foundry force by his attempt to shift the failure of analysis to produce the desired quality of iron upon some one else, as has frequently been the case.

The following difference of opinion of chemists from "The Foundry," illustrates the failure of analysis to solve all the problems met with in foundry iron.

The Hoodoo in Pig Iron.—Replying to N. W. Shed's communication in the September Foundry, regarding the "Hoodoo in Pig Iron," Mr. H. Hood writes as follows: " I wish to take exception to his statement that he hopes this superstition will be permitted to die a natural death.

" While unable to claim 25 years' experience, the writer, nevertheless, is in a position to state that there is a vital difference in different pig irons of the same general composition. In my experience as a foundry chemist, the opportunity has been afforded to become more or less familiar with the operation of a large number of foundries, and I am forced to admit that there is some quality in pig iron which the chemical laboratory is unable to determine.

" Mr. Shed asks for a published list of the furnaces which make unsuitable pig iron, but this would obviously be a decided mistake. A black-list is always to be deplored and an iron found unsuitable for one class of work would not be found so for castings widely different in design and section.

" The writer was very recently called in to advise a foundry making a specialty of automobile cylinders. The storage yard contained a number of brands of pig iron of suitable chemical composition, and as the daily analysis of the cast was entirely satisfactory the writer was forced to fall back upon the ' superstition ' that the pig iron was at fault. Another brand was used with a still greater loss, although the laboratory could detect no difference in the chemical composition. The next brand of iron tried was found eminently satisfactory, and we believed the problem was solved. A few days later a car of iron was used and the only remaining car of that brand was a trifle low in silicon, and it was decided to use 10 per cent. of a third brand to make up this difference. This third brand was undoubtedly one of the " bad irons " for it caused a loss of upwards of 50 per cent. The next day this 10 per cent. was left out, the deficiency in silicon being made up in another way, with the result that the cylinders were satisfactory. The results of the third day prove conclusively that the quality of the pig iron, and not any chemical difference was at fault. The mixture of the third day was identical with that of the day previous, but the usual 20 per cent. of foundry returns used were from the heat containing this "off" iron with the result that there was another heavy loss. When it is considered that on the third day there could be present but 2 per cent. of this particular pig iron, it must be admitted that this deleterious quality is an extremely potent one. Needless to say, the chemical contents were maintained practically uniform.

"As a foundry chemist, and interested in chemistry, I do not like to assert that chemistry *per se* is not all-sufficient, but the result of my experience compels me to do so, and although chemistry is doing wonderful things for the foundryman, it must be used intelligently and in conjunction with the mechanical processes and methods.

"Instead of letting the superstition die, let us investigate it with an unbiased and open mind and get at the bottom of that unknown quantity which most certainly exists in pig iron."

CHAPTER XIII.

TESTING CAST IRON.

Definition of Test.—The term "test" as applied to cast iron means the subjecting of the iron to such conditions as will disclose its true character and indicate its stability for the work to be cast from the quality or grade of it tested. This may be done by chemical analysis, the characteristics of the iron before it is cast being indicated by determining the per cent. of various metalloids it may contain, the effect of these metalloids upon it being such as to give to it certain characteristics that are known. Or, by physical tests, which means the subjecting of the iron after it has been cast to such tests as will disclose its physical characteristics and indicate whether it is suitable for the work to be cast. These characteristics are appearance of grain in fracture, shrinkage, depth of chill, hardness, softness, strength, change of shape while under stress, etc.

Physical tests are made by means of test bars which, when subjected to various tests, indicate the characteristics of the iron as follows: Shrinkage test indicates the extent to which iron contracts in cooling from its length when hot. This test is made by casting a test bar of a given length and determining the extent it shrinks by comparison with the pattern from which it was moulded. To insure accuracy in this test some means must be provided to prevent the sand at the end of the bar being forced back by the molten iron and the test bar from being longer than the pattern. This is done by a cast iron yoke, against which the ends of the bar are cast, an exact length of the pattern being thus insured. This test is of value in determining the length and size the pattern should be made to insure a casting of a given length or size, and also in determining whether castings that are to be assimilated, as in stove plate, will be of a proper size if cast from different brands of iron.

Fracture Test.—By fracture is meant the breaking of a piece of iron or test bar and judging the quality of the iron from the appearance of the fresh fracture, which is indicated by the size of the crystals, the luster, chilling tendency, etc. This test indicates the hardness or softness of the iron as the crystals are large or small. A large crystal with a dark luster is evidence of a soft iron, a small crystal and light luster of a harder iron, and a white crystal of a very hard iron. A white outer edge indicates the tendency of the iron to chill, and that it is too hard for very thin castings. Fracture also indicates to some extent the strength of iron, a sharp-pointed crystal being evidence of a stronger iron and a dull crystal of a weaker iron.

Transverse Test is the breaking of a bar of iron under a known weight, and is made by supporting a test bar at each end and applying an increasing pressure or weight to the center of the bar until it breaks, and recording the number of pounds required to break it. Cross breaking is the most common break in cast iron, and this test, together with deflection or bending of the bar before breaking, is considered the most important test of cast iron.

Change of Shape.—By change of shape under strain is meant the deflection or bending of a test bar before breaking. This is carefully measured, and indicates the extent to which the iron is likely to give or bend in a casting before breaking when subject to strain.

Tensile Test.—By this test is meant the pulling or drawing apart of a piece of iron or test bar. This test is considered of little importance for cast iron, it being seldom subject to this strain in actual use. It is a very difficult test to make accurately owing to the difficulty in holding the test piece in the testing machine so as to place an even strain on all parts of it, and is seldom used for cast iron except in foundries where cylinders are cast for steam pumps, hydraulics, etc.

Impact Test, means the breaking of a piece of iron by a blow, and recording the number and weight of blows required to break it, and also observing the condition of the test-piece after each blow, as to whether it is battered, chipped off, cracked or broken. Little attention is given to this test, which can only be accurately made in a machine constructed for the purpose and by an expert. Foundrymen usually make it with an ordinary hammer or sledge, and judge the quality of the iron by the weight of the hammer or sledge and the number of blows required to break it and its condition after breaking.

Crushing Test, means the placing of sufficient weight upon a short cylinder or square piece of iron to crush it. This test is of little value to the founder and the weight or stress required to make it is so great that it is not often applied.

Direct Physical Test.—This means the breaking of a casting, an exact duplicate of a cast from the same iron whose strength and other qualities it is desired to learn. This test is only of value when a large number of castings are cast from the same pattern.

Relative Test.—All tests are relative tests, for it is only by comparison with a standard test, which means the greatest amount of desired quality in an iron, that any conclusion can be drawn as to the quality of iron being tested.

Standard Test.—The standard test may be that designated by scientists for the various tests and mean the best results they were able to obtain under the most favorable conditions in a testing laboratory, or it may be the best results the tester himself has been able to obtain. The latter will generally be found to be the most satisfactory, for there are elements such as hardness, softness, shrinkage, etc. which must be considered in the production of each line of castings, that were probably not kept in view by the scientist making the established test, his only aim being to obtain the best results from material tested.

Standard Foundry Test is a test that shows the best results that have been obtained in all the qualities desired in the line of castings to be made. It may include one or more methods of testing, each of which has a standard such as, standards of strength, softness, shrinkage, hardness, chill, etc., which, when combined with each other, in a test-bar or piece, indicate the quality of iron desired in work to be cast.

Chilled Test.—By chilled test is meant the tendency of molten iron to chill when run against a cold iron and suddenly cooled. This test is made by moulding a piece the thickness and shape of the part of a casting to be chilled and forming the side or a part of the mould with a chill the thickness of the one to be used for chilling the casting, and filling the mould with the quality of iron to be used for the chilled casting. This test-piece when broken shows the depth of chill, the extent to which the chilled fibers extend into the soft iron, resistance to shock, etc. This test is of value in making chilled castings, such as car wheels, crusher-jaws, plows, plow-points, etc.

Test Bars.—Owing to the variation in strength of test-bars, it is generally considered that one bar does not fairly represent the actual strength of the iron, and it is the practice to cast three or more bars of each size, test them, and take the average breaking strength of the bars as indicating the actual strength of the iron cast. When it is only desired to learn the strength of iron cast in a certain part of a heat, these bars may all be cast from one ladle. But if it is desired to learn the strength of iron throughout the entire heat, they must be cast from different parts of the heat, and may be cast singly or in pairs. As these bars are made for comparison with each other, it is very important that they should be of exactly the same size, for a large bar shows a greater strength than a small one, even when the difference in size is so small that it cannot be detected by the eye. It is therefore absolutely necessary that the greatest of care should be taken in making patterns and in moulding. Iron patterns are the best, for they are more stable than wooden ones, which are liable to shrink when not in use and, when placed in damp sand, or wet in sponging, expand to such an extent that the second bar, moulded from the pattern, may be larger than the first one. If the bar is to be broken in the centre it should be gated at the end, and every bar should be gated in the same way and have the same size gate. It is good practice to use a set gate. Care should be taken to not wrap one bar in moulding more than another, and to have the temper of the moulding sand the same for each bar. Special care should be taken to ram each bar evenly throughout its length, and ram all bars to give the same degree of hardness to the mould.

It is good practice to have all the bars moulded by the same moulder. The iron should be carefully skimmed before pouring, and all the bars should be cast with iron of as near the same temperature as possible. When bars are cast from different parts of a heat they should be moulded in separate flasks, for the pouring of one or more bars in the same flask, dries out the sand, and causes each succeeding bar to be heavier, strained, etc.

Length of Test Bars.—Test bars may be cast of any length that suits the fancy of the tester, but for transverse tests, they are generally cast 12 or 24 inches long. Twelve inches is the most common length and testing machines are generally constructed for this length, it being also best for comparison with standard tests, which are generally made with the twelve-inch bar. By the latter is always understood twelve inches between the bearings upon which the bar is placed for testing, and the bars are generally cast twelve and a half, or thirteen inches long, and are sometimes sixteen inches. This is done to test the iron farther from the gate, but there is no special advantage in this, and it is just as well to cast them only long enough to give a proper bearing upon the testing machine.

Care in Casting Test Bars.—Cast iron is such a complex body that its strength and general characteristics may by the manner of manipulation be changed to such an extent as to have test-bars indicate a totally different grade of iron from the one actually cast for testing. These changes are to a large extent under the control of the founder and moulder, and should be duly considered in making a few test-bars that are designed to indicate the strength and quality of iron in a heat of many tons of castings. By cooling iron rapidly, the size of the crystal and general appearance of the fresh fracture are entirely changed from those of a test-bar of the same size cooled slowly, and the strength of the bar is less. Hence the importance of casting bars for comparative tests in sand of the same temper so that one bar may not be cooled more rapidly than another by wet sand. Bars should never be shaken out when red-hot, and each bar should be permitted to remain in the sand about the same length of time as another. It is not good practice to let the bars remain in the sand over night to be annealed by the hot sand, unless the castings are permitted to remain in the mould over night. The temperature at which the iron is poured also greatly affects the strength of iron, and we may cast two bars from the same ladle of iron and have them show a wide difference in strength by pouring one with very hot iron and the other with dull iron. Some irons give a stronger bar when poured hot and others when poured dull, so that no definite temperature for pouring to obtain the strongest bar, that will apply to all irons, can be stated. But as the strength of the bars are for comparison with each other and to indicate strength of iron in castings, they should all be poured as near the same temperature as possible and as near that of the iron for pouring the castings as possible. The part of the heat from which iron for test-bars is taken is another important matter. The first iron melted is always hardened to a greater or less extent by moisture in the sand bottom, by a damp spout, cold ladles, etc., and does not fairly represent the quality of the metal. From five to twenty hundredweight of iron, according to the size of cupola and heat, should be poured before test-bars are cast.

Iron is hardened by boiling in a green ladle, and chilled to an extent that makes the grain closer, by a cold ladle. A hot ladle should therefore always be used for casting test-bars.

Tensile and Other Test Pieces.—Tensile bars or pieces are made of a size and shape to fit the testing machine in which they are to be drawn. They, as well as all other test pieces, whether for strength, chill, or drilled tests, should be cast with the same care, for they are designed to indicate the quality of iron in the castings and should be cast under as near the same conditions as possible.

Strength of Cast Iron.—The strongest part of cast iron is generally considered to be in the outer surface of the iron or casting, and the cutting away of this reduces the strength of the iron. This is due to the outer surface being cooled more rapidly than the center and graphite, carbon, sulphur, etc., segregating to the center as the iron changes from a molten to a solid state. But this does not apply to all irons or castings, for very thin castings cooled quickly throughout show about the same structure or size of crystal at the center as at the outer edge, and the removal of the outer scale reduces the strength only to an extent corresponding to the reduction in size of the iron. Then again, irons that do not contain an excess of the segregating elements are not weakened to the same extent by the cutting away of the outer surface as those that do, and this weakness in not apparent in a close iron to the same extent as in a soft, open one. The cutting away of the mere casting or skin scale has very little effect upon the strength of the iron, for it does not lie in the scale but in the structure of the iron beneath it. This structure changes in heavy castings from the outer surface inwardly and, as it nears the center, the crystals become larger and the iron more open, and weaker. Hence the greater the amount of the outer surface cut away, the less the strength of the iron will be. Civil engineers and others who have learned that the greatest strength of cast iron lies in its outer surface have attempted to obtain an extra-strong iron in their castings by having test-bars made from the iron used for them. To do this they have required test-bars four inches square, or two by four inches, to be furnished with the castings, and from the center of these bars have cut a one inch square bar for the test, and required this bar to show the strength called for in the specifications for the castings. This test is unfair to the founder, for it is made from the very weakest part of the iron, and were he required to give the specified strength for the casting in this part of the iron, he would have to far exceed the strength of cast iron.

It was this kind of trickery, not only by private firms but by government officials also, that induced the Foundrymens' Associations to take up the matter of testing and endeavor to establish a standard test for the various grades of castings. By doing so it was hoped to establish a standard that will be fair to both parties, and not admit of a founder being required to furnish castings of a strength above that of cast iron. To fairly represent the strength of iron in a casting a test bar should be cast of the same thickness as the casting, and tested without removing the outer surface of the bar.

Adding Strength to Cast Iron.—The strength of cast iron may be increased to almost any desired extent by adding steel to it when melting in a cupola. In doing this, care must be taken to select an iron that will absorb the steel without being hardened by it to so great an extent as to make it unfit for the work to be cast. This is controlled by the per cent. of silicon the iron contains. A high-silicon iron carries a larger per cent. of steel than a low one without hardening. The casting of a few test bars for a mixture of steel and iron in the yard will determine the per cent. of steel to be melted in the mixture. When making mixtures of this kind, for strength specifications, care must be taken to not exceed the strength of cast iron. A founder who resorted to this means of bringing his iron up to the strength called for in a government contract, succeeded in obtaining a transverse strength of 4500 lbs. in a IxI bar, and had the casting condemned for the reason that it exceeded the strength of cast iron, and therefore was not cast iron, as called for in the specifications.

Wrought iron also increases the strength of cast iron when melted with it. In making this mixture, the per cent. of wrought iron used, like the per cent. of steel, is controlled by the per cent. of silicon the iron contains. But as the object sought for is a strong iron, the silicon should be as low as possible to insure a soft casting, and in this case, the wrought iron should not exceed thirty per cent. This mixture, as well as that with steel, should be melted very hot to insure an even mixture of iron, and sound castings.

Cast iron may also to some extent be strengthened by adding wrought iron or steel drillings, and turnings to the iron in a ladle. But this is a very unsatisfactory process, for the heat absorbed from the iron in melting the turnings is so great that the iron becomes dull so rapidly that only a very limited amount can be added. If the turnings are not thoroughly absorbed into the iron they cause blow-holes, and the least excess of borings makes it difficult to get a sound casting. A better way of adding wrought iron or steel to iron in a ladle is to heat a bar in a forge to a white heat, and place it in the iron, or stir it with it. It is then mixed with the iron as it melts off the bar, and the excess is removed when the bar is withdrawn. This insures a more even and sound casting as the bar can be removed when the iron is at a proper temperature for pouring.

Annealing increases the strength of a close hard iron, but lessens that of a soft open iron.

A low-silicon iron generally produces a stronger casting than a high-silicon iron.

By varying the proportions of different irons in a mixture, a stronger iron can sometimes be produced from the same iron. The larger the per cent. of No. 2 iron in a pig mixture, the stronger the castings as a rule will be.

A good grade of scrap added to an all-pig mixture invariably increases the strength of castings. About 50 per cent. should be added for this purpose.

Testing Machines.—A home-made testing machine may be constructed in various ways at a very small cost. But such machines are only makeshifts at best, and require a great deal of time and labor in manipulating, and frequently do not accurately indicate the strength, hardness, softness or shrinkage of the iron; and it is better to buy a standard testing machine or send bars to a testing laboratory to be tested.

One of the best machines manufactured for light castings is that of W. J. Keep, Detroit, Mich. This machine, or rather system of testing, indicates very accurately the strength, deflection, shrinkage and chilling tendency of a half inch square test bar. It is very highly spoken of by founders making stove plate and light castings. Mr. Keep also makes a drill-testing machine for testing hardness for heavier work that indicates very accurately the hardness of iron.

For heavy work probably the best testing machines are those manufactured by Riehlé Bros. Testing Machine Co., Philadelphia, Pa. This firm makes a line of testing machines suitable for all the various tests required in specifications for castings. and for the one inch square transverse test. Their machine is probably the most convenient in use for a general test.

CHAPTER XIV.

STANDARD TESTS.

FOR many years foundrymen have been annoyed by the trickery of inexperienced civil engineers and others in demanding that test bars be cast in a way that did not fairly represent the strength of the iron, and condemning castings from tests made from these bars. To overcome this difficulty the American Foundrymen's Association, in 1898, appointed a committee to make a series of tests with a view of establishing a standard system of casting test bars and testing that would be fair to the foundrymen and purchaser of castings, and enable the founder to say to his prospective customer that he would furnish test bars subject to the standard test conditions only. Several series of test bars were cast and tested by this committee; one of this series is given below, with report made by the committee.

Second Series of A. F. A. Tests.—Report of committee on test bars cast under the auspices of the American Foundrymen's Association committee on a standard system of test bars for cast iron, Dr. Richard Moldenke, of Pittsburg, chairman. In the tables herewith are given the results of transverse, tensile and compression tests of bars made in Cast B, the iron being such as is used for dynamo frame castings. As indicated by the cuts accompanying the tables, the bars were both square and round, machined and unmachined. The committee reserves comment on the results for the foundrymen's convention of next month, in Pittsburg, but it has prepared the following memorandum:

Cast B, Dynamo Frame Iron.—This set of 198 bars, cast vertically and at the same time, in accordance with the specifications of the American Foundrymen's Association committee on standardizing the testing of cast iron, furnished 262 test pieces and 286 separate tests. This set was presented to the committee by the Westinghouse Electric & Mfg. Co., in the interest of the trade. The cast was made by Mr. Jos. S. McDonald. Cast B illustrates a class of castings which must machine readily, be soft in sections, little over one-half inch thick and yet sound when 14 inches is reached. About 45 per cent. scrap is carried in the mixture. A good transverse strength and resilience are essential, tensile strength being less so. The composition of this cast as taken from the 1-inch dry sand and square bar is as follows:

Total carbon	3.82	per cent.
Graphite	3.23	per cent.
Silicon	1.95	per cent.
Manganese	.39	per cent.
Phosphorus	.405	per cent.
Sulphur	.042	per cent.

The cross section of the square bars and the round is approximately equal for the relative sizes. The machined bars were turned or planed to the size indicated, for the purposes of comparison. In the transverse tests the supports were all 12 inches apart. The fresh fracture of each size of round and square, green sand and dry sand transverse bar was preserved, will be mounted in a case, and is expected to be on exhibition at the coming convention of the American Foundrymen's Association, in Pittsburg. From the physical structure of these bars it is seen that the larger sizes would be much better available for standard tests than was the case with Series A, shrinkage spots not being very much in evidence. However, there is a slight tendency to pipe, a circumstance fatal to the value of a test bar cast in any other position than the vertical. But two bars proved unserviceable. The fluidity strips ran up nearly full.

TABLE I.

TRANSVERSE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND NOT MACHINED.

No.	Approx. Cross Section. Inches.	Actual Size. Depth. Inches.	Actual Size. Width. Inches.	Breaking Strain. Lbs.	Deflection. Inches.
281	.5 x .5	.53	.57	380	.190
282		.52	.53	320	.200
283		.54	.56	460	.210
284		.54	.55	340	.190
285	1 x 1	1.04	1.04	2,140	.130
286		1.01	1.03	2,580	.110
287	1.5 x 1.5	1.52	1.52	8,060	.102
288		1.57	1.53	7,920	.102
289	2 x 2	2.03	2.04	16,180	.101
290		2.01	2.03	14,920	.087
291	2.5 x 2.5	2.57	2.59	30,500	.103
292		2.51	2.50	27,680	.101
293	3 x 3	3.03	3.02	45,790	.099
294		3.03	3.02	45,660	.102
295	3.5 x 3.5	3.52	3.54	68,470	.091
296		3.57	3.56	70,140	.092
297	4 x 4	4.00	4.06	over 100,000	*
298		4.02	4.05	over 100,000	†

* .055 in. at 100,000 lbs. † .056 in. at 100,000 lbs.

TABLE II.

TRANSVERSE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND MACHINED.

No.	Approx. Original Cross Section Inches.	Actual Size as Machined. Inches.	Breaking Strain. Lbs.	Deflection. Inches.
299	1 x 1	.5 x .5	250	.299
300			270	.287
301	1.5 x 1.5	1 x 1	2,080	.170
302			2,400	.159
303	2 x 2	1.5 x 1.5	6,640	.142
304			6,390	.146
305	2.5 x 2.5	2 x 2	15,390	.119
306			16,400	.116
307	3 x 3	2.5 x 2.5	27,770	.106
308			28,460	.091
309	3.5 x 3.5	3 x 3	44,070	.093
310			46,180	.090
311	4 x 4	3.5 x 3.5	66,240	.052
312			63,100	.059

TABLE III.

Transverse Test.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND NOT MACHINED.

No.	Approx. Cross Section. Inches.	Actual Size. Depth. Inches.	Actual Size. Width. Inches.	Breaking Strain. Lbs.	Deflection. Inches.
313	.5 x .5	.53	.53	320	.220
314		.50	.56	340	.230
315		.52	.52	280	.190
316		.55	.56	240	.160
317	1 x 1	1.07	1.01	2,300	.110
318		1.05	1.06	2,660	.105
319	1 x 1.5	1.55	1.54	7,470	.100
320		1.58	1.53	7,100	.091
321	2 x 2	2.09	2.03	16,100	.087
322		2.07	2.03	16,230	.091
323	2.5 x 2.5	2.56	2.51	27,840	.112
324		2.51	2.54	29,800	.105
325	3 x 3	3.09	3.10	49.360	.102
326		3.00	3.06	46,050	.100
327	3.5 x 3.5	3.58	3.61	74,920	.090
328		3.62	3.53	72,450	.091
329	4 x 4	4.15	4.00	99,650	.069
330		4.16	4.02	99,820	.072

TABLE IV.

Transverse Test.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND MACHINED.

No.	Approx. Original Cross Section. Inches.	Actual Size as Machined. Inches.	Breaking Strain. Lbs.	Deflection. Inches.
331	1 x 1	.5 x .5	220	.300
332			200	.294
333	1.5 x 1.5	1 x 1	2,020	.182
334			2,000	.180
335	2 x 2	1.5 x 1.5	6,470	.123
336			6,000	.130
337	2.5 x 2.5	2 x 2	15,840	.118
338			15,430	.114
339	3 x 3	2.5 x 2.5	25,840	.103
340			27,780	.100
341	3.5 x 3.5	3 x 3	43,000	.086
342			41,370	.082
343	4 x 4	3.5 x 3.5	60,620	.051
344			62,510	.049

TABLE V.

Transverse Test.

SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND NOT MACHINED.

No.	Approx. Diameter. Inches.	Actual Size. Depth. Diameter. Inches.	Actual Size. Width. Inches.	Breaking Strain. Lbs.	Deflection. Inches.
345	56	.59	.52	250	.100
346*		....	....	....	....
347		.58	.59	220	.106
348		.56	.58	200	.107
349	1.13	1.17	1.18	2,490	.120
350		1.15	1.18	2,120	.130
351	1.69	1.74	1.74	7,130	.081
352		1.73	1.74	7,020	.077
353	2.15	2.26	2.26	15,680	.083
354		2.26	2.27	15,880	.089
355	2.82	2.86	2.84	31,770	.102
356		2.84	2.89	31,170	.100
357	3.38	3.53	3.48	46,790	.098
358		3.44	3.41	49,620	.091
359	3.95	4.01	4.02	71,440	.095
360		4.01	4.00	75,660	.092
361	4.51	4.61	4.64	100,120	.061
362		4.62	4.62	over 100,000	†

* Defective—Shot. † .044 in. at 100,000 lbs.

TABLE VI.

Transverse Test.

SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND MACHINED.

No.	Approx. Original Diameter. Inches.	Actual Diameter as machined. Inches.	Breaking Strain. Lbs.	Deflection. Inches.
363	1.13	.56	230	.310
364			230	.302
365	1.69	1.13	2,040	.168
366			2,190	.152
367	2.15	1.69	6,170	.113
368			6,070	.118
369	2.82	2.15	11,040	.079
370			11,090	.082
371	3.38	2.82	23,530	.092
372			24,830	.098
373	3.95	3.38	41,520	.072
374			41,050	.074
375	4.51	3.95	66,090	.069
376			64,210	.061

TABLE VII.

Transverse Test.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND NOT MACHINED.

No.	Approx. Diameter. Inches.	Actual Size. Depth. Inches.	Diameter. Width. Inches.	Breaking Strain. Lbs.	Deflection. Inches.	Contraction. Inches.
377	.56	.52	.58	200	.204	...
378		.58	.60	190	.203	...
379		.53	.60	200	.190	...
380		.51	.58	180	.220	..
381	1.13	1.18	1.13	2,610	.110	...
382		1.14	1.12	2,240	.120	...
383	1.61	1.77	1.74	8,080	.085	...
384		1.72	1.74	7,480	.082	...
385	2.15	2.34	2.29	15,620	.087	.12
386		2.26	2.26	15,260	.078	.12
387	2.82	2.87	2.89	31,900	.107	...
388		2.86	2.84	30,770	.111	...
389	3.38	3.42	3.44	48,280	.093	...
390		3.48	3.49	47,810	.089	...
391	3.95	3.97	4.02	72,530	.095	...
392		3.99	4.02	74,400	.094	...
393	4.51	4.60	4.62	over 100,000	*	...
394		4.60	4.62	over 100,000	†	...

* .040 in. at 100,000 lbs. † .044 in. at 100,000 lbs.

TABLE VIII.

Transverse Test.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND MACHINED.

No.	Approx. Original Diameter. Inches.	Actual Diameter as machined. Inches.	Breaking Strain. Lbs.	Deflection. Inches.
395	1.13	.56	210	.311
396			240	.320
397	1.69	1.13	1,820	.178
398			1,750	.162
399	2.15	1.69	5,880	.114
400			6,030	.112
401	2.82	2.15	11,220	.088
402			10,840	.091
403	3.38	2.82	23,740	.089
404			24,420	.088
405	3.95	3.38	39,220	.075
406			39,570	.078
407	4.51	3.95	62,880	.052
408			63,120	.058

TABLE IX.

TENSILE TEST.

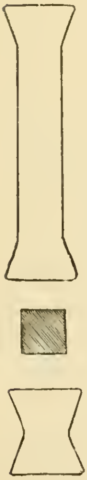
SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND NOT MACHINED.

No.	Approximate Cross Section. Inches.	Actual Area, in Square Inches.	Breaking Strain. Lbs.	Ultimate Strength per Sq. In. Lbs.
409	.5 x .5	.28	4,910	17,540
410		.29	4,920	17,600
411		.26	4,440	17,080
412		.28	4,490	16,180
413	1 x 1	1.01	15,900	15,740
414		1.04	15,150	14,570
415	1.5 x 1.5	2.26	28,450	12,590
416		2.24	29,470	13,150
417	2 x 2	4.02	47,930	11,920
418		4.01	45,120	11,000
419	.5 x .5	.30	5,050	16,830
420		.31	4,990	16,100
421		.31	5,030	16,220
422		.29	4,650	16,030
423	1 x 1	1.01	15,700	15,540
424		1.04	14,980	14,400
425	1.5 x 1.5	2.30	30,280	13,170
426		2.31	31,090	13,460
427	2 x 2	3.97	41,030	10,330
428		3.97	42,480	10,700

TABLE X.

TENSILE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND MACHINED.

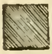


No.	Approximate Original Cross Section. Inches.	Area as Machined, Square Inches.	Breaking Strain. Lbs.	Ultimate Strength per Sq. In. Lbs.
429	1 x 1	.25	4,790	19,160
430		.25	4,020	16,080
431	1.5 x 1.5	1.00	14,220	14,220
432		1.00	15,790	15,790
433	2 x 2	2.25	24,930	11,080
434		2.25	32,580	14,480
435	1 x 1	.25	4,030	16,120
436		.25	4,860	19,440
437	1.5 x 1.5	1.00	15,360	15,360
438		1.00	14,580	14,580
439	2 x 2	2.25	25,970	11,540
440		2.25	28,720	12,760

TABLE XI.

TENSILE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND NOT MACHINED.



No.	Approximate Cross Section. Inches.	Actual Area, in Square Inches.	Breaking Strain. Lbs.	Ultimate Strength per Sq. In. Lbs.
441	.5 x .5	.27	4,510	16,700
442		.30	4,840	16,130
443		.29	4,840	16,700
444		.28	4,440	15,710
445	1 x 1	1.03	15,120	14,680
446		1.03	15,480	15,030
447		1.02	15,550	15,240
448		1.01	15,570	15,410
449	1.5 x 1.5	2.25	29,150	12,950
450		2.27	30,980	13,640
451	2 x 2	3.92	41,940	11,210
452		3.98	43,810	11,060
453	.5 x .5	.28	4,420	15,800
454		.25	4,150	16,600
455		.27	4,280	15,850
456		.28	4,090	14,610
457	1 x 1	1.03	15,320	14,870
458		1.09	16,700	15,320
459		1.04	15,790	15,180
460	1.5 x 1.5	2.24	28,840	12,870
461		2.23	26,650	10,610
462	2 x 2	4.00	45,480	11,370
463*		....	....	....

* Dirty iron.

TABLE XII.

TENSILE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND MACHINED.

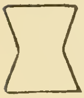
No.	Approximate Original Cross Section. Inches.	Area as Machined, Square Inches.	Breaking Strain. Lbs.	Ultimate Strength per Sq. In. Lbs.
464	1 x 1	.25	4,460	17,840
465		.25	4,750	19,000
466	1.5 x 1.5	1.00	14,690	14,690
467		1.00	15,180	15,180
468	2 x 2	2.25	26,000	11,560
469		2.25	28,460	12,650
470	1 x 1	.25	3,990	15,960
471		.25	4,200	16,800
472	1.5 x 1.5	1.00	15,330	15,330
473		1.00	12,940	12,940
474	2 x 2	2.25	25,920	11,520
475		2.25	28,530	12,680

TABLE XIII.

TENSILE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND NOT MACHINED.





No.	Approximate Original Diameter. Inches.	Actual Area in Sq. In.	Breaking Strain. Pounds.	Ultimate Strength. Lbs. per Square Inch.
476	.56	.25	4,020	16,080
477		.25	4,410	17,640
478		.26	4,280	16,000
479		.28	4,600	16,430
480	1.13	.96	15,220	15,860
481		1.00	15,870	15,870
482	1.69	2.26	28,590	13,090
483		2.26	29,700	13,140
484	2.15	4.03	47,040	11,670
485		4.05	46,120	11,140
486	.56	.26	4,450	17,110
487		.26	4,176	16,040
488		.26	4,170	16,040
489		.28	4,380	15,650
490	1.13	1.00	15,310	15,310
491		.99	14,180	14,320
492	1.69	2.26	30,380	13,440
493		2.31	32,260	13,970
494	2.15	4.00	42,200	10.550
495		4.14	50,180	12,120

TABLE XIV.

TENSILE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN GREEN SAND AND MACHINED.



No.	Approximate Original Diameter. Inches.	Area as Machined. Square Inches.	Breaking Strain. Pounds.	Ultimate Strength. Lbs. per Square Inch.
496	1.13	.25	4,810	19,240
497		.25	4,690	18,760
498	1.69	1.00	14,760	14,760
499		1.00	15,990	15,990
500	2.15	2.25	27,900	12,400
501		2.25	26,510	12,670
502	1.13	.25	4,220	16,880
503		.25	4,800	19,200
504	1.69	1.00	14,340	14,340
505		1.00	13,400	13,400
506	2.15	2.25	30,910	13,740
507		2.25	30,950	13,760

TABLE XV.

TENSILE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND NOT MACHINED.

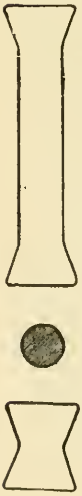
No.	Approximate Original Diameter. Inches.	Actual area in Square Inches.	Breaking Strain. Pounds.	Ultimate Strength. Lbs. per Square Inch.
508	.56	.26	4,090	15,730
509		.24	4,000	16,670
510		.24	4,170	17,790
511*	...	...	....	.....
512	1.13	1.01	16,650	16,480
513		.96	14,850	15,470
514		1.02	16,700	16,370
515	1.69	2.27	30,240	13,320
516		2.25	29,220	13,000
517	2.15	4.00	44,700	11,110
518		4.00	43,650	10,910
519	.56	.25	4,450	17,800
520		.26	4,190	16,110
521		.27	4,280	15,810
522		.20	3,520	17,600
523	1.13	1.03	16,650	16,160
524		1.02	16,340	16,510
525		1.10	17,790	16,170
526		1.14	18,420	16,200
527	1.69	2.33	34,590	14,840
528		2.27	30,640	13,500
529	2.15	4.09	46,680	11,410
530		4.01	43,210	10.770

* Lost.

TABLE XVI.

TENSILE TEST.

SERIES B.—DYNAMO FRAME IRON. BARS IN DRY SAND AND MACHINED.



No.	Approximate Original Diameter. Inches.	Area as Machined. Square Inches.	Breaking Strain. Pounds.	Ultimate Strength. Pounds per Square Inch.
531	1.13	.25	4,390	17,560
532		.25	4,040	16,160
533	1.69	1.00	15,780	15,780
534		1.00	14,400	14,400
535	2.15	2.25	29,280	13,010
536		2.25	29,740	13,220
537	1.13	.25	4,670	18,680
538		.25	4,000	16,000
539	1.69	1.00	15,770	15,770
540		1.00	13,940	13,940
541	2.15	2.25	28,570	12,700
542		2.25	31,010	13,790

TABLE XVII.

COMPRESSION TEST, ½-INCH CUBES.

SERIES B.—DYNAMO FRAME IRON.

No.	Approximate Cross Section of Bar, Inches.	Crushing Strength in Pounds					Remarks.
		Middle ½ Inch.	First ½ Inch from Edge.	Second ½ Inch from Edge.	Third ½ Inch from Edge.	Fourth ½ Inch from Edge.	
543	.5 x .5	38,360	....	....	....	....	The cubes were cut from the square bars cast in dry sand (vertically), and were compressed along the length of the original bar. Test pieces were cut along a line at right angles to the sides of the bar. The value of the middle cube is repeated where it rounds out the series.
544	1 x 1	23,000	....	....	....	....	
545		....	27,440	....	....	....	
546	1.5 x 1.5	20,980	....	20,980	....	....	
547		....	24,820	....	....	....	
548	2 x 2	18,130	....	....	....	....	
549		....	21,640	....	....	....	
550		....	....	18,740	....	....	
551	2.5 x 2.5	15,060	....	....	15,060	....	
552		....	18,270	....	....	....	
553		....	....	15,940	....	....	
554	3 x 3	13,790	....	....	....	....	
555		....	17,000	....	....	....	
556		....	....	14,410	....	....	
557		....	....	....	13,900	....	
558	3.5 x 3.5	13,160	....	....	....	13,160	
559		....	15,970	....	....	....	
560		....	....	15,200	....	....	
561		....	....	....	13,560	....	
562	4 x 4	12,430	....	....	....	....	
563		....	16,140	....	....	....	
564		....	....	13,950	....	....	
565		....	....	....	13,760	....	
566		....	....	....	....	12,830	

NOTE.—In these series of tests the bars for each test were cast in a different foundry under exactly the same conditions. The object in having them cast in this way was to ascertain the strength of different mixtures of iron and of mixtures required for different lines of castings. All of the series of tests contemplated, we believe, were never made, and those made show such a wide variation in strength that no standard of strength has yet been established for cast iron or for any line of castings. In the above tests a good quality of soft foundry iron was used, and the strength indicates about the strength a founder may expect to find in bars of the same size. It will be observed that no two bars of the same size show the same transverse or tensile strength. This is always the case with test-bars, and it is the practice to cast two or more bars and take the average strength as indicating the strength of the iron.

Method of Casting Test Bars.—A few extracts from the report made to The Pittsburg Foundrymen's Association by Thos. D. West on methods of casting test bars for The American Foundrymen's Association's Testing Committee may be of value in showing the care taken in casting these bars and the number of bars required to establish standard tests.

"There is no metal whose physical qualities are so easily and radically affected by thickness and rate of cooling as cast iron. A casting one-half inch thick and another four inches thick, in steel, for example, show very little difference in structure of grain, whereas such variation in thickness in cast iron may cause the lighter body to be very dense and hard, while the heavier body may be open-grained and soft. Then again, we can take the same thickness in two castings and by cooling one more quickly than the other, cause one to be white while the other will be gray in its body, all being poured from the same ladle of metal. The rate of cooling is a factor as important in its effect in altering the structure or grain of cast iron as that of the differences in thickness of casting, and can be controlled in three ways. First: By having the mould of sand or of iron. Second: By varying the nature and dampness of the sand, or thickness of the iron chill forming the mould. Third: By variation in the temperature of fluidity of the melted metal at the moment it is poured.

"Variation in the pouring temperature of metal, often greatly affects the strength of iron but in what direction, according to the grade used, is yet to be clearly established, as in some mixtures a dull iron increases the strength while in others the reverse is true, on account of the influence affecting the carbon in being combined or free in the iron. A study of the various conditions affecting the grain of cast iron will demonstrate that any attempt to obtain comparative test-specimens from which correct deductions can be expected to define the physical qualities of cast iron, should be made on a plan which permits pouring at the same temperature, and casting in a position permitting the most uniform cooling and giving the most uniform grain in these specimens. These are conditions which the writer in previous papers has shown to be essential in making any set of test specimens to be used for comparative purposes. Very contradictory or at least unreliable results are all that can be compiled from most all existing records of tests intended to be comparative. This is largely due to the intricate and delicate nature of cast iron and the want of practical knowledge of founding on the part of most experimenters. It was in recognition of the great need of a more correct basis for comparative physical tests that The American Foundrymen's Association at the suggestion of Dr. Richard Moldenke, appointed a committee at the last annual meeting to take up the work of showing what cast iron is, and what may be expected of it, in the production of castings, and the use of different sizes of test-bars. To do this properly, it is necessary to obtain test-bars for more than one grade of iron. It is an error to think that one grade will establish comparative records that would show what cast iron is. Instead of there being but one grade of iron to be tested, we have fully eleven grades which must be gone through before complete records of any value can be had to represent the physical qualities of cast iron. When it is stated that there are about two hundred bars in each of the grades of iron ranging from one half inch to four inches square and round, 15 inches long, half to be made in green sand and half in dry sand moulds, the weight being nearly two tons for a single set, or 22 tons in all, the magnitude of the work which the American Foundrymen's Association has in hand, as outlined by Dr. Moldenke, will be recognized.

" In this work much time was expended in completing plans of procedure as the magnitude of the undertaking required that every step be well studied to make sure of giving the best that was possible to attain, the true strength, contraction and chilling qualities of cast iron, as it is used today. After all plans were arranged, the work of constructing patterns, core boxes and flasks was taken in hand and furnished by Dr. Moldenke and myself. Designing the method for casting these bars, and making the first set was assigned to the writer. Knowing the importance of casting on end, and pouring all bars in any set, (to be used for comparative purposes) from the same ladle of iron and, if possible, at the same time and temperature, the writer organized the plan shown herewith, which has proved most successful and embodies principles that may be utilized to advantage in other lines of founding. The Westinghouse Co. is kindly allowing Mr. McDonald to make two sets of these bars and at this writing he is about ready to pour his second set. After this is finished, J. S. Seamon, of The Seamon Sleeth Co., Roll Manufacturers of Pittsburg, Pa., will receive the flasks and rigging, and thus they will be transferred from shop to shop, until the whole 11 sets or nearly 22 tons of test bars is completed.

"All having taken part in this important work will be given full credit in the report which the committee will present giving the results of the tests of all the bars. It is but just to remark, that it requires experience in founding and men of ability to successfully oversee and mould up such a set of test bars after the plan herein described, but judging from the character of the men and firms who have consented to do this work, all may rest assured that the end sought will be as nearly attained as is possible with our present knowledge.

"The flasks used for this work were all made of malleable iron so as to make them strong and light for handling. The cross bars were arranged in the flasks so as not to come over the part of the test bars which should fracture when tested.

"In ramming the sand in the flasks, care was taken to ram it evenly and firmly, so that no swelling or scabbing could take place. Much care is also taken in venting as well as finishing the mould. The swab was only allowed to be used at the junction of the gate and pattern. The reason for this is that if one part of the face of the mould is of damper sand than another, it will cause an uneven texture in the grain of the iron, and hence every precaution was taken not to use the swab anywhere near that portion of the bar which will break when tested.

" Some will wonder why to get the dry sand effect in making the test bars, we did not mould them in iron flasks, and dry in an oven upon the plan generally followed for dry sand work. The reason this was done and the plan of making them of cores adopted, was that not all the shops that would be kind enough to assist in the work have drying facilities for flask work. In making a sand mixture for the cores it was very desirable to have it of a character to crush easily when the bars commence to contract. After some experimenting, the following mixture was adopted for making the cores.: I part lake, river or bank sand, 3 parts of fine white silicon or crushed sand".

CHAPTER XV.

SEMI-STEEL.

THE metal produced by melting and casting a mixture of cast-iron and steel is commercially known as semi-steel, this term having been applied to it to distinguish it from cast-iron, malleable iron, and steel castings. It was not discovered by any one in particular, but was the result of replacing wrought iron scrap with steel scrap by many founders for the purpose of strengthening castings for special purposes requiring great strength. Very little was heard of this metal prior to 1871–2. About this time, Pittsburg, Pa., founders commenced using it for rolling mill rolls, pinions, etc., castings which require great strength, and about the same time the Whitney Car Wheel Co., Philadelphia, Pa., began placing steel in their car-wheel mixture. After this date, car-wheel foundries began adding steel to their mixtures until the practice has become almost universal in these foundries. But it was not until a much later date than 1872 that semi-steel was made to any great extent by machinery and jobbing foundries. In the early days of semi-steel, considerable trouble was experienced in getting a homogeneous metal which was due to the steel not mixing, or entering evenly into combination, with the iron. To overcome this difficulty, resort was had to placing the steel in pig moulds and casting the iron around it, to insure a more even mixture of the iron and steel when the pig was remelted. The iron and steel were also melted together and cast into pigs to be remelted for castings, but these methods have been generally abandoned, and since the discovery that silicon is the controlling element in semi-steel making, a homogenous semi-steel containing almost any desired per cent. of steel is cast direct from the cupola, when the metals are properly mixed and melted. In making a semi-steel, the first thing to be done is to select a pig iron having the required per cent. of silicon to carry the desired per cent. of steel. This is determined by the thickness, size or shape of the work to be cast. Light semi-steel castings to insure softness, require about 2 per cent. silicon, heavier ones ½ to 1 per cent., and still heavier ones a smaller amount, all depending upon the line of work to be cast. The steel contains no silicon and the pig must be sufficiently high in silicon to impart the above per cent. of it to the mixture of semi-steel.

By this method as high as 60 per cent. steel has been melted in mixtures for comparatively light castings to be machined, and a soft strong casting procured that finished like steel, and had a strength far superior to that found in any cast iron. The roll plate or high carbon steel is to be preferred, for it melts more readily than heavy steel rails and, when only one charge of semi-steel is melted on the bed, leaves the cupola free from steel. When steel rails are melted in a single charge on the bed, they sometimes hang up in the cupola, melt slow, and affect the iron throughout the entire heat. But steel rails or low carbon steel give equally as good results as high carbon steel, and may be melted, when steel is melted throughout a heat, without any more danger of hanging up than when melting plate steel. Steel plate punchings are also melted for semi-steel, but these small particles are very liable to be oxidized by the blast in melting, and hard spots in castings have been attributed to them.

The effect of steel in cast-iron is to add tensile and transverse strength to it, close up the grain, and make a more dense metal resembling steel, and the larger the per cent. of the latter the more closely it resembles that metal both in strength and finish. The per cent. of steel that gives a maximum strength to semi-steel is a very much disputed question, some founders claiming that 5 to 10 per cent. gives equally as great an increase in strength as 50 to 60 per cent. This probably depends to a large extent upon the characteristics of the iron with which the steel is mixed, but it is fair to presume that the nearer a semi-steel comes to steel by the addition of that metal, the closer it will approximate the strength of steel.

As low as 3 per cent. of steel in a mixture of iron is claimed to have increased the transverse strength of a one inch square test bar 200 pounds, and 5 per cent. to have increased it 500 pounds.

In the making of semi-steel in a cupola the carbon in the metal is increased in melting, and with 25 per cent. steel containing only a small fraction of one per cent. carbon and the pig containing 3 per cent. carbon, analysis of the semi-steel has repeatedly shown three per cent. carbon in the metal, whereas it would have shown 2.5 per cent. less than in the pig if carbon had not been taken up.

Semi-steel mixtures are now made in almost all of the jobbing and machinery and specialty foundries for castings requiring a strong iron, but many of these mixtures can hardly be called a semi-steel, for they contain only from 3 to 5 per cent. steel to give strength to the iron, while a real semi-steel contains at least 50 per cent. steel, but the mixtures to which this name is generally applied, contain from 20 to 25 per cent. of steel. This amount has been found to give the desired strength for most castings, and the per cent. of silicon it contains the required hardness. For gear wheels such a mixture is said to give a casting equal to steel gear.

The following very complete paper on semi-steel was prepared by H. E. Diller, and read at the Boston meeting of The American Foundrymen's Association:

" *The Effect of Melting Steel With Iron in the Cupola.*—It is well known that melting steel with iron in a cupola adds strength to the resultant casting. But to what degree this is so, and the best proportion of steel to use are not so clearly understood. With a view of learning something more definite in regard to these two subjects, and also to see if it were possible to trace some connection between the percentage of total carbon in the iron, and the tensile strength, I have made the tests given in the accompanying table.

"The tensile and transverse strength given, are the average of two, and in some cases three, test bars. For the tensile strength a 1⅛-inch round bar was used. The transverse strength was obtained from a 1-inch square bar placed on supports 12 inches apart.

"The object sought in the following classification is to have the silicon about equal in the tests of each set, the amount of the other elements being as nearly alike as it was possible for me to get them.

No.	Silicon.	Sul.	Phos.	Mangan.	Comb. C.	Graphite.	Total C.	Tensile Strength.	Transverse Strength.	Per cent. of Steel.
1....	1.43	.047	.564	.82	.67	3.14	3.81	23060	2550	0
2....	1.50	.065	.532	.33	.64	3.44	3.08	30500	2840	25
3....	1.76	.062	.488	.53	.51	3.12	3.63	22180	2440	0
4....	1.76	.139	.515	.57	.43	2.94	3.37	27090	2770	12½
5....	1.77	.069	.339	.49	.56	2.87	3.43	32500	3120	12½
6....	1.83	.100	.610	.55	.51	2.44	2.95	36860	3280	25
7....	1.75	.089	.598	.35	.74	2.12	2.86	30160	3130	37½
8....	1.96	.104	.446	.44	.63	3.18	3.81	21950	2230	0
9....	2.12	.037	.410	.26	.38	3.26	3.64	21890	2470	12½
10....	2.16	.060	.315	.20	1.06	2.30	3.36	26310	2670	12½
11....	1.97	.093	.470	.48	.57	2.83	3.40	32530	3050	37½
12....	2.35	.061	.515	.56	.54	3.40	3.94	21990	2200	0
13....	2.53	.104	.490	.54	.60	2.56	3.16	33390	2850	25
14....	2.36	.064	.327	.24	1.08	2.15	3.23	31560	3200	25

"Tests Nos. 1 and 2 show comparatively little difference in the chemical contents, except in the manganese and graphite. As the manganese in No. 1 should be beneficial to the strength of the bar, the only way to account for the greater strength of the iron from No. 2 is the lower percentage of graphite, or the molecular structure resulting from the 25 per cent. of steel in the mixture.

"Comparing Nos. 3 to 7 we find that the strength increases with the percentage of steel used, and the decrease of total carbon with the exception of No. 7. In this 37½ per cent. of steel was used, and the total carbon was less than in any other test, but it is weaker than either No. 5 or No. 6. This being a solitary case, it can hardly be used as proof that 37½ per cent. of steel is more than it is well to melt in a cupola. But test No. 11, which also contained 37½ per cent. of steel and more carbon, was only a little stronger.

"Test No. 4 was considerably weaker than No. 5, but its higher percentage of sulphur with its lower combined carbon would seem to indicate that these bars were either cooled slower, or poured from duller iron than were the bars from No. 5, which may account for their being weaker than the No. 5 bars.

"In looking at Nos. 8 to 11 we see that No. 9, although containing 12½ per cent. of steel, is no stronger than No. 8, in which there was no steel. And No. 10 with 1.06 combined carbon, and 12½ per cent. of steel, gives less strength than might be expected. As these tests are so much lower in manganese than Nos. 8 and 11, it may be that their weakness is due either to the lower manganese or to the conditions of melting, which reduced the percentage of manganese so much more than in Nos. 8 and 11. The four charges each contained about .50 manganese before melting.

"Nos. 13 and 14, each from charges containing 25 per cent. of steel, show a marked increase in strength over No. 12.

"We find that all the tests from charges containing 25 per cent. of steel are stronger than those from the charges containing but 12½ per cent., with the exception of No. 5, which is stronger than two of the tests which had 25 per cent. of steel in the mixture.

"The tests were made with pig iron, ferro-silicon and steel scrap, no cast iron scrap being used. This was done in order to better control the percentage of the elements in the iron.

"In some cases when a large percentage of steel was added, it was necessary to use ferro-silicon to get the desired amount of silicon in the charge. To see how this and the steel mixed with the pig iron two tests were taken from No. 13, which contained 1,000 pounds of steel, 400 pounds of ferro-silicon (8.5 per cent. silicon) and 2,600 pounds of pig iron. The charge was tapped from the cupola into a ladle, and the tests taken at different times, as the iron was being poured from the ladle. The one sample contained 2.53 and the other 2.54 per cent. of silicon.

"Two tests taken in the same way from No. 14 contained 1.97 and 1.94 per cent. of silicon. This charge was made up of 1,500 pounds of steel, 450 pounds ferro-silicon, and 2,050 pounds of pig iron.

"Similar tests from charge No. 2, which was made up of 1,000 pounds steel and 3,000 pounds pig iron, contained 1.50 and 1.52 per cent. of silicon.

"These three cases offer pretty strong proof that the pig iron, steel, and ferro-silicon mixed thoroughly.

"Although of a limited number, the tests given seem to indicate that 25 per cent. of steel will add about 50 per cent. to the strength of the iron; and 12½ per cent. of steel approximately 25 per cent. The tests containing 37½ per cent. of steel were hardly as much improved in strength as those with 25 per cent. of steel, from which we may infer that the limit of the amount of steel it is beneficial to melt with iron in a cupola, is between 25 and 37½ per cent."

Melting Semi-Steel.—A higher heat is required to melt steel than cast iron, and when the two materials are melted together in a cupola more fuel is required for the metal to be at a sufficiently high temperature when drawn from the cupola to insure a thorough mixing and uniting of the iron and steel. When only 2 to 5 per cent. steel is melted throughout a heat for the purpose of increasing the strength of the castings, very little if any extra fuel is required, but when a greater amount than this is used, or a special charge of from 10 to 60 per cent. steel is melted on the bed, it is the practice to increase the height of the latter from two to three inches above that required for a hot iron, and when a larger per cent. of steel is used throughout the heat the charges of coke are also increased a like amount. The exact amount of increase must be determined by experience in melting a semi-steel, but it must be sufficient to give a very hot metal at the cupola spout, as when this is not done, a spotted metal will be the result. The steel should be charged on the fuel and the iron on top of the steel. When melting a large per cent. of plate steel, care must be taken to charge the steel in such a manner as to permit the blast and heat to pass between the plates to melt them. If this is not done, the steel may be converted into a solid mass in the cupola that cannot be melted at all, as has been the case in a number of instances. To avoid this the plates must be bent in such a manner as not to admit of them becoming packed and welded to each other, and to make openings through which the blast and heat can pass around them. When melting steel rails or railroad track steel, it is good practice to cut the rails into short pieces and charge them around the cupola with the ends towards the center, and fill in coke between them before charging the pig iron, a hot metal and even casting being thus insured. By charging the steel on the coke it receives the first greatest and most prolonged heat, and is ready to melt as soon as the pig and the two metals come down together, the result being a more even mixture of the two metals. For large castings, it is the practice to draw all the semi-steel into a large ladle and thoroughly stir it with a bar before casting, but this is seldom done for small castings, the metal being taken direct from the cupola in small ladles and poured. Always melt a semi-steel mixture hot and fast. When hard spots are found in the castings, the first thing to be done is to look to the charging and mixing of the metals.

Very light clean turnings of steel can be melted in a ladle of very hot iron, and from 2 to 3 per cent. of steel added to the iron in this way. The turnings must be put into the iron in a way that will not admit of them balling up or adhering to the bottom of the ladle.

A higher and more prolonged heat is required to melt steel than cast iron, and the destruction of lining material is greater in melting semi-steel than in melting iron, but with up to 25 per cent. steel this destruction has not been found to be any great objection, and a lining, when properly kept up, lasts almost as long as in melting iron.

Semi-Steel Mixtures.—With the ordinary jobbing and machinery foundry pig, containing from 2 to 3 per cent. silicon, from 15 to 25 per cent. steel may be used. For gear wheels, pinions, etc., this mixture gives a strong, close metal that wears well and is not too hard for finishing. For the lighter castings 15 per cent. is used, 20 per cent. for the heavier ones, and for thick, heavy castings, 25 per cent. Should either of these mixtures prove too hard, or the metal uneven, a less per cent. of steel should be used or a pig higher in silicon. To make a 50 per cent. steel mixture a pig higher in silicon than No. 1 or 2 foundry pig is required, as the castings should contain from 1 to 2 per cent. silicon according to thickness and, the pig must furnish all of it.

The following semi-steel mixtures for steam cylinders were recently published in *Castings*, by James A. Murphey, foundry foreman of the Hoover, Owens, Rentschler Co., Hamilton, Ohio, and include a very satisfactory mixture for large Corliss cylinders. The lowest amount of steel to do much good is 10 per cent., the maximum about 30 per cent., for all such work. Below are given a few analyses and tests of Corliss cylinders, made by the Hoover, Owens, Rentschler Co., whose cylinders are all semi-steel and who have a very desirable record on this class of work. The making and testing of these cylinders was in each case subject to the supervision of the purchaser's inspectors:

30-inch jacketed pumping engine cylinders. No. 1. Silicon, 1.66; sulphur, .065; phosphorus, .70, and manganese, .90; transverse test, 4,100 lbs.; tensile test, 36,000 lbs.

No. 2. Silicon, 1.60; sulphur, .063; phosphorus, .72; manganese, .85; transverse test, 4,400 lbs.; tensile test, 37,300 lbs.; mixture, 80 per cent. pig and 20 per cent. steel.

50-inch jacketed cylinders. Silicon, 1.70; sulphur, .07; phosphorus, .70; manganese,. 75; transverse test, 3,560 lbs.; tensile test, 30,400 lbs.; mixture, 80 per cent. pig and 20 per cent. steel.

30-inch plain Corliss. Silicon, 1.70; sulphur, .075; phosphorus, .60; manganese, .92; transverse test, 3,350 lbs.; tensile test, 31,300 lbs.; mixture, 80 per cent. pig and 10 per cent. steel.

The latter mixture is good for any ordinary cylinder, as far as the analysis is concerned, but the carbon must be watched to get the desired grain. The percentage of steel can be raised for heavier work, or, what is often better, a somewhat harder pig iron may be used. The graphite carbon should be kept from 2.50 to 2.80 per cent. and the total carbon about 3.50 per cent.

Calculating Mixtures.—A simple way of calculating the semi-steel mixtures is as follows:

	Per Cent. of Silicon in Pig Iron and Scrap.	Per Cent. of Silicon in Mixture.
40 per cent. high-silicon pig iron.......	3.10×0.40	1.24
20 per cent. high phosphorus pig iron...	2.30×0.20	0.46
15 per cent. cast iron scrap.....	2.00×0.15	0.30
25 per cent. steel scrap...............	0.04×0.25	0.01
Total silicon in mixture............		2.01

	Per Cent. of Phosphorus in Pig Iron and Scrap.	Per Cent. of Phosphorus in Mixture.
40 per cent. high silicon pig iron.......	0.65×0.40	0.26
20 per cent. high phosphorus pig iron..	1.50×0.20	0.30
15 per cent. cast iron scrap............	0.60×0.15	0.09
25 per cent. steel scrap...............	0.08×0.25	0.02
Total phosphorus in mixture.........		0.67

When making semi-steel to be finished without annealing, care should be taken not to use too high a per cent. of steel in the mixture; 25 per cent. is about the limit that can be used with the general run of foundry pig, and to have a casting sufficiently soft for planing and boring. Good mixtures are made with from 10 to 15 per cent. steel and with more certainty of a homogeneous casting than with a higher per cent. When making cupola semi-steel, it is better practice to use a pig that contains about the desired per cent. of silicon, phosphorus and manganese the semi-steel is to show than to depend upon adding these elements to it in the cupola, or after the metal is melted. Melt a semi-steel mixture hot, and pour it hot to insure a sound casting.

Test-bars 2 × 2 × 24 inches show a greater proportional transverse strength and deflection than bars 1 × 1 ×24. This is due to the chilling tendency of the metal whereby the strength of the lighter bar is reduced.

Shrinkage in Semi-Steel.—The shrinkage in steel castings when being cast is so great that very large gates and runners have to be used for light castings, and large sinking heads have to be placed upon heavy castings to prevent shrink holes, and to obtain perfect castings. So great an amount of metal has to be used for this purpose, that the remelt of gates, sink heads, etc., amounts to from 12 to 40 per cent. of the heat melted. Steel when melted with iron increases shrinkage in proportion to the per cent. of it melted with the iron. When a large per cent. of steel is used in a mixture of semi-steel, provision must be made for this shrinkage by larger gates and runners for the castings than for iron, as well as for sink heads through which heavy castings may be fed up and churned. On account of this shrinkage a semi-steel is better suited for small, chunky and heavy castings than for large light ones, such as large frames, which frequently shrink and warp to so great an extent that they can only be used after annealing. The shrinkage in such castings has also been found to be uneven, and in this case they are no better or stronger than cast iron ones, even if they do not warp.

Semi-Steel Malleables.—A new industry in the foundry line known as steel malleables has in the past few years sprung up. These malleables are cast from a semi-steel containing from 40 to 80 per cent. steel in combination with a malleable iron pig mixture containing only sufficient silicon and carbon to give the necessary fluidity to the metal for casting. The metal when cast is white, hard and brittle, and after casting is put through the malleable annealing process to render it soft, malleable, and strong. It is claimed that these malleables are much stronger than iron malleables and that, when the higher percentage of steel is used in the mixture, they may be forged and tempered, excellent cold chisels and other tools having in this way been made. The semi-steel malleable mixture is drawn from the cupola into very small hand ladles and cast into the lightest of bench work malleables with no trouble in running them. This shows that when semi-steel is properly melted there is no difficulty in casting the lightest of castings.

Iron and Steel Founding.—Many iron founders who have an occasional call or order for steel castings have an idea that they can put in a baby Bessemer converter or open-hearth furnace and make these castings as readily as iron ones, or as a steel foundry. This is a mistake, for there is very little in common between the iron and steel foundry except the patterns. In steel founding heavy iron flasks are generally used and a totally different grade of moulding sand as well as a different kind of blacking is required, and an entirely different system of moulding and gating. The metal has not only to be melted, but to be made. Its temperature and shrinkage are different from those for iron, and a different system of handling it is required. By the time the iron founder has learned all these things, he will conclude there is about as much difference between iron and steel founding as between iron and brass founding. The most difficult problem, however, the founder will encounter is the manipulation of the converter or furnace. The average iron founder and foreman know nothing whatever about the manipulation of these furnaces or the making of steel from pig iron and scrap iron or scrap steel. Before they learn the mysteries of these processes many heats and castings will be lost, and probably the steel founding project abandoned with the cost of converter or furnace charged to profit and loss.

It must be remembered that the making of steel is a separate and distinct business and science, and with the Bessmer converter, largely a science of the eye, for the quality of steel must be judged or decided by the various colors of the flame thrown out from the mouth of the converter. The eye must be trained to this work, either with or without the spectroscope, and it must be kept in training for this work, for even an expert could not accurately judge the quality of a steel if only called upon to do so once a week or month. In the open-hearth process the flame also has its indications which are judged by the eye, and there are many other points that an operator must be in constant training for to be an expert and produce a steel of a desired quality with any degree of certainty. It will thus readily be seen, that the iron founder can not afford to undertake to make a few steel castings now and then for his iron casting customers. But the iron founder may engage in steel founding if he has enough orders for steel castings to justify him in putting in a baby Bessemer converter or open-hearth furnace, and employ a steel expert to make a steel suitable for the work to be cast.

Strengthening Cast Iron with Steel.—Cast iron is strengthened by the addition of steel for the following reasons: First, it breaks up the graphite carbon into a fine grain or flake, which makes the casting closer-grained and stronger with very little increase in hardness. Second, because it counteracts the influence of high phosphorus and silicon, which have a tendency to make the iron weak or erratic. The amount of steel scrap used does not to any extent affect the per cent. of carbon present in the iron, as the steel in every case takes up from the fuel the amount of carbon that has been reduced in the total mixture by the use of steel scrap. For example, if an iron containing 3.50 per cent. of total carbon is melted with an equal amount of steel containing 0.50 per cent. carbon, theoretically the resultant mixture would contain about 2.00 per cent. carbon. But this is not the case, for the melted metal takes up carbon from the fuel until it contains almost as great an amount as the original pig iron. The introduction of steel into cast iron in a cupola converts it back into iron, but with this difference, that the graphite carbon is broken up into finer flakes, or the carbon taken up by the steel from the fuel exists in a different chemical combination than that in the iron. The diffusion of this carbonized steel through the iron imparts to it the strength of a semi-steel which is greater than that of cast iron. This illustrates the control of carbon in cast iron when this control is not destroyed by other elements, and the elimination of these elements would no doubt give a stronger cast iron without the steel scrap.

The following opinions and descriptions of semi-steel by other writers illustrate many of the characteristics of this metal and may give desired information to our readers in regard to it.

USE OF STEEL SCRAP IN THE CUPOLA.* THE PRODUCTION OF SEMI-STEEL CASTINGS—PROPORTIONS OF STEEL USED IN THE MIXTURES—INTERESTING TESTS.

BY C. R. MCGAHEY.

The foundryman of to-day is confronted with the problem of what kind of cast iron he shall try to make; whether to go into irons that show greater elasticity and strength, or to adhere to softness regardless of what the work is intended for.

In working out this problem, I took for my standard of comparison a test bar longer than the ordinary, as this did not run the breaking strengths too high, and also gave deflections more readily observable than with the ordinary 1¼-inch round bar broken on supports 12 inches apart.

My tests ran from 750 pounds up to 2,400, with a 1 × 1 × 24-inch bar, separately cast—not as a coupon. The deflections approximated from 0.10 up to 0.55-inch. This range obtained with all kinds of iron in the ordinary run of shop work is not at all satisfactory, and it would seem that some point ought to be selected to which foundrymen should work in order to get the most satisfactory product in regular jobbing castings, not special work.

Elastic Limit.—To best resist repeated strains, shocks, and

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*Presented at the Cincinnati convention of the American Foundrymen's Association.

heavy work, it is necessary to run the elastic limit up as high as possible and yet hold a good deflection. Since the breaking strength and elastic limit in cast iron are not far apart, we would naturally try to get our transverse test quite high, and for the bar in question aim at 2,000 pounds, and perhaps even higher, the deflection running up to 0.50-inch.

It is further necessary to reduce the shrinkage to a minimum, so that the interior strains may be obviated as much as possible. This is particularly the case where pulleys, fly wheels, and the like are made. A careful study of the chemistry of iron will aid in this, and the addition of steel to the mixture, thus reducing the total carbon, gives us the best solution. In this way it is possible to run up the strength of the bar 70 per cent. and also greatly increase the deflection.

Semi-Steel and Ferro-Carbon.—The terms semi-steel and ferro-carbon, while used with good intentions, are entirely misleading, as we do not convert the iron charged to steel or anything like steel, but simply dissolve the steel scrap added in the iron mixture, making it of higher strength. It is cast iron just the same.

In using steel scrap, much depends upon the coke. I have found that with mixtures of the same composition, with one coke I would get a high strength, and with another quite the reverse. The melting conditions were exactly the same, and the peculiar results are doubtless due to the composition, structure and behavior of the coke in the cupola, causing the iron to melt more or less rapidly, and remain in contact with the fuel to a greater or less extent. Thus a coke with a low ash, or in other words high fixed carbon, gave a very hot iron, but with a much lower transverse strength than another coke higher in ash, but with the same sulphur. The addition of steel scrap to the better coke gave the strength more nearly equal to the other metal, showing evidently a greater absorption of carbon from the fuel with the better coke and hotter metal.

It is therefore necessary to understand the fuel and melting conditions well in order to obtain desired results. It is further necessary to run quite hot, and when much sulphur is present, to carry high manganese, as this tends to flux off the sulphur, as a manganese-sulphide. A very interesting observation was made when an accident stopped operations for a short time. The test bars made from the metal right after starting up again ran very much better than the average of the run. It seems as if the stoppage gave the steel time to reach a high temperature, and hence it melted more readily, thus producing lower carbon cast iron, with consequent higher strength.

Mixing the Materials in the Cupola.—To get the materials of the charge to mix well is very desirable. I have had the best results when allowing the bed to burn for two hours, having it heavy enough to allow this, then to use very mild blast (from five to six ounces only). This always gave me higher strengths than when I used an eight ounce blast or higher. If time is given for the steel to melt and mix with the cast iron, the total carbon will be lower than if the cast iron of the mixture flows rapidly past the steel and has no chance to unite. For this reason it is also better to place the large pieces of steel low in the cupola, and the smaller pieces above. This allows the cast iron to wash it as it goes down, and unite with the steel, making a low carbon cast with consequent strength.

The reduction of the total carbon by steel additions makes the resulting castings very much denser. If the sulphur is controlled by hot melting and high enough manganese, and the phosphorus kept down (my best work has been with phosphorus about 0.230 per cent.) very serviceable castings are made.

Silicon and Sulphur.—Another point that will be observed in this steel scrap melting is the rather great irregularity of the silicon reduction in hot runs, and in the sulphur content. The latter shows wide variation. Silicon, on the other hand, usually runs about 0.25 per cent. loss in normal heats, but is much greater if the temperature rises rapidly. The deflection is better when the sulphur is low.

The following are some results that may be of interest: Metal which would have ¾-inch chill and be entirely gray when cast in sand, in the 1-inch square section, had silicon, 0.82 per cent.; sulphur, 0.097 per cent.; phosphorus, 0.23 per cent.; and manganese, 0.54 per cent. This metal in a bar 1 × 1 × 24 inches broke at 1,800 pounds with a deflection of 0.38 inch. The percentage of steel carried was 7. The coke used contained sulphur, 0.54 per cent.; phosphorus, 0.63 per cent.

Another test gave silicon, 0.88 per cent.; sulphur, 0.081 per cent.; phosphorus, 0.24 per cent.; manganese, 0.67 per cent. The test bar broke at 2,200 pounds with 0.40 inch deflection, and the charge contained 20 per cent. steel.

A third test gave silicon, 0.58 per cent.; sulphur, 0.097 per cent.; phosphorus, 0.25 per cent.; manganese, 0.44 per cent. The bar broke at 2,250 pounds with 0.48 inch deflection, and had 23 per cent. steel scrap (structural material).

Another good mixture gave silicon, 0.79 per cent.; sulphur, 0.081 per cent.; phosphorus, 0.239 per cent. and manganese. 0.64 per cent. This carried 21½ per cent. steel scrap.

I find that to get the strongest bars, I have to keep pretty close to these analyses, and have made my strongest bar at 2,350 pounds, with 0.55 inch deflection. The iron had a fine grain, was low in graphite, but machined nicely.

When ferro-manganese was used, about 1 per cent. was found to be best. The above resulting compositions are intended for castings ranging from 1 to 2½ inches in section. Should heavier work be required it is better to run the silicon in the pig up to 2.75 per cent., add the manganese up to 2 per cent., and to use 33⅓ per cent. steel scrap.

THE WEARING QUALITIES OF SEMI-STEEL VERSUS GRAY IRON. GRAY IRON PLUS STEEL SCRAP OR WITHOUT IT, THE CHARACTERISTICS OF SEMI-STEEL AND THE PURPOSES FOR WHICH IT IS BEST FITTED, ALSO CERTAIN CAUTIONS NECESSARY TO GREATEST SUCCESS WITH STEEL SCRAP IN THE CUPOLA.

BY JAMES A. MURPHY.

Perhaps the question may be better stated, Is gray iron containing from 15 to 25 per cent. of steel scrap in the mixture superior in wearing qualities to common strong machinery gray iron?

When the steel is properly melted and used in the right proportions for the job in hand, I unhesitatingly answer, Yes, when when both mixtures are from the cupola. Semi-steel is the mermaid of the metallurgical world. There are those who say of it as Sailor Jack of the mythical mermaid, "There ain't no such thing in natur'."

The term semi-steel is a misnomer and like "gun iron" and other popular names given ostensibly to denote a superior article or hide a supposed secret process of manufacture. Semi-steel is a trade name having the one redeeming quality that it is meant to express the fact that some percentage of steel was used in the mixture and with the hope that this will convey the idea of a superior quality of gray iron.

Semi-steel and Air-furnace Iron.—Semi-steel is no better, if properly made, than an air-furnace iron reduced from cold-blast charcoal iron. On this hinges the whole question. For strength in any form, homogeneity and fine wearing qualities, it is far superior to the ordinary mixture made from all gray iron in either cupola or air furnace, provided it is mixed and melted right and the proper proportions used for the purpose in hand.

For steam, gas, hydraulic and other cylinders it has no superior in great strength, rigidity and closeness of grain, homogeneity and durability. Steel becomes such in the first place by the elimination of carbon, principally, and it again returns to cast iron when reduced in the cupola in the presence of fuel; as it again absorbs carbon, just as any other iron does in its original production in the blast furnace.

No Steel in it.—There is no steel nor any sign of it in semi-steel. The only way we know it is by its fracture, the grain being fine, the carbon particles being minute and finely distributed, giving a very close and even fracture in even the thickest sections, being in that respect equal to and mostly superior to good air-furnace iron.

Semi-steel, to use its popular name, has many enemies, principally among those who have been failures in its production, and they are legion. Neither all foundries nor all foundrymen can successfully melt steel scrap in the cupola, nor do they know how to mix it for attaining a desired result. It is to these causes, together with a general metallurgical ignorance, that the many dismal failures in the use of steel may be attributed.

"It does not mix" is a sort of cant expression. Many cannot keep it from running to holes. Others cannot keep it from chilling. Some have experienced such a combination of troubles that they could not be described in a short article, all of which, however, are caused by unscientific mixing, bad melting, and in some cases bad molding and pouring practice.

Mistakes in Melting and Mixing.—I would venture to say that a cylinder cast from this unmixed metal or one in which white spots, streaks or patches show up in the bore or valve seats after being machined, would be unfit for use, as it would wear and cut very rapidly. Such spots are not unknown in all gray-iron mixtures, for if the metal is not melted right, whether by oxidation, burning or melting at too low a temperature in the cupola, spots and streaks invariably show up on the finished surfaces as white iron.

Failures and Founders.—All engine builders who aim for the highest possible quality use either air-furnace iron or semi-steel in their cylinders. Some even chill the bore, but whether this last method has any advantage over semi-steel or air-furnace iron is a much-debated question; the bore is so close that the lubricating effect of the carbon pits and particles is almost entirely lost. The melancholy failures that have been the portion of many in attempting semi-steel have been the result of no other reason that I can see than the lack of a competent foundryman in their employ. These people usually join the Knockers' Club on the steel proposition.

Practical Requirements.—It is surprising at this stage of advancement in the foundry industry to still find people who ought to know better saying that steel and iron do not mix or make a perfect alloy. When wrought iron or hard steel is used, this is often true, but neither of these is fit for the purpose in the smallest degree, the assertions of some metallurgical authorities on the subject to the contrary notwithstanding. In my own practice I never use wrought iron or hard steel and I would not advise anyone to do so. They will mix, but the temperature of the cupola can never be relied upon to reduce them properly, and for machine or finished work they are unfit for use.

Relies on Steel Scrap.—After a long and varied experience in the engine and heavy jobbing business, I have nothing but the highest regard for steel scrap and the greatest confidence in its efficiency, having often found it to be the great panacea for the ills to which castings are heir. It closes the grain, reduces the graphitic and total carbon according to the percentage used, and what is more important, through its quicker cooling distributes it more minutely and evenly throughout the section. It prevents sponginess and segregation, lessens liability to cracking, adds to the tensile and transverse strength, increases deflection and modulus of rupture, gives a high resistance to shock, is higher in sulphur than air-furnace metal, which latter is an advantage in wearing qualities. On the whole it is so far superior in every way to common gray machinery iron for cylinder work that there is but very little comparison between them.

IS SEMI-STEEL A MISNOMER?

BY DAVID MCLAIN.

Twenty years ago, foundrymen generally agreed that there was no such metal as semi-steel. In the early days, castings made from steel mixtures were hard, filled with blow holes and resembled the defective crucible steel castings of that period. Many foundrymen still assert that there is no mixture which can be properly termed semi-steel. They claim that the two metals do not mix; that the steel does not unite with the iron and castings containing steel have many hard spots. Nevertheless, at the present time semi-steel castings, such as small cylinder heads, cylinders, piston rings, ammonia castings of comparatively light section, generator sections, etc., containing as high as 30 per cent. of steel scrap, can be made in the foundry at a lower cost than many fancy iron mixtures. I have a letter in my possession dated February 1, 1904, from one of our most noted foundry metallurgists condemning the use of the term semi-steel. However, my method of producing this mixture was commended. Referring to my practice of using from 30 to 40 per cent. of steel scrap in the mixture and quoting from his letter, this metallurgist said: "I can only, therefore, congratulate you on this work, and hope you may reap some good returns from it. Nevertheless, it seems a pity that others should be made to lose money all the time from the lack of this information." An eminent electrical engineer a few months later wrote as follows: "Regarding the use of semi-steel castings in direct-current generators and motors, would say that I have found it possible to work both in density and cross section just half way between steel and cast iron. In other words, a cast-iron magnet frame that would require 100 square inches of metal would only require 75 of semi-steel and 50 of steel. It is particularly useful for machines in which the speed is from 10 to 20 per cent. lower than that of standard types."

Heretofore the electrical engineer had only two metals, iron and steel, to consider. Now he has iron, steel and ——. In some cases there is as high as 50 per cent. steel in the mixture. Would you call it semi-steel?

J. Jay Metzger gives in *Castings* the following semi-steel mixtures for gasoline engine cylinders. There are various mixtures of iron for cylinders. According to analysis no two are alike. Each foundryman thinks that his is the best, and not without reason either; but what would apply to one make of cylinders with success may fail in others of different construction. Therefore, it is quite a problem to create a mixture that will insure a close grain and stand wear and tear. The following mixtures have been used successfully:

No. 1.

Pig silicon, 2.50 per cent	300 pounds.
Remelt, silicon, 2 per cent	1,200 pounds.
Boiler plate steel	500 pounds.
Ferrosilicon, 50 per cent	3½ pounds.
Ferromanganese, 80 per cent	9 pounds.
Pure aluminum	1 pound.

First charge the steel on the bed, then add 200 pounds of coke; charge the pig, then the remelt; place the silicon and aluminum in the ladle. Use ground ferro-manganese and pour it in the spout when the iron is running. Do not, under any circumstances, mix the steel with the cast iron in the cupola or you will get the steel in the following charge. Use 72-hour coke not to exceed 7.5 per cent. in sulphur and of firm structure. The aluminum is needed to deoxidize the mixture; it is necessary to prevent gas holes.

A Close Grain that Machines Easily.—The above mixture carries a big percentage of remelt, but that is better than a large amount of pig iron and will have a very close grain and machines very easily. Do not use steel unless you add the manganese. This mixture is sometimes called semi-steel and it is exceptionally good for cylinders and pistons. The steel is the cutting and trimmings from regular boiler plate.

No. 2.

Charcoal pig silicon, 2 per cent	500 pounds.
Remelt, silicon, 2 per cent.	1,300 pounds.
Boiler plate steel	200 pounds.
Ferrosilicon, 50 per cent	2 pounds.
Ferromanganese, 80 per cent	8 pounds.
Pure aluminum	1 pound.

Mix No. 2 according to the directions given for No. 1.

Silicon and Manganese.—The silicon in No. 1 should run about 1.45 per cent., and in No. 2 about 1.50 per cent. in the casting.

The manganese in No. 1 should run about 65 per cent. and in No. 2 about 70 per cent.

The above mixtures are perfectly reliable. Be accurate in weighing and charging.

No. 3. For Piston Rings.

Charcoal, silicon 2 per cent	800 pounds.
Remelt, silicon, 1.50 per cent	1,100 pounds.
Boiler steel	100 pounds.
Pure aluminum	1 pound.

Quality of Piston Rings.—Charge this mixture the same as No. 1. The silicon should run about 1.35 per cent. and manganese about 0.40 per cent. in casting. This mixture is very good. It machines nicely and the rings are springy. The silicon seems to be very low, but it is important that the rings should be on the hard side.

NOTE.—There is a wide difference of opinion among chemists as well as foundrymen as to the per cent. of manganese a semi-steel should contain, some claiming 0.40 and others 1.60. The best per cent. probably depends upon the quality or kind of iron used in the mixture, a strong iron requiring less than a weak one.

Semi-steel properly mixed and melted requires no aluminum to produce sound castings and its use has been discontinued by all practical semi-steel founders.

Mixture for six-inch cylinder, thickness five-eighths inch.

Per cent.		Silicon Per Cent.
50 Coke iron,	2.20 Silicon	1.10
10 Car Wheel,	0.60 "	0.06
10 Steel Scrap,		
30 Cast Scrap,	1.80 "	0.54
Total Silicon		1.70

Mixture for twenty-inch cylinder, thickness one and one-half inches.

Per Cent.		Silicon, Per Cent.
40 Coke Iron,	2.20 Silicon	0.88
10 Car Wheel,	0.60 "	0.06
20 Steel Scrap,		
30 Cast Scrap,	1.80 "	0.54
Total Silicon		1.48

If any of these mixtures fail to give a satisfactory metal it is not due to the steel or car wheel scrap, but to the unknown quality of the pig and scrap, which should be varied or another quality substituted in the mixture.

Semi-Steel Gears.—A good mixture for gears should carry about 25 per cent. steel scrap. This can be made of pig iron, machinery scrap and steel scrap. The pig iron should have approximately the following analysis:

	Per Cent.
Silicon	3.25
Sulphur	0.04
Phosphorus	0.50
Manganese	0.75

Use about 50 per cent. pig iron, 25 per cent. machinery scrap, 24 per cent. steel scrap and 1 per cent. ferro-manganese in the cupola. Have the metal hot. The semi-steel should have approximately the following composition:

	Per Cent.
Silicon	2.00
Sulphur	0.10
Phosphorus	0.50
Manganese	0.60
Graphitic carbon	2.40
Combined carbon	1.00

CHAPTER XVI.

MALLEABLE IRON.

History.—The discovery of the process of making malleable iron appears to have been due, many years ago, to the efforts of numerous founders to soften hard castings by annealing them in contact with various substances. In 1722, Réaumur collected the results of these operations and published the fundamental principles of making malleable iron, but this knowledge does not appear to have at that early date been reduced to a practical science even in Europe. So little of foundry history or practice was published in early days, that there is no telling when the process of making real malleable castings was first practised in foreign countries. But it is not likely that there was any real malleable plant at that early day, and even at this time the output of malleables is very small, being estimated for 1907, at only 50,000 tons for all Europe.

History in this Country.—Malleable iron founding was first started in this country by Mr. Seth Boyden, in the year 1826, at No. 28 Orange Street, Newark, N. J. It was there that he began casting and annealing buckles and bits for harness makers, and it was from him that all the malleable iron foundries learned the art of decarbonizing castings and giving to them the strength of wrought iron, the material from which such things were forged prior to this date. In 1828, the Franklin Institute of Phila., Pa., offered a silver medal for the best specimen of annealed cast iron, to consist of not less than one dozen pieces; the following is taken from the report of a committee, of that year:

" Premium No. 4, for the best specimen of annealed cast iron, is awarded to Seth Boyden of Newark, N. J., for specimen No. 163, being an assortment of buckles, bits, and other castings remarkable for their smoothness and malleability. This is the first attempt in this country to anneal cast iron for general purposes that has come under the knowledge of your committee, and the success attending it fully entitles the maker to a silver medal."

Mr. Boyden continued in the business for nine years during which time he established quite an extensive trade, and his plant grew from a very small foundry to one employing sixty moulders which was quite a large one for those days. But Mr. Boyden was a natural-born investigator and inventor and not one of those that could stay at any one thing very long and, in 1835, he sold out the business to The Boston Malleable Cast Iron and Steel Co., which failed two years later, when the plant passed into other hands and since that time has been managed by a number of firms, but is still in existence at the old stand, although very little of Mr. Boyden's original plant remains.

Although Newark has been the home of many prominent foundrymen, among them Mr. Mackenzie, the designer of the famous two-hour Mackenzie Cupola, which was the first real improvement made in the construction of cupolas in this country, Seth Boyden is the only one to whose memory a monument has been erected in the city park. This monument which is cast in bronze with the inscription, "Seth Boyden, Inventor" stands almost within a stone's throw of the sight of his original malleable plant.

Soon after Seth Boyden's discovery of annealing castings, which he failed to patent, Newark became the center of malleable foundings, there being at one time eight plants in operation in that city. In 1837, Alex Boyden, a brother of Seth Boyden, established a malleable plant in Boston, Mass., and in 1850, one was operated in Cincinnati, Ohio, and in this way the business has spread from Newark all over the country until the output of malleables in this country, has grown from a few pounds, at Seth Boyden's plant in 1826, to an estimated output of 980,000 tons for 1907.

In 1882, the writer met Mr. William G. Morris, whose father had been an apprentice of Seth Boyden, and he himself had grown up in the Boyden plant, and became the practical manager of it and was regarded as one of the highest authorities in the art of malleable iron making in this country. It was about this time that Mr. Morris had gotten hold of the writer's first work, "The Founding of Metals," in which he was very much interested and an intimate acquaintance sprang up between us. It was from Mr. Morris that the writer first learned that Seth Boyden had gone through exactly the same experiments as himself when engaged in the malleable business in 1872, and tried everything imaginable as a packing for annealing such as sand, plaster of paris, lime, borax, salt, saltpetre, alum, various pulverized iron ores, etc., without any satisfactory results, the same as probably every investigator in this line has done before settling down, as Seth Boyden did, to the red oxide of iron as the best material known for packing in annealing malleables, and also to certain brands and grades of iron which from experience have proved to be the best for making malleable castings.

In Seth Boyden's first experiments all his iron was melted in crucibles, probably because he desired only a limited number of castings for his experiments in annealing, but as soon as he had done his experimental work, he constructed an air furnace from which the iron was dipped in small hand ladles coated outside and within with clay For use in this furnace he patented, in 1831, a fuel composed of fine coal, rosin, pitch, or tar in suitable proportions for the intensity of heat desired. This fuel was designed to produce the flame required in air-furnace melting. In 1832, he constructed a cupola to take the place of the air furnace, using anthracite coal as a fuel.

Patterns were made of wood, white metal, brass and iron, and attached to gates. Flasks were made of sheet iron and round so that there might not be any spring to them, and castings were cleaned in a wooden tumbling barrel with a door on the side, and furnished with holes to permit the sand to escape from the barrel. His annealing pots were made of iron and, upon the whole, he appears to have covered the ground so thoroughly that since his day very little, if any improvement has been made in the process of manufacturing malleable iron, and it remains the same, although chemistry has explained it, and better facilities have been provided for doing the work.

Iron for Malleables.—The most important factor in the making of malleables is a suitable quality of iron to begin with, for without this no satisfactory product can be turned out. The best iron for this purpose is the cold blast charcoal iron a number of brands of which are considered the standard or best, among them being the Mable, Briar Hill, Hinckley, Ella, etc. Other local brands used in different sections of the country are equally good. Of these irons only the higher numbers, ranging from three to eight, are used, because the castings before annealing must be practically free from graphite carbon, and present a perfectly clear white iron in the fresh fracture. Good malleables can be made from several grades of any one of these brands but, as in gray iron, a mixture of several brands is generally considered to give better results than one brand. At malleable plants, mixtures are guarded even more carefully than at gray iron foundries but, where brands of iron mentioned can be obtained, they are made about as follows, for a five-ton charge:

Mabel	2500 lbs.
Briar Hill	1500 "
Hinckley	1000 "
Ella	1750 "
Sprews	3250 "

A mixture in which malleable scrap is used would with these irons be made about as follows:

Mabel	2000 lbs.
Briar Hill	1000 "
Hinckley	500 "
Ella	2000 "
Sprews	3250 "
Malleable Scrap	1250 "

A mixture to which steel scrap is added is made about as follows:

Mabel	2000	lbs.
Briar Hill	1000	"
Hinckley	500	"
Ella	1500	"
Sprews	3250	"
Malleable Scrap	1250	"
Steel Scrap	500	"

In mixtures to which malleable scrap or steel scrap, or both, are added, a softer or higher silicon iron must be used than in all pig and sprew mixtures, to give life and fluidity to the iron for small castings. The following analysis is recommended for malleables:

Silicon	0.75 to 1.50	per cent.
Carbon	3.00	"
Sulphur not over	0.04	"
Manganese not over	0.60	"
Phosphorus not over	0.200	"
Malleable Scrap, Sil	0.45	"

This shows the analysis in the castings and in making mixtures, but allowances must be made for loss in melting. The loss of silicon in air-furnace melting is about 0.35 per cent.; in cupola melting 0.25 per cent.; loss of carbon 0.25 to 0.50 per cent.

Steel when used in malleable mixtures increases the shrinkage to so great an extent that not over 5 per cent. can be used without increasing the size of patterns to allow for extra shrinkage in the casting.

Coke Iron.—Coke and anthracite irons were years ago many times tried for malleables with almost complete failure. After the introduction of foundry chemistry they were again tried with little better results, and many heavy losses occurred, but of late years blast-furnace chemists have solved the problem of making coke iron suitable for malleable purposes, and iron known as coke-malleable is now regularly made at many furnaces. For this iron certain brands of ore are used and a limited amount of mill cinder is added to the mixture. Plenty of coke is used in smelting and the iron smelted from this mixture, which contains from 0.75 to 1.75 per cent. silicon, is generally considered to be equal to charcoal iron. It is doubted by many if this is really the case, but malleables are now regularly made from this iron and appear to give good satisfaction. All coke irons, however, are not suitable for this purpose and only those especially made and known as malleable pig are used. This pig is generally very high in manganese and that containing as high as 2 per cent. is used in mixtures. One foundry, whose reputation for good malleables stands very high, reports using this iron with 10 per cent. steel rails in their mixture.

Malleable Scrap.—Malleable scrap for many years was a drug upon the market. The malleable founders or gray iron founders could not use it, rolling mills did not care for it, and in fact there was no market for it. A junk dealer who was stuck with a lot of it by a competitor is said to have shipped a lot to an imaginary customer in the west to get rid of it, and make his competitor believe he had found a market for it. But of late years malleable founders have been using it for casting annealing boxes, and it is said to be the very best material for this purpose. It is also to some extent used in regular malleable mixtures, and is said to make a stronger casting than an all pig and sprew mixture, especially for heavy work. In this mixture it has about the same effect as steel, requiring a higher silicon pig to carry it and more fuel to melt it. But its effect is not so radical as that of steel and a larger per cent. of it can be used without so great an increase of silicon as with steel. Mixtures have been made with as high as 80 per cent. of malleable scrap, but such mixtures are difficult to run, the castings do not present a good appearance, and the common practice is not to use more than 20 per cent., and this amount principally for heavy work.

Melting Furnaces.—At the first malleable plant in this country the iron, after the first experimental work had been done, was melted in a hot air or reverberatory furnace, but after a few years' use of this furnace, a cupola was constructed and found to answer the purpose equally as well and melting was done at a less cost. From this time on to the introduction of coke irons for malleables, both furnaces were used with a large preponderance in favor of the cupola, which melted the iron more rapidly at less cost and, when the iron was right to begin with, produced as good malleables as the air-furnace. But with the introduction of coke iron and the necessity of testing and doctoring the iron before pouring into castings, the air-furnace took the lead and, according to data collected by the Foundry, in the February issue of 1910, there are now in use in this country 369 air-furnaces, 21 open hearth furnaces, and 42 cupolas. According to these data, the cupola would seem to be doomed as a furnace for malleables, but its use will no doubt be continued in those plants for boxes and other foundry castings, and it may again take the lead for malleables when the making of malleable pig becomes better understood, and there is less need of testing and doctoring it before pouring. The air-furnace, while more difficult and expensive to operate than a cupola, presents advantages that the latter does not possess. The iron may be seen during and after melting and, the bath of iron, as it is termed, after melting may be held in the furnace as long as desired. From this bath a small quantity may be dipped out and cast into test bars or pieces. Should the fracture indication of this piece not be satisfactory, the iron may be poled or boiled to thoroughly mix and remove graphite carbon, or this element may be added by addition of high-silicon iron or ferro-silicon. After the iron has been found to be right for the work to be cast, the furnace is tapped at both sides and thus the work can be more rapidly poured than from a cupola. These furnaces for malleable work are now generally run by a forced blast, which is blown into the closed ash pit, and places the furnace under better control of the operator than when depending upon the draft of a high stack. But even all these advantages of the air-furnace over the cupola do not always insure a perfect quality of iron, and heats are sometimes cast that do not pour well or produce a strong malleable when annealed which, to begin with, is no doubt due to unknown or uncontrollable elements in the iron, and a better knowledge of the latter may before long not only overcome this difficulty but restore the cupola to its former prestige, for without doubt it is the most economical furnace, is more easily controlled and, with a proper grade of iron, produces a malleable of as good a quality as the air-furnace.

Shrinkage.—The shrinkage of white iron is about one-eighth of an inch to the foot greater than that of gray iron, and an allowance to this extent is made in patterns for malleables. However, in malleableizing a slight elongation takes place and in small malleable castings shrinkage is not a matter of any great importance so far as the size of the finished malleables is concerned as they compare very favorably with gray iron castings made from the same pattern. But in making the castings from malleableizing white iron, shrinkage is a matter of great importance, for while the shrinkage in length is only slightly greater than that of gray iron, the tendency to shrink and draw apart is far greater, and various schemes have to be resorted to to prevent this. Sharp angles have sometimes to be dispensed with, thin places have to be thickened, ribs have to be put on, parts of the casting cast in chills, crush cores used, etc., to prevent checking in the casting. These are matters that have to be met as they occur and means devised to overcome them to produce a perfect casting, for these defects are not improved by annealing, and it is more profitable to scrap in perfect castings before than after annealing.

CHAPTER XVII.

ANNEALING OF MALLEABLES.

Annealing Ovens.—Annealing ovens are constructed of a capacity to suit the size of the plant and character of the work. In large plants they are generally about seven feet high, twelve feet long, and eight feet wide, with an arched roof, and open at one or both ends, which are bricked up after the annealing pots are placed in the oven. Flues constructed in the sides and under the floor are so arranged as to convey the flame and heat evenly through the rows of annealing boxes, and thus produce an even temperature throughout the oven. The material used in constructing these ovens expands when heated, and on cooling contracts to such an extent as to greatly injure them. It is therefore the practice to keep them hot after once being heated and, to admit of this being done, to construct them of such a size that the boxes, when hot, can be taken out and replaced by others without permitting the ovens to become cold. Natural draft, which is secured by a high chimney, is used for combustion of the annealing fuel, and the fires are carefully regulated during the whole period of annealing, which is from four to eight days, depending upon the character or size of the castings. During this period, the temperature is brought up to a bright cherry-red heat or about 1800° F. When bricking up the ends of the oven, sight holes are provided for observation, and the experienced annealer depends more upon the color of the heat and other indications than on thermometers, which are frequently unreliable. A blue flame thrown out at the joints of the boxes gives to the experienced operator an indication of the annealing process going on inside where the combined carbon leaves the iron to combine with the oxygen of the scale, and he regulates his firing to suit this indication. After the annealing process is completed, the firing is relaxed, and the furnace permitted to cool down for a day or so. The ends of the oven are then removed and the boxes drawn out while hot and permitted to cool in the air. The furnace is at once refilled with boxes, which have been packed for annealing, and in this way the oven is kept hot, and annealing goes on continuously. Ovens are sometimes constructed with the floor on an incline to facilitate removing the boxes, the latter being pushed in at one end and out at the other. But this is not the common practice and the floors are generally constructed level. Various means are also provided for removing the hot boxes and replacing them with others for annealing. After the boxes removed from the furnace have cooled to a sufficient extent, they are dumped, and the castings picked out and cleaned in tumbling barrels or otherwise, and the scale is prepared for another heat, which requires several days. To make the process a continuous one, sufficient scale, boxes and castings must be provided so as to have another set of boxes ready to take the place of the one removed from the oven. Hence the importance of having the ovens of a size to suit the number of castings to be annealed.

Revolving Annealing Ovens.—An entirely new style of annealing oven was designed and patented a few years ago by Mr. Walter S. Vosburgh, of Deposit, N. Y., and now of Williamsport, Pa.

This oven is constructed round of any desired diameter and the floor upon which the boxes are placed is arranged in such a manner that it may be revolved from the outside by means of a crank and gear. A door is placed in one side of the oven and a small crane is provided for placing the boxes to be annealed in the oven and removing them from it when annealed, without cooling the oven to any marked degree. The advantages claimed for this oven over the ordinary square one are that light and heavy castings may be annealed in it at the same time, without danger of burning the light ones by too prolonged annealing, or injuring the heavy ones by decreasing the heat of the oven in removing the light ones when sufficiently annealed. Before the malleable plant at Deposit, N. Y., went out of business, this oven was there in continuous use for over two years, and during this time small castings were successfully annealed and no bad effects upon the heavy castings noted, such as might have been due to the reduction of temperature of the oven from placing cold boxes in it during the process of annealing.

This oven, if it can be as successfully manipulated as claimed for it, would no doubt be of value in many plants making a variety of castings, but not a sufficient quantity of any one size or weight to fill an oven, and also for turning out rush orders of small quantities of light castings.

Annealing Boxes.—In the early days of malleable founding, annealing boxes were made bee-hive shape that the opening at the top might be small and more readily closed, and the castings, after annealing, be readily removed. The ovens were low and only one set of boxes was placed in them. With the enlargement of ovens and piling of boxes, these boxes were no longer practicable and a plain round box was adopted, this shape being considered liable to the least warping, but it was found castings could not be packed in them to advantage. Later on the boxes were made square and at the present time they are generally made oblong and about 24 inches long, 15 inches wide and 15 inches deep. But the size and shape vary somewhat to suit the size or shape of the castings, or the fancy of the founder. The boxes designed for the bottom row are provided with a bottom which may be cast in or consist merely of a plate upon which the box is placed. The other boxes are simply frames designed to be placed upon the bottom boxes and upon each other. The boxes may be cast from gray iron, white iron or malleable scrap, but they are generally cast at the end of a heat from white iron, to which is frequently added a little condemned pig or other refuse iron collected about the plant, that is not desirable in a malleable mixture. But if a fairly good quality of iron is not used the boxes are liable to crack the first heat, which condemns them for further use, and if they should crack very badly may spoil the castings packed in them. Malleable scrap is said to make the best lasting boxes, but this metal cannot be melted and run into boxes by itself, and its lasting qualities are determined by the per cent. of silicon pig melted with it to give it life and fluidity. Even the best of these boxes, after being used a certain length of time, which is determined by the quality of iron from which they are cast, become warped or bulged on the sides to such an extent that they are no longer fit for use and have to be replaced by new ones. The old boxes may be remelted and again run into boxes, but the iron in them has been so completely changed by heat that boxes cast from it are more liable to crack and warp, and it has been found more profitable to sell the old material at a nominal price per ton than to remelt it. The writer has never learned of wrought iron or steel boxes having been used for this purpose, but they have no doubt been tried.

Packing the Boxes.—When packing the boxes the bottom box or plate upon which it rests is placed upon two blocks in such a manner that the prongs of the charging truck or machine can be placed underneath in lifting it to place it in the oven. A layer of scale is then placed over the bottom of the box; upon this are carefully laid the castings to be annealed in such a manner that they do not touch each other, and scale is placed between them. When this layer has been covered with scale, other layers of castings and scale are put in in the same way, until the box is filled. Other boxes or sections are then put on and filled in the same way, until they are built up to the desired height which is about five feet for the larger ovens, and for the smaller ones a corresponding height. The heavier the castings the more time is required for annealing, and in packing, the heavy castings are put in one set of boxes and the light ones in another for different ovens. When there is not a sufficient number of large castings to fill the oven, they are put together with the small ones in the hottest part of the same oven, and an attempt is made to give them more heat than the small ones, but this is a very unsatisfactory process and frequently fails to produce a good malleable. In packing, care is taken to place the castings in a position that will reduce warping to a minimum, but this frequently fails to produce the desired result, and the castings have to be put back into their original shapes after annealing. This is done by hammering, hydraulic pressure, drop hammering, etc., and in some cases steel forms have to be made to get the castings back into their original shapes, considerable expense being in this way incurred. Nothing is gained by heating a malleable in straightening it, and the best results are obtained at the ordinary temperature or at about 50° to 100° F. After the boxes have been packed, the joints are carefully luted with clay, and the top is covered in the same way. They are then placed in the oven in two or four rows, with stacks a sufficient distance apart to admit of a free circulation of the heat around them. The ends of the oven are then closed with a temporary brick wall, after which firing and annealing are begun.

Packing Material.—The generally accepted theory of the malleable cast iron process is that by treating the metal at a high heat with an oxide which will yield a portion of its oxygen to the carbon in the metal, the latter is decarbonized in consequence of the formation of carbonic oxide given off. The oxidizing agent usually employed is a thin scale of iron that falls from wrought iron in rolling, and is known as rolling mill scale. Red hematite iron ore is also to some extent used for this purpose. That these materials extract the carbon from the iron there can be no doubt, for when an iron too high in graphite is used, the castings are porous and the surface has the appearance of being full of small pin holes. When this occurs the iron is too high in carbon, and the castings are weak and imperfect. Another theory of malleables is that the carbon is not extracted from the iron, but changes its form under the influence of the long heat, the resulting product being malleable iron, and that this change may by a prolonged heat be effected without packing, or with a packing of sand or clay. This theory was exploded in the days of Seth Boyden, for while small malleables may be made in this way, it can only be done with a certain quality of iron, and even then they are inferior to those annealed with mill scale; it is practically impossible to make heavy malleables in this way. In the malleableizing process carbon is the important factor, and the manipulation of this element determines the quality of the malleable. In annealing, the carbon is not entirely removed from the iron, and when the latter contains only the exact amount of carbon for a good malleable, prolonged heat will change the form of the carbon and any packing material that keeps the castings apart and excludes the air answers the purpose. But when there is an excess of carbon this must be removed or an inferior malleable is the result. It is therefore more profitable to use a packing material that has the power to remove any excess of carbon the iron may contain. This material has by long experience been found to be rolling-mill scale, which can readily be reoxidized after each annealing heat, and lasts indefinitely. The burned scale falling from the annealing boxes can also be used for packing, and the amount of this material obtained from the boxes after each annealing heat is said to be sufficient to replace that lost, and to keep up the supply of scale.

Red hematite ore answers the purpose equally well, but this material is not so readily reoxidized as scale and in time wears out and becomes worthless.

Preparing the Scale.—The red oxide, or rust, upon the scale is what does the work in converting cast iron into malleable iron, and this has to be renewed after each annealing heat. This is done by spreading the scale out upon the floor, wetting it and permitting it to rust for several days. To increase the rusting tendency a variety of substances have been added to the water with which the scale is wet, such as sal-ammoniac, salt, saltpetre, etc. But none of these substances have any effect in the annealing process, they being only used to save time in rusting the scale, and as good malleables can be produced by wetting the scale with clear water. However, sal-ammoniac is commonly used, as it rusts the scale more rapidly than clear water, and when business is rushing anything that saves time is of value. In preparing the scale it is spread out upon the floor in a thin layer and wet with just sufficient water to corrode it. As it becomes dry it is wet again, and raked or turned over, and this is repeated until the scale is properly rusted, which can only be determined by experience. This is the only preparation of the scale that is necessary, but before rusting it should be occasionally passed through a very fine riddle to remove sand and dust from it, as such substances, although they may by themselves be used for annealing, are not desirable in scale annealing.

Time Required for Annealing.—The time required for annealing an ovenful of malleables depends upon the size and thickness of the castings, the size of the packing boxes, the quick or slow heating tendency of the oven, etc. More time is required for annealing heavy or thick castings than light ones, for heating through large boxes than small ones and bringing them up to the annealing point, as well as for bringing the castings up to this point in an oven with a poor draft or badly arranged flues. The time therefore varies to a considerable extent, but it may be said to be from six to ten days of actual time in the oven. A high heat of 1800° to 1900° F. is said to anneal more rapidly, but a lower heat of from 1600° to 1800° F. is claimed to produce a stronger iron. But thermometer indications above 600 degrees are as a rule unreliable, and annealing is generally done by the indications of the oven which to the expert operator are a better guide than the thermometer. However, in large plants managed by supposed experts, the use of a thermometer frequently saves the annealer considerable trouble when the castings turned out are not satisfactory. Malleable founders have advertised to turn out malleables in two or three days, but it has been noticed that it takes from two to three weeks to get the malleables if they are any good. Any white iron may be annealed in this length of time and made a soft iron, but it has not yet been malleableized in so short a time. Numerous schemes have been devised for quick annealing by the use of chemicals and various substances, but up to the present time they have all proved failures so far as the production of malleable iron on a practical or commercial scale is concerned, although fine specimens said to have been produced by the quick annealing process on a small scale have frequently been shown.

Cleaning Castings and Malleables.—Before annealing, the castings must be thoroughly cleaned of all adhering sand, for this material not only interferes with annealing but makes the annealing scale dirty. The castings are very brittle and easily broken before annealing and in cleaning have to be handled with care to avoid breaking. Cleaning is generally effected in very small tumbling barrels which are frequently lined with hard wood; they are run very slow for very light castings and only a limited amount of them is put in at a time. Heavier castings are tumbled in the ordinary gray-iron tumbling barrel, and light frames that are easily broken are cleaned with a steel brush or sand blast. After annealing, the castings may be tumbled to any extent, and are generally tumbled until they shine as if polished. Castings that become heavily coated with annealing oxide are sometimes cleaned in an acid bath after which they are dipped in a lime-water bath to kill the acid in the iron. But this is seldom necessary, for the tumbling barrels, if properly arranged and provided with stars, generally do the work.

Physical Properties of Malleable Iron.—Malleable iron resembles wrought iron in strength but lacks the fibrous structure of the latter due to rolling, and therefore cannot be drawn or welded in the common acceptance of these terms. But a good malleable may be drawn and shaped by very careful heating and hammering, and has been welded by expert welders. The tensile strength of malleable iron is from 40,000 to 50,000 lbs., and that of a good quality of cast iron from 20,000 to 30,000 lbs. to the square inch. It is therefore much stronger than the best cast iron and is not subject to fracture from a blow or jar, as the latter is. The transverse strength of a one inch square malleable bar, is about 4,000 lbs., but this strength is not considered of so great importance as in cast iron, for malleables are generally small and seldom submitted to any great extent to this strain. The torsion or twisting test is the one commonly resorted too by founders of malleables to show customers the quality of their iron. This test is made by placing a flat bar of malleable iron in a vise and twisting it several times around with a large monkey wrench. Several of these samples are generally kept on hand for exhibition. The test in itself amounts to but little for the iron is subjected to but little strain in twisting and any fairly good malleable will stand this strain. Another test for exhibition is bending the piece into a circle and doubling it over on itself without cracking at the bend. It requires a good malleable to stand this test without showing any cracks or indication of fracture.

CHAPTER XVIII.

PRODUCTION OF MALLEABLE IRON.

The Making of Malleable Iron as a Business.—As a business, gray iron founding is very trying and disappointing. With the best of molders, patterns, flasks, sand, etc., castings upon which many hours and days work have to be paid for, are frequently lost. If perfect, the iron may be too hard, soft, or week for the casting, and the latter be condemned, and in this way heavy losses are frequently sustained. But these are nothing as compared with the chances taken by the malleable iron founder, for while the gray-iron founder may in a few hours or days turn out and deliver a perfect casting, from two to four weeks are required to mold, anneal, and turn out a batch or large ovenful of malleables, and at the end of this time part or all of them may turn out to be bad, due to imperfect patterns, bad molding, poor iron for malleables, bad packing, imperfect oxidation of the packing scale, irregular firing of the oven, overheating, underheating, etc. The expense for labor, fuel, and other supplies required in producing this batch of malleables have to be paid for, and the entire loss falls upon the founder. Two to four weeks are required to reproduce the castings, and the customer, who has been waiting all this time for them, may take his patterns away or cancel his order. Altogether, there is not a more trying business than malleable iron founding. On a smale scale, a malleable foundry cannot be made to pay unless the founder has a special line of castings of about the same size or thickness and a sufficient quantity to keep his furnaces and ovens in constant operation, for additional expense is incurred by permitting ovens to become cold, for repairs, and fuel in heating. Very small light castings cannot be properly annealed in the same box or oven with large ones, although they are frequently put in to fill up the holes, and different grades of iron are required for various classes of castings. For these reasons, malleable founding tends towards large plants with numerous furnaces and ovens in which iron for various-sized castings, may be melted and annealed. A small malleable plant in connection with a gray iron foundry, as the writer learned from experience many years ago, cannot be made to pay, for the business is almost as separate and distinct from gray iron founding, as the running of a rolling mill or blast furnace; in fact, about the only thing in it having a resemblance to this business is the molding and cleaning of the castings. The smallest plant of this kind the writer ever knew to pay, was one with a daily capacity of about 5 tons, and having a specialty for from three to four-fifths of this amount. With a specialty covered by letters patent, for which a gilt-edge price can be demanded, the profits of the plant are greatly enhanced, and many of the large plants have one or more of this line, and when business is dull frequently fill in with jobbing work, at almost any price, to keep the plant running. The cost of producing malleable castings, which are generally of the bench-work line and small, is about one cent per pound more than that for gray iron castings of the same grade. The price at which they are sold, varies as in gray iron, with their size and the difficulty of molding, annealing, etc., and with the demand for malleables. In good times they have sold as high as 8 cents per lb. for the standard line of castings and jobbing work, while in dull times they have sold as low as 2 cents per lb., which of course is at a loss, for with the high price for labor in this country no malleable can be produced at any such price, no matter how low the price of malleable pig. A malleable plant is more expensive to construct and manage than a gray iron one and, owing to the greater length of time required to turn out an order of castings, from three to four times the working capital is required to run the business.

But that there is room for an extension of this line of founding would seem to be indicated by data collected by *The Foundry*, which show that in 1907 there were in the United States only 131 malleable plants, with an estimated capacity of 1,291,484 tons, and an output of 969,399 tons, and that in 1910 the number of plants had only increased to 168.

CHAPTER XIX.

FOUNDRY NOTES.

All white irons or low-silicon irons do not chill to an extent that gives a satisfactory depth of chill; hence they do not impart chilling properties to other irons when mixed with them. The chill test should be used on all irons for chilled castings.

Annealing Cast Iron.—Pack the castings in sand, charcoal or saw dust, in iron boxes. Heat to a bright red, which will take about twelve hours, in an oven. Allow the castings to cool slowly in the boxes for twelve hours. Castings may be annealed in this way without packing, but packing prevents warping to some extent. Any hard casting may be softened by annealing in this way; even a half-inch chill may be removed if the heat is sufficiently prolonged.

Hard castings may be softened by heating in a forge or ordinary fire, but the time required to heat them is so short and, when removed from the fire, they cool too rapidly to be softened to any great extent. To increase the annealing process, heat and cool slowly.

Malleable scrap, when melted alone, produces white iron in castings. Owing to the low content of silicon, carbon, and phosphorus in malleable scrap, it does not make a satisfactory mixture with foundry irons for soft castings, and it is only when the pig melted with it is high in these elements that it can be used. Only a very small amount of malleable scrap can be used in the ordinary foundry mixture without its hardening or spotting effect being seen in soft castings. Malleable scrap is sometimes added to car-wheel mixtures of coke iron to aid in producing chill.

A good ladle flux that increases the fluidity of iron prevents small holes in castings due to gas in the iron.

Blow holes may be due to wet sand, hard ramming, improper venting, damp cores and gas in the iron.

The Foundrymen's Associations are doing a great deal for the advancement and development of the foundry industry; to reap the benefit of their work, the founder must use a little common sense.

It is more profitable to use an extra hundredweight of coke to melt iron hot, than it is to lose a hundredweight of castings from dull iron.

Steel increases the strength of cast iron to a greater extent and with more certainty of results than vanadium, and at a greatly reduced cost.

Vanadium, when melted with charcoal iron, gives better results as to increase in strength than with coke pig,

A low-silicon iron shows a greater increase in strength when melted with vanadium than a high-silicon iron. The lower the silicon, the better the results.

Vanadium, when melted in a regular soft foundry mixture for soft castings, gives no increase in transverse or tensile strength.

Vanadium is claimed to greatly increase the strength of a semi-steel.

At the present price of steel scrap, it is cheaper to make a semi-steel, than an iron mixture with cast iron scrap.

Rat tail on covers is due to an accumulation of gas in the mould and may be overcome by freely venting the surface and back of the cover. It is also formed by blacking dusted on the mould, it being washed before the iron into ridges on the surface of the mould. Use a better grade of blacking or less of it on covers or other pieces upon which rat tail appears.

Rat tail is also due to lack of fluidity in the iron. The iron of the different streams thrown into the mould from the gate rolls over in filling the mould, and the undersides of the streams when they come together do not unite to form a perfect casting, and leave the rat tail.

Any mixture of cast iron that can be punched when cold, due to a jet of steam being thrown into the cupola at the tuyeres, can be punched just as readily without the steam being used.

When a large per cent. of steel is added to cast iron for castings the mould should be made of silica sand with just enough loam to bind it and should be dried before casting.

For gear-wheels, ferro-manganese as spiegel iron heated to a very high heat, and placed in the ladle to be melted by the iron, closes the grain of the latter and hardens it.

Crusher jaws, drop weights, etc., requiring a very strong tough iron, may be made by adding sufficient spiegel iron to ordinary gray iron to give 3 to 6 per cent. manganese in the mixture.

Test bars one inch square, twelve inches between centers, have shown 2,800 lbs. transverse strength in cupola melted iron; in air furnace melted iron, 3,200 to 3,400 lbs.

Transverse strength for light castings should be 1,800 lbs., for medium heavy, 2,200 lbs., for special high strength medium, 2,400 lbs., and for heavy 2,600 lbs.

The average variation of transverse strength of test bars cast from the same iron, same ladle and from same runner, is about 6 per cent.

It is very difficult to accurately determine the loss of iron in cupola melting owing to carelessness of cupola men in weighing charges, recovering iron from dump, weighing over-iron etc. Figure the loss at 4 per cent. on pig and 8 per cent. on light scrap, and you strike it about right.

To prevent blow holes in steel castings use about one ounce of aluminium in the ladle to 100 lbs of steel.

Aluminium is of little value as ladle flux for cast iron.

The cupola beats the air furnace out of sight for economical and fast melting, but the air furnace has the best of it for removing or adding metalloids.

A cupola gives as good an iron as an air furnace, if you have a good healthy iron to begin with, but when the iron is sickly, and has to be doctored, give it a bath in the air furnace.

Always melt cast iron and semi-steel hot and pour them hot.

The heat in a cupola is not so great as that of a blast furnace in which cast iron is made, and iron when remelted is not heated to so high a temperature. It is therefore not possible to burn iron in a cupola by melting it hot.

The best results in castings are obtained by melting cast iron hot and fast in a cupola.

When iron run against a chill shows a light chill, or well-defined line between the soft and chilled iron, the silicon is too high in the iron for chilled castings, and a lower silicon iron, should be used if a good chill and strong iron are desired.

To test limestone for iron pyrites or sulphur, wet the stone in the sun when the sulphur will appear in bright golden spots.

Hard spots in castings may be caused by iron sputtering as it falls into a mold and the small globules being chilled by the damp sand before the molten iron reaches them. Such hard spots will generally be found on the bottom side of the casting and in clusters. To prevent this, gate the castings so that the iron will run in a good-sized stream over the mold and not sputter. Cast iron expands as the iron sets in a mold, and to this is due the filling of every little line in the casting.

There are two losses in foundry iron, one in melting, the other in manipulation, and the latter may be the heaviest of the two. All iron not in sight or accounted for, is lost.

To prevent shrink holes in castings that cannot be fed up, use a very low phosphorus iron. This iron sets more rapidly than a high phosphorus one, and shrink holes in hubs and the interiors of castings are not so liable to occur. To avoid dirt in castings decrease silicon in the mixture as low as possible, melt and pour iron hot.

Uneven shrinkage in castings is generally due to uneven thickness in the pattern. Dont blame the poor iron for everything.

High silicon causes sand to peal from castings more readily than low silicon.

For mine car wheels, soft foundry iron when mixed with old chilled wheels does not make a good mixture. The bulbs are generally too soft, even when the chill is right. Regular car wheel pig or a hard grade of foundry pig should be used with the old wheels. If the arms crack increase silicon.

Silicon is the chemist's dope for all the ills of foundry irons.

Grate bars are generally cast from any old iron that can be thrown into the cupola at the last of a heat, but a soft iron makes a better grate bar.

Specifications furnished for grate bars by a prominent firm recently called for 40 per cent old grate bars in the mixture. The firm may have known what it was doing, or only experimenting.

W. J. Keep recommends a 2.75 silicon iron for grate bars. Stove grates are made of this iron and they stand the heat well.

Iron does not absorb carbon or silicon from the melting fuel in a cupola, but to a limited extent loses both of these elements. Hence iron is hardened in melting and a softer iron than is actually required in the castings has to be melted in a mixture to obtain the desired softness in them. Heat removes dirt and dross from iron, and the hotter it is melted and poured the cleaner it will be in castings.

Silicon above 3.50 per cent drives carbon out of iron very rapidly and decreases its life and strength. Mixtures should not be made that give more than about 2.75 per cent silicon in the castings.

For sash weights cast iron of any quality, pig or scrap, tinplate, wrought iron and steel scrap, wire or any old iron or steel, may be melted, for it is not quality, but weight, of iron that is required in these castings. When iron is not fluid when very hot, phosphorus should be added to increase fluidity. The only way to add this element is to purchase pig high in phosphorus for use in mixtures of sluggish iron.

Molding sand is a porous substance that admits of gas generated in a mold by molten iron coming in contact with its surface to escape from the mold. The troweling or slicking of the surface of a mold closes the pores and causes a blow or kick of the iron in the mold, due to explosion of gas under it. To prevent this, leave the mold as the pattern left it. Dust on blacking and return the pattern to press it down, or apply blacking with a camel's-hair brush, and rub in with the hand if necessary.

A little of some of the core compounds when mixed with ladle daubing leaves the ladle clean and increases the life of the lining; ten to fifteen per cent. compound by bulk is recommended.

A clay daubing requires a high heat in drying to drive off the water of combination in the clay. If this is not driven out in drying, the iron will boil in the ladle until it is.

A loam sand makes the best daubing material for small ladles, and a loam clay and sharp sand mixture the best for large ladles.

A molder should never be permitted to build up a hand ladle with daubing to make it hold more iron. Such daubing frequently gives way and iron is spilled along the gangway.

It is poor foundry practice to have every molder daub and dry his own ladle, for the time spent at such work decreases the output of castings. A molder is a high-priced man and should not be required to do work that can be done equally as well by a cheaper man.

It is more profitable to employ laborers to shake out and take out castings, temper sand, and put the pattern and flask in place for the molder to go to work in the morning, than it is to have a molder do this work, even if he is working piece-work and does the laborer's work for nothing, because relieving the molder of this work keeps him in better condition and gives him more time for molding and increases his output of castings. The molders are the only producers in a foundry, all other employees being dependent for their wages upon the profits on the castings turned out by the molders.

All unnecessary laborers, clerks, supers, etc., employed in a foundry decrease the foundryman's profits on his business.

A certain amount of non-productive labor is necessary in every foundry, and the profits of a small foundry are not so great as those of a large one, for this non-productive labor is necessarily out of proportion to the number of molders employed.

The Use of Waste Coke.—Considerable partly burned coke falls from the cupola when the bottom is dropped and various ways have been devised for using it. It has been the common practice for years to pick out the larger pieces of this coke and put it back into the cupola at the next heat. The very small pieces are shoveled into the tumbling barrel together with the dump, ground up in tumbling and thrown into the foundry dump. Since the introduction of the water tumbling mill all the very small pieces of coke are saved. This coke is too small to be used in the cupola and the question has frequently been asked what to do with it. It may be used to good advantage for blacksmiths' fires. It may be mixed with coal and used as a core oven fuel, or in the foundry heating stoves, and in stoves for skin-drying molds. When all of it cannot be used up for these purposes it may be sold at a nominal price to employees for domestic use, as it makes an excellent fuel for cooking and heating stoves.

Tinning Cast Iron.—To be successful in coating with tin the castings must be absolutely clean and free from sand and oxide. They are usually freed from imbedded sand in a rattler or tumbling box, which also tends to close the surface grain and give the articles a smooth, metallic face. The articles are then placed in a hot pickle of 1 part of hydrochloric acid to 4 parts of water, in which they are allowed to remain from one to two hours, or until the recesses are free from scale and sand. Spots may be removed by a scraper or wire brush. The castings are then washed in hot water and kept in clean hot water until ready to dip. For a flux dip in a mixture composed of 4 parts of a saturated solution of sal-ammoniac in water and 1 part of hydrochloric acid, hot. Then dry the castings and dip them in the tin pot. The tin should be hot enough to quickly bring the castings to its own temperature when perfectly fluid, but not hot enough to quickly oxidize the surface of the tin. A sprinkling of pulverized sal-ammoniac may be made on the surface of the tin or a little tallow or palm oil may be used to clear the surface and make the tinned work come out clear. Some operators again dip in a pot of hot palm oil or tallow at a temperature above that of the melted tin, for the purpose of draining the excess of tin and imparting a smooth, bright surface to the castings. As soon as the tin on the castings has chilled or set they should be washed in hot sal-soda water and dried in sawdust.

Breaking Up Cast Iron Guns.—The Government recently sold a large number of old cannon, among the largest of which were some 15-inch smooth-bore Dahlgrens cast in the early '60's. The purchasers were confronted with the problem of converting these heavy pieces of cast iron into marketable shape as scrap iron, wherein no single piece should exceed 200 pounds in weight. After doing considerable experimenting they adopted the method of drilling a row of holes longitudinally, afterwards driving steel wedges into these holes until the gun split open. To permit of the drilling being done as rapidly as possible the guns were jacked up on the roller bearings so that they could easily be revolved, when a frame carrying 15 drills was set over the gun and 1-inch holes drilled to a depth of about 7 inches. In this way the guns were split into suitable sections when they could easily be broken into smaller pieces. Each gun weighed 42,000 pounds and had a thickness of metal varying from 17 inches at the breach to 3 inches at the muzzle. Many of these guns had never been fired and these were found much more difficult to break up than those which had been in use.

Blow-Holes in Aluminum Castings.—The repair of aluminum castings having large blow-holes, or which have been mis-run, is a comparatively easy operation when the burning-on process is practiced. In one large plant the castings are examined for blow-holes or other apparent imperfections, before the cores are removed. In case of a large blow-hole, a cake core is used, having a hole cut in the center exactly the size of the hole in the casting. A flow-off is cut in one end of this core to carry off the metal, and while the aluminum is being poured from the ladle, the core is held firmly in position on the casting, to prevent lifting. Before the metal in the core opening has set, the surplus aluminum is struck off to nearly the surface of the casting, which greatly improves the appearance of the job and reduces the amount of machining necessary.

Hardening the Face of Castings.—A process for hardening the face of castings has been patented by Morgan A. Perrigo, of Wilkesbarre, Pa. Briefly described, the process consists in mixing pulverized sulphur with that part of the sand which will come in contact with the part of the casting it is desired to harden. The inventor claims that he can by this method produce a face of greater density than the casting would otherwise have had.

The Behavior of Cupola Bricks.—A brick which contains 60 per cent. or more of silica *expands* on heating, but a brick containing 53 per cent. or less of silica *contracts* at temperatures above 3000 degrees Fahr. On this account, if a high-silica brick is used in lining a cupola, there should be a layer of sand between the shell and the brick in order to make an elastic lining.

Iron for Car Wheels.—At a recent meeting of the American Society for Testing Materials, Chas. B. Dudley recounted some of his experiences in car-wheel founding while connected with the Pennsylvania Railroad at Altoona, Pa. The attempts made to predict, from a chemical analysis, the amount of chill an iron would show have not proven successful, and the speaker stated that the chilling qualities of an iron were somewhat difficult to understand, as identical analyses will not produce a casting of like chill. At the Altoona shops the car-wheel mixture employed contains from 3.25 to 3.60 per cent. of total carbon, about 0.75 per cent. silicon, 0.50 per cent. manganese, 0.50 per cent. phosphorus and 0.13 to 0.15 per cent. of sulphur., of which the limit was formerly 0.8 per cent. The total carbon is lowered to the desired point by the addition of from 5 to 10 per cent. of old steel rails. The depth of chill produced by this mixture is about 1 inch.

Cupola Daubing.—For ordinary cupola work the daubing material used in mending the lining should contain from 20 to 25 per cent. of silica sand and from 80 to 75 per cent. of fire-clay.

Carborundum in the Cupola.—In lining an ordinary cupola the joints should be made as tight as practicable, the bricks being dipped in a thin clay wash before they are placed in position. The bricks or blocks should fit accurately, leaving the smallest possible space. After the lining is in place, the inside surface may be washed or daubed over with a solution made by adding from one to two pounds of finely ground carborundum to a pail of very thin clay wash, or the carborundum can be mixed with from 8 to 10 per cent of water-glass, and then daubed on the inside of the cupola. The carborundum melts and forms a glaze or skin which closes the joints and protects the brickwork.

Welding Cast Iron to Steel.—Coat the steel with silicate of soda, and before it is dry dust on dry, powdered ferro-manganese. The silicate will form a coat of glass over the clean surface of the steel, which is melted off by the molten iron. This keeps all air and moisture from the joint, and if no oxygen can reach the steel there can be no rust. If the surfaces are bright and the iron hot there will be an absolute union. One inch steel bars, with the ends bedded in cast iron in this manner were tested, and broke off, but did not pull out.

Welding Cast Iron.—One of the English papers reports the welding of cast iron by the use of a flux consisting of 65 per cent potassium chloride, 15 per cent chloride of lithium, and 20 per cent potassium fluoride.

The surfaces to be joined are first heated, sprinkled with the flux, and then heated to the melting point, presumably with the aid of a blowpipe. A rod of the same composition of the iron is used to solder up any space that may require it.

In this country practically the same work has been done by the autogenous welding process without the use of any flux.

Punched Castings.—The publication of a series of punched cast-iron plates from iron made by the Thomas Iron Company of Hokendauqua, has brought out a similar piece of work, for which we are indebted to Edwin C. Will, foundry foreman of Russell & Co., Massillon, Ohio. The castings were made from coke iron melted with coke and cast in green sand molds in a horizontal position, the iron being the same grade always used by the firm in question in making their engines, harvesting machinery and saw mills. No alloys of any kind were used, nor were the castings annealed in any way. The punching was done on the regular machine without a crack or break. The plates had no supports about the edges and have not been altered or changed since they were punched. The plate, No. 4, was 5/8 inch thick, while No. 11 was 1/4 inch thick, and No. 14 1/8 inch thick. Nos. 7, 9, 10 and 12 were punchings from these cast-iron plates, 3 inches in diameter. Some of these punchings were 1/2 inch from the edges of the plates, and since then other plates have been punched as close as 1/4 and 1/8 inch from the edge without a crack or break. Nos. 3 and 8 were full-length cuts 2 inches wide and 16 inches long from the hub of a pulley without a break. Nos. 5 and 6 are test bars broken on a Riehlé testing machine, showing 30,000 pounds per square inch tensile strength.

Pickling Castings.—For pickling iron castings, the strength of the solution is generally 1 part sulphuric acid to 10 parts water, and the castings are left in the dip for several hours, or in some cases, over night, but for large castings, or where the capacity of the dipping tank is not sufficient to accommodate the work, the solution may be stronger and in the proportion of one part sulphuric acid to 4 parts water. The castings are merely immersed in the pickle, and are then laid aside for eight or twelve hours, or until covered with a white powdery deposit, when they are rinsed in hot water. When the scale is so firmly attached that one treatment is not sufficient to remove it, the operation can be repeated until the desired effect is produced.

Mr. J. L. Eckelt describes his method of using acid water for pickling castings, in place of using the scratch brush. The plan is to have stone tables covered with sheet lead, pump the acid water into an overhead tank, from which it descends upon the castings in the form of a fine spray, this also taking place from several sides so that all portions of the work are covered. The surplus acid-water collects into a sunken vat to be pumped up again. After the castings have been sufficiently acted upon, they are left stand, say 48 hours, or as long as it may be necessary, until the sand comes off easily when the work is washed with clear water. After thorough rinsing the castings are removed and left stand a further two days in the air, when they will be coated with an even layer of brown. In this country we would hate to give the castings all this time, unless the foundry is way ahead of the machine shop. The advantages claimed are in labor saving, tools, clean and smooth surfaces, and no breakage. Figures are further given to show the economy of the process, which indicate 67 per cent. benefit over hand cleaning. Our conditions and prices would, however, require the figures given to be taken with due allowances. The process is, unfortunately, not compared with the tumbling barrel.

Mixture for Sand Match.—

	Parts.
Finely sifted gangway sand	89
Finely sifted steel or iron borings	1
Pulverized litharge	3
Boiled linseed oil	7

Mix the sand, borings and litharge when dry, taking care to keep out all molding sand, gravel or water, and after thoroughly mixing add 7 parts boiled linseed oil, and mix to the temper of molding sand. This is rammed hard into the cope match and a bottom board is bedded-on, and afterwards firmly secured by screws in preference to nails. A match made in this manner will last for years, outlasting plaster of paris matches.

Steel or Iron—How Browned.—In order to give iron or steel a brown tint and render them moisture-proof, dissolve two parts of crystallized iron chloride, two parts of antimony chloride (as slightly acid as possible), and one part of gallic acid in four parts of water; apply the solution to the article with a sponge or cloth, and dry it in the air; repeat this until you obtain the desired shade of brown; then wash the article with water; dry it, and finally rub it over with boiled linseed oil.

Process for Tinning Cast Iron.—M. Bertrand has used sulphophenolic acid to obtain tinning on iron. He dissolves salts of tin in a mixture of water and sulphophenolic acid at the rate of 1 per cent. of tin salt and 5 per cent. of sulphophenolic acid. In this mixture the article, which is previously cleaned, is dipped, and is at once covered with an adherent coating of tin, and afterward, by the means of rotating brushes in wire and cloth, the coating of tin is polished, and a result obtained which is both effective and cheap.

Coppering Iron Castings.—The following information on the subject is from "Brannt's Metal Workers' Handy Book": To provide cast-iron articles with a beautiful and durable coating of copper proceed as follows: Scour the article with a pickle consisting of 50 parts of hydrochloric acid of 15 degrees B. and 1 part of nitrate of copper. Then rub them with a woolen rag or a soft brush dipped in a solution of 10 parts of nitrate of copper and a like quantity of cupric chloride in 80 parts of nitric acid of 15 degrees B. After a few seconds rinse the articles in clean water and polish them with a dry woolen rag. This rubbing and subsequent polishing is repeated until the layer of copper is of the desired thickness. In this manner ground or rough objects can be entirely or partially coppered, the process being recommendable on account of its simplicity, cheapness, and the durability of the coppering. To give articles thus coppered the appearance of antique bronze, touch them up with a solution of 4 parts sal-ammoniac, 1 part oxalic acid and 1 part of acetic acid in 30 parts of water, the operation being repeated until the object has acquired the desired color.

Cleaning Foundry Windows.—A handful of oxalic acid to a pail of water. An important feature of the cleaning is to go over the glass with a woolen rag or soft skin and give it a polish, which will prevent dust collecting as quickly as it otherwise would. Glass cleaned and polished in this way will stay clean for a longer time than if left unpolished.

I have used dilute sulphuric acid followed by a scouring with a mixture of fine sand and soft soap for cleaning foundry windows. I have seen very rusty and dirty windows made quite presentable in this way. While I do not consider this a positive success I know no process which is better.

The windows of a foundry may be cleaned quickly and perfectly by using parting sand (sand that is brushed off the castings) mixed with a weak solution of sulphuric acid and water. Brush this on the glass and allow it to remain for a few minutes, then finish with more of the same mixture. I have used this method of removing the oxide of iron and emery from the windows of the polishing room and foundry for years with success. The acid softens the iron, which is removed by the friction of the sand.

Compressed air is used to clean foundry windows, when they are not coated with oxide of iron, the air alone doing the work; when heavily coated with oxide, the sand blast removes it. Before using this method of cleaning be sure the glass is securely fastened in the sash.

Silvery Iron.—An important change has been made in the sliding scale of prices of silvery pig iron by the Jackson County, O., blast furnaces. There will be an advance in price hereafter with every one-half of 1 per cent. of the silicon content. Up to and including 10 per cent. silicon the difference will be 25 cents per ton, and above 10 per cent., 50 cents per ton for each one-half of 1 per cent. silicon content. To illustrate this more clearly and give the range of silicon content to be understood in contracts, the following table is presented, which is based on the present market price of $18.50 furnace for 8 per cent. silicon:

Per cent.	Silicon will range per cent.	Price.
4	3.75 to 4.25	$16.50
4½	4.25 to 4.75	16.75
5	4.75 to 5.25	17.00
5½	5.25 to 5.75	17.25
6	5.75 to 6.25	17.50
6½	6.25 to 6.75	17.75
7	6.75 to 7.25	18.00
7½	7.25 to 7.75	18.25
8	7.75 to 8.25	18.50
8½	8.25 to 8.75	18.75
9	8.75 to 9.25	19.00

Per cent.	Silicon will range per cent.	Price.
9½	9.25 to 9.75	19.25
10	9.75 to 10.25	19.50
10½	10.25 to 10.75	20.00
11	10.75 to 11.25	20.50
11½	11.25 to 11.75	21.00
12	11.75 to 12.35	21.50

MELTING POINTS OF CAST IRONS.

Melting point. deg. Fahr.	Combined carbon. Per cent.	Graphitic carbon. Per cent.	Silicon. Per cent.	Manganese. Per cent.	Phosphorus. Per cent.	Sulphur. Per cent.	
2,030	3.98	....	0.14	0.10	0.22	0.037	Pig iron.
2,100	3.52	0.54	0.47	0.20	0.20	0.036	Pig iron.
2,140	2.27	1.80	0.45	1.10	1.46	0.032	Pig iron.
2,170	1.93	1.69	0.52	0.16	0.76	0.036	Pig iron.
2,200	1.69	2.40	1.81	0.49	1.60	0.060	Pig iron.
2,210	1.48	2.30	1.41	1.39	0.17	0.033	Pig iron.
2,230	1.12	2.66	1.13	0.24	0.089	0.027	Pig iron.
2,210	0.84	3.07	2.58	0.47	2.12	0.051	Pig iron.
2,250	0.80	3.16	1.29	0.50	0.22	0.020	Pig iron.
2,280	0.13	3.43	2.40	0.90	0.08	0.032	Pig iron.
2,350	1.32	....	0.21	0.49	?	?	Steel.
2,210	6.48	(carbon)	0.14	44.59	?	?	Ferro-manganese.
2,255	5.02	(carbon)	1.65	81.40	?	?	Ferro-manganese.
2,190	3.38	0.37	12.30	16.98	?	?	Silico-spiegel.
2,040	1.82	0.47	12.01	1.38	?	?	Ferro-silicon.
2,400	6.80	(carbon)	(chromium 62.70)		..	..	Ferro-chrome.
2,280	..	....	(tungsten 39.02)		..	..	Ferro-tungsten.

Method of Selling Castings.—It has long been the practice of iron-founders to sell their castings by the pound. This system has its advantages and disadvantages, for, while it enables the founder to obtain pay for every pound of iron in his castings, and to determine at the end of each month or year the exact weight of castings produced and cost per pound for iron, labor, etc., in producing them, it also subjects him to the demands of his customers for a reduction in the price of castings when that of pig iron goes down, and a dispute with probable loss of customers to get prices up, when pig iron advances, and the profits on his outputs of castings being in this way limited. For it enables the regular consumer of castings, who always watches the price of pig iron, to at once point out the difference between the price of pig iron per pound and castings per pound, and assert that he is being overcharged by the founder. Now there is no more reason why the price of castings should be based upon the price of pig iron, than that of a piece of furniture upon the price of lumber consumed in making it, or that of a packing box on the cost of the few boards used in its construction, and no purchaser of these articles ever thinks of objecting to the price, for the reason that that of lumber has gone down. It is not the cost of raw material consumed in producing an article that determines its value, but the cost of skilled labor required in manufacturing it. A piece of furniture may be worth double the price of another piece made from lumber of the same price or grade. The cost for labor in making a complicated piece of core work may be three or four times greater than that of a plain piece cast from the same ladle of iron. It is therefore absurd, to base the price of castings upon the price of pig iron or scrap.

The price per pound system was probably adopted before there was any means of determining the weight of a casting from a wood pattern. But this difficulty has been overcome, and we now have not only the weight of iron per square inch of pattern, but also tables giving the weights of castings cast from patterns made of various kinds of wood per pound of wood in them which give accurately the weights of castings when properly molded and poured, so that the weight of a casting may be accurately determined from the wood pattern before casting. This being the case there is no reason why castings should not be sold by the piece at a price based upon the cost of labor required to produce them in place of per pound based upon the price of pig iron, and a better price be thus obtained.

I have recently met a number of founders who have adopted the piece price system, as far as possible with their competitors selling by the pound. In Indiana a founder was making a small arrow-head casting for decorating graves, for which he received twenty-five cents a piece, this price netting him about fifteen cents per pound. A Hartford, Conn. founder making automobile cylinders by the piece, realized thirty cents per pound for the casting, and at a Baltimore, Md. foundry, I was shown a small propeller wheel sold at a price that netted the founder forty cents per pound. Had the buyer of the castings been asked any such price for a pound of cast iron, even if he knew nothing about the price of pig iron per ton, he would no doubt have objected to it, but when asked a given price he paid it the same as he would have done for any other manufactured article, and was satisfied with it.

But the piece price cannot be adopted by a founder at an advance price for anything but a speciality so long as his competitors are selling by the pound. To illustrate this; I recently met a founder in a Massachusetts town who had an order for two small propeller wheels weighing three and a half pounds each, to be made from a brass wheel taken from a motor boat. The price charged for these wheels was five cents per pound or thirty-five cents for the two wheels. This was not sufficient to pay for the core box, and placing of a core print on the pattern. When the founder's attention was called to this, he said five cents was the price for light castings in the town, and he could not charge any more, but he would make it up on work done on the wheel in the machine shop. This may have been all right, but I failed to see why a machine shop should be made to pay for running a foundry. While the piece price would no doubt advance that of castings, this would in many cases be an advantage to the consumer especially in the heavier class of machine castings, as it would result in a better grade of castings being made. For with the pound price, every pound of iron that goes into a casting increases the founder's profits and he is not at all interested in keeping the casting down to weight, and castings are frequently swelled and strained by soft ramming and improper pouring.

The consumer is thus required to pay for increased weight and if the casting is to be finished on the lathe or planer an additional cost is incurred for removing the excessive weight. The result is, that a consumer never knows what a casting cost until it is weighed and delivered, and the expense of finishing is always an uncertain factor until the work is done, so that he can never know what a machine cost until it is actually finished.

With a piece-priced system, every pound of swell and strain would be a loss to the founder, and he would be interested in keeping castings down to weight and making more perfect castings.

Contract Castings.—Foundrymen frequently enter into a contract or agreement to make at a given price, whether plain or core work, all the castings for a machine shop or other consumer of castings. This price is always below that of core work and above that of plain work, and the founder figures on making up his loss on the core work from the profits on the plain work, and thus realize a profit on the contract. This theory figures out very well when the plain and core work are of proper proportions, a profit being then realized on the contract. But the buyer of the castings frequently discovers that he is paying more for his plain castings than he can get them for at other foundries, and sends all of the heavier pieces of the plain castings to the other foundry at a lower price leaving only the core and light plain castings to be made on his contract. In this way the contracting founder frequently finds himself making castings at a loss and is compelled to throw up the contract.

As it is an easy matter for the contractor or machine shop to shift the responsibility for this kind of work onto their customers and the founder has no redress for violation of contract and, if he has a written contract to make all their castings at a certain price per pound, may find himself making them at a heavy loss and bound to continue to do so.

With a piece price it would not make any difference to the founder whether he got the plain or core work at a price based upon the cost of labor etc. for producing it.

Unfair Practice.—Another bad and unfair practice is that of founders with machine shops selling castings below cost of production and depending upon making up the loss by overcharge for work done on them in their machine shop. This practice is not only unfair to foundries having no machine shops, but also to both the machine shop and the foundry of the concern where it is carried on. For the machine shop soon gets the name of a high-priced place, and the foundry is required to make castings that are to be machined at another plant where no loss has to be made up on them and the work can be done cheaper, at as low a price as those that are to be finished in its own machine shop.

Every plant should be run on a paying basis and the man who undertakes to make a machine shop pay the running expenses of a foundry will soon find that neither plant pays. The piece price may readily be adopted by foundries making a specialty of duplicate castings, as it is only necessary to count the castings in place of weighing them, and such castings are now sold by the piece by many founders. For other work no more labor is required to figure a piece price than a pound price, for only the same elements or items have to be considered in determining the cost per piece as per pound. In the opinion of the writer, the foundry industry can be greatly improved by the universal adoption of a piece-price system of selling all kinds of castings.

Cleaning Castings.—Not so many years ago castings were made in green sand without facing or blacking, cleaned with an old file or shovel, and shipped from the foundry with a heavy coating of sand upon them. But now almost every mold has to be faced, black-leaded and skin-dried to prevent sand burning onto the castings, and to remove any sand that may adhere to them; we have the acid bath, steel wire brush, improved tumbling barrels of all sizes and shapes and, last but not least, the sand blast, which is capable of not only removing the sand, but also of cutting away the iron of the casting, and we find even sash weights polished in the tumbling barrels before they are shipped from the foundry.

It is very nice to be able to send out fine-looking castings, but it is not always to the interest of the founder or purchaser to do so, for there are many lines of castings upon which a coating of sand burned upon the iron in casting is a greater protection than any paint or protective material that can be put upon them. The advantage of sand protection may be seen in sash weights that have been polished and those with a coating of sand upon them, the former when placed in use. in a damp wall soon becoming heavily coated with rust and eaten away by it, while the latter remain as good as new for years under the same condition. In castings placed in the ground the sand-coating protection may be seen to a still greater extent, and in Chicago, at the present time, all castings of man-holes, sewer inlets, etc., are used with only the loose sand brushed from the exposed surface. From the part of the casting placed in the ground the sand is not even brushed, and no facing is used. These castings have been found to last much longer than when cleaned and painted with coal tar. Water and gas pipes last much longer when protected by the sand burned on them in the foundry than when the mold is faced or blackened and the casting painted, and there are many more castings, such as foundation plates, grate-bars, etc., upon which much money could be saved for facing and cleaning and a more durable casting turned out.

This is a matter that should be looked into by every foundryman, for in late years the foundry industry has been very much injured by the adoption of steel, both rolled and cast, for purposes for which cast iron was formerly used. That the lasting properties of cast iron are superior to those of steel for many purposes is rapidly being proven, and the founder should take every advantage of these developments to improve the foundry industry and regain its lost prestige.

INDEX.

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