THE PRODUCTION OF MALLEABLE CASTINGS

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Richard

The Production of Malleable Castings

A practical treatise on
the processes involved
in the manufacture of
Malleable Cast Iron

By Richard Moldenke

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Dedication

To my beloved Wife, who with exemplary patience has sacrificed much of that home life so dear to us, in order that the call of civic and industrial duty might be met, this book is affectionately dedicated.

Preface

OF the closely held *secret* processes of the great iron industry, none can rank with the production of *Malleable*. From its earliest discovery until very recent times, at even the most advanced works the knowledge of the process did not extend beyond the use of certain brands and grades of pig iron which, when annealed, would produce serviceable malleable castings. The why and wherefore was a closed book.

This volume represents a life's work devoted to clearing up the mysteries of this practice, to at least a small degree. Such has been the feeling of having *vested interests* involved in the production of malleable castings, that the information contained in this book, and published serially in The Foundry, has met and will meet with occasional condemnation by the old time malleable man. It is giving away the business—as if the man who really knows his business is afraid of progress.

That the author has done the iron industry, as well as the public, a service in publishing what he hopes is a clear exposition of the principles underlying, and a description of the practice of making malleable castings, is shown by the heavy correspondence he has received from those who have been continually receiving inferior work, as well as from makers who are anxious to raise their establishments up to the highest state of perfection. We all make and have made poor malleable castings, but there is no excuse for doing this deliberately—by closing our eyes to progress.

What is contained in the following pages is only the story of the malleable casting, as the author has seen it developed, and perhaps he has taken an important part in this development. But he does know that the work is by no means completed. Many problems of the practice are still unsolved.

If this, the first comprehensive work on the subject, will serve to stimulate interest in a very important branch of the iron industry—not in multiplying establishments, but in improving them — the aim of the author will have been served.

Richard Moldenke.

Watchung, New Jersey,
February 6, 1911.

The Production of Malleable Castings

I

History, Early Development and Present Importance of the Malleable Iron Industry

PROBABLY no branch of the iron industry has experienced so little change from early methods as the production of malleable castings. Only quite recently, comparatively speaking, have the uncertainties of the process been overcome by a greater knowledge of the principles underlying its various stages. We may safely say, that beyond the fact that castings made from certain irons, and showing a white fracture on being broken, when melted in certain ways and then annealed turned out to be malleable, nothing specific, which would serve as a guide in daily work, was known to the trade previous to 1890.

As the result of our investigations along scientific lines, practically applied, we know today that by giving proper heat treatment to castings of a composition between definite limits, they will invariably be malleablized. It is the author's purpose in this book to describe and discuss every stage of the manufacture of malleable castings, and to attempt the explanation of some of the mysteries that once baffled every attempt at correction until heavy losses had resulted.

The fact that success, after the right composition and proper melting have been obtained, depends solely upon the application of heat high enough and long enough continued to effect a change in the condition of the carbon present, without its necessary removal or diminution, places malleable casting practice in a unique position. There are few products of the iron industry that can be made either valuable or positively worthless, as the result of a final heat treatment, and this considerably below the melting point of the metal.

Inasmuch as the processes involved are not difficult to carry out, even by rule-of-thumb methods, provided everything is running smoothly at the time, and as the malleable casting has many valuable properties to commend it, a great industry has grown up, the United States taking the lead. The annual production at the close of the first decade of the twentieth century may easily be placed at a round one million tons for the world, of which America's share is easily nine-tenths. In Europe, England is now second to Germany in output, France and Italy are small producers, while Sweden is forging ahead slowly and is replacing much drop forge work by malleable cast iron.

In tracing the causes for this enormous preponderance in the tonnage of the United States and Canada, as against the rest of the civilized world, we find two principal reasons. The first lies in the radical differences in machining practice. In England and on the continent, where labor is cheaper than in the United States, it is customary to finish machine parts to a much greater extent than in America, and hence much of the very best part of the malleable casting is removed. Necessarily the poorer, often spongy part of the casting has to stand the service strains, and frequently fails. Hence the more prevalent use of steel castings.

The second cause is to be found in the progressiveness of the American manufacturer. Not content with the comparatively thin sections made in Europe to this day, heavier and thicker work is demanded, so that chills are extensively used to get the metal white as cast. And this in spite of the fact that in no branch of the iron industry is the chance for loss so great, and the profits so sharply cut as the result of fierce competition.

The capital required to build and operate a malleable casting plant is four times as great as for a gray iron foundry of corresponding tonnage. On the other hand, the work is very steady, enormous numbers of the same piece are usually required, and with long time contracts it is possible to make a fairly good profit in brisk times.

Until the great change came in malleable practice, ignorance on the part of the purchaser permitted the founder to do pretty much as he pleased, and when inferior material was sent out, as was often the case—though only through imperfect knowledge of the art—the claim was invariably made that only good irons had been used, which was true. Yet in spite of this, car and machine builders would demand a malleable casting even if the corresponding gray iron section would answer the purpose. Unquestionably, a malleable foundry located to insure an economical supply of material, with a market for its product, and properly conducted, should prove a paying institution.

The first record we have of the production of malleable cast iron is by Réaumur, in 1722. This, however, did not seem to prevent Lucas from taking out a patent on the process in 1804, nor Brown, and Lennox half a century later. Since Réaumur's announcement, however, technical literature may be searched in vain for additional light on this subject. Seth Boyden, of Newark, N. J., was the pioneer manufacturer of malleable castings in the United States. His recorded experiments stand as a monument to his memory, especially in view of the fact that they were made at a time when all scientific study, as applied to industrial problems, was frowned upon. Even though he failed to solve the underlying principles involved in the production of malleable castings, he accomplished more than others before him.

It should not be forgotten that in the time of Réaumur, and even Seth Boyden, iron was an expensive luxury used principally for purposes of war. Few could afford to burn up a lot of metal in experiments, which, therefore, were conducted on an extremely small scale. The production of a few tons of malleable castings a week, in the early part of the nineteenth century, required as much thought and worry as the operation of a modern plant having a daily capacity of 75 tons.

However, from a study of the records as well as the traditions of the iron industry, it appears highly probable that the production of malleable castings in a crude and sporadic way must have originated before the eighteenth century. The old slag piles of Hungary tell a story of blast furnace perfection unequaled today, though the cost in fuel must have been tremendous. The ancient disciples of Tubal Cain certainly knew how they wrought, though not why. The forests of Germany had within them many a small forge and hearth furnace adapted from England, in which every variety of steel and iron was made. Since any one can take a No. 6 grade of pig iron and make *malleable* from it by simply annealing with the other castings, it is reasonably certain that the metal gathering at the spout and receiving successive heat treatments, gave the old furnacemen a taste of the modern article. This still happens today, as one will find where rebuilding old air and open-hearth furnaces.

From the earliest times the manufacturer, then small, now great, maintained the greatest secrecy in his establishment. The spread of knowledge from these old plants, could it be recorded, would read like a romance. It would not do to lose a point as a rival might gain by it. The consumer, however, as usual, seemed to have been left out of the calculation. The result was that the plant would work up to a routine which it was believed could not possibly be improved, and there it remained. Occasionally a molder from some other shop would tell of a different way of doing things, and straightway the man responsible for the change was induced to migrate. In this way it often happened that a collection of expensive men was accumulated, for it was considered dangerous to let a man go—the secrets of the business might go with him.

Particularly the melter of a malleable works was the *czar* of the establishment, and had to be handled with gloves. So much were the owners in the hands of their melters, that the latter always became partners in the end, and only then considered the interests of the works before their own.

It is by no means in the remote past that the melter was known on the floor as *Daddy* so-and-so. He would frequently order a heat held for hours or poured on the floor if for some mysterious reason he did not think it would make good castings. The result was that the molders were compelled to go home early, as their floors were full. The real reason may have been that the melter's *toddy* did not agree with him, or the *super,* if not an ex-melter, did not greet him with proper respect.

The melter knew whether his heat was *high* or *low*—his test plug gave him a clue to this—this being before the days of steel additions, but he would supplement his eye and sense of temperature by inserting a thin wrought iron rod into the bath, leaving it there long enough to acquire the temperature of the molten metal, then drawing it out and sweeping it through the air. By the scintillations he would judge the fitness of the heat to be poured, providing he was satisfied with the augury of the test plug.

The swishing of the rod through the air was always looked upon with reverence by the molders, whose bread and butter were involved, and great was their satisfaction when the czar looked wise and said, "Give her another 10 minutes and let 'er go." Occasionally, however, the molders took a hand in the game. One of the leaders would get out on the gangway, hold up his shovel, and in 10 minutes all hands would be out on the street endeavoring to ascertain the grievance that so suddenly terminated operations. The heat frequently had to be run out on to the floor, and it was usually necessary for the management to circulate among the men and beg them to go back to work again.

This condition was the rule and not the exception in the malleable casting industry in the early days and was founded on, and resulted entirely from the secrecy that surrounded the practice. More could be written on this phase of the subject, but the above will show the great odds that were overcome and the heartbreaking struggles that were experienced by those who brought order out of chaos.

Perhaps to one man more than any other, of the self-made men of America, William McConway, of Pittsburg, is due the credit for the great change in the industry. Patiently and persistently he supported the scientific study of the process, until it was developed to an exact art. His reward came during the early nineties of the last century when the improvements made as the result of what his friends and competitors called "wasting good money experimenting" rolled up a handsome surplus and allowed the easy weathering of that terrible industrial depression. The author desires here to pay tribute to the genius of the man under whose guidance he learnt much of what he knows of *malleable.*

A knowledge of the sound methods thus worked out was disseminated by the men who went from shop to shop, and with the others at work along similar lines, the practice was revolutionized, these changes having affected not so much the principles of the process as the methods by which they were carried out.

Today, in properly conducted establishments, the iron, mixed by the metallurgist, is delivered to the foreman or melter on the furnace floor, is melted, and invariably tapped on schedule time.

Without doubt, the process of malleablizing iron castings called *tempern* in German, was carried out in substantially the same manner from the earliest times, the secret having been handed down from father to son in Europe. It came to the United States from England.

The fact that the process did not advance was in great measure due to the regularity of the pig iron used, the ability on the part of the melter to start anew in case of trouble by melting a straight heat of No. 2 charcoal iron, and finally by his gaging of the annealing temperatures in the ovens by the appearance of the cracks in the brickwork. This, together with the fact that the principal requirement of the process is the change in the state of the total carbon, kept the history of malleable cast iron barren of incidents. Rèaumur and Seth Boyden left notes explaining their work, but the others did not. All of them produced much good and some very bad castings, as the old scrap piles plainly showed before this material went into new malleable castings and basic steel.

The dawn of the progress in the malleable foundry followed the introduction of coke iron. Before this, charcoal iron was considered indispensable and the only grade that could be successfully used. The use of coke pig iron was undertaken in fear and trembling and only a very small amount was added to the mixtures. This fact was guarded as a secret, not because of rivals, but to prevent the trade from learning of the cheapening of the product. Doubtless the first place in which coke pig was tried was in a combined gray iron and malleable works. The current belief that pig iron took its *nature* from the ore and exhibited diversified properties was then firmly rooted. Even today the metallurgist who hears of European pig with the names of the ores from which it was made tacked on, or is learnedly told of the difference between northern and southern strong, weak and soft irons, smiles and hopes that enlightenment may some day become more general. The terrors of the malleable man, had he known that his cold blast charcoal was being made by a warm blast process, can only be imagined. The iron salesmen themselves were not advised of this fact, although the furnace operators soon appreciated the value of stoves.

After the prejudice against coke iron was removed, the swing of the pendulum was in the opposite direction and all grades were tried, with the inevitable result that in many works all coke irons came to be mistrusted. All kinds of job-lot irons, off-Bessemer, and metal that should have never darkened the door of a foundry of quality castings, were tried during the hard times in the nineties, and much bad material produced. Had a rational way of making mixtures with new irons been pursued, such as using as much of it as possible in the heat, then repeating, using the sprues of the first heat, and casting test bars for trial, many of the troubles of the manufacturer, and annoyances experienced by the consumer would have been avoided.

Today, coke irons for the malleable foundry are especially made. That is, they are *honest irons* in the making of which plenty of coke is used and little *cinder*. The several grades are known as Coke Malleables, and if specified to contain not less than 0.75 per cent silicon, can be considered as first class.

Even when the use of coke iron had come to be predominant, it was considered necessary to impress the customer that charcoal irons were used for his castings. The author remembers that at the time when he used coke irons exclusively—to the extent of 2,000 tons a month—it was considered necessary by the management, for business reasons, to have a small stock pile of charcoal metal in the yard.

It is interesting to note that the change from charcoal to coke iron was one of the principal reasons for the reduction in the price of the former material, and today only those plants, which on account of their location find charcoal iron as cheap as coke, are justified in adhering to it for their mixtures.

The introduction of steel scrap into the mixture marked the next forward stride in the history of the malleable casting industry. Coincident with it was the use of malleable scrap, that is, scrapped annealed castings. The latter was, however, only attempted where the proper knowledge had been acquired, for it is no easy matter. The result of this introduction was a marked increase in the strength, and may be called the dividing line between the old and the new *malleable.*

It goes without saying that all the improvements were the outcome of laboratory investigations, and the subsequent scattering of foremen and men, now quite as common as rare, formerly. Information disseminated rapidly, and former scoffers eagerly took what it had cost them nothing to develop. Many other improvements were also made in the construction end of the industry which will be duly discussed in the succeeding chapters.

As the industry stands today, it is furthest advanced in the United States. While the process, in its scientific aspects, is known to but few men, and the investigating laboratories of the world in this branch of the industry can be counted on the fingers, enough has now been made public to enable the malleable foundry to turn out creditable work regularly, and where eternal vigilance is the rule rather than the exception, an especially good material can be made, day in and day out.

Further advancement is dependent upon the solution of problems dealing with the constitution of malleable castings. We do not know at the present time why cupola malleables require an annealing heat several hundred degrees higher than air or open-hearth furnace iron. The underlying principles of the oxidation of the bath, which is a frequent cause of defective iron, and is practically unknown to the majority of those engaged in this industry. Heats are frequently made that will not anneal properly, but the causes are still being sought. To produce castings from successive heats so that with the same composition they will have the same physical strength regardless of how they are tested, is a problem partially solved for steel, but not yet approached for malleable cast iron.

Sufficient progress in the study of iron with the microscope has been made to warrant the belief that in the not distant future we may be able to distinguish the constituents of the material by means of etching with various chemicals. When the sulphides and phosphides of iron, or the manganese-sulphur compounds can be seen directly under the microscope it is probable that a method may be found by which the dangerous ingredients may be so scattered or arranged that they will do the least harm.

The book on malleable cast iron has, therefore, only been opened and with the abandonment of secrecy—really only a mask for ignorance—forward strides may be anticipated that will overshadow all previous advancement.

II

Characteristics of Malleable Cast Iron

TO OBTAIN an idea of the value of a material, it is well to compare its properties with those of similar substances; thus, gray iron castings range from those nearly black in fracture to white, with all degrees of softness to glass hardness. They may be strong or weak, but still serve their purpose. The desirable characteristic, however, of the gray iron casting is its extreme resistance to compression. Where shock is to be cared for, great massiveness is required, but again the metal may be run into any desired form with comparative ease.

The steel casting has the highest strength so far attainable in cast materials coupled with no undue difficulties in the making. It may be deformed considerably without danger, and is cheaper than a corresponding forging.

The malleable casting is somewhere between the two above mentioned. It is stronger than the gray casting, but not as strong as cast steel. It can be bent and twisted considerably before giving way and approaches cast iron in compressive strength; but its most valuable characteristic is resistance to shock. For the repeated stresses of severe service the malleable casting ranks ahead of steel, and only where a high tensile strength is essential, must it be replaced by that material. This is best illustrated in the passing of the car coupler made of malleable cast iron. Not only have a large number of drop tests shown the high value of the malleable coupler as compared with one of cast steel, but the scrap heap tells an interesting story. In making comparisons of broken malleable couplers with steel, a large number of each were selected in which the heads were badly battered by the succession of blows occurring in railroad service. Coupons were cut from the barrels of these couplers. These, when pulled apart in the testing machine, with but few exceptions, gave the palm to the malleable casting.

A study of the characteristics of *malleable* and steel will explain this to some extent. The constitution of the steel casting, as shown by the microscope, is found to be in the nature of distinct crystals of pure iron closely packed together with other crystals of iron carbide. There is no space between these groups and aggregations of crystals to amount to anything. Hence, batter them and they will separate along the lines of crystallization, and cracks will extend somewhat similar to those in the gray casting. Where actual cracks or separations of crystals do not occur, there is at least introduced a series of strains, not unlike the casting strains the founder is so familiar with, so that no matter how good the material was originally, but little further pressure put on it will bring about failure. When, therefore, a steel which should ordinarily resist a strain of 65,000 pounds per square inch, and doubtless did when the coupler was new, fails under but 20,000 pounds, it would show that this material was not the best for shock resistance.

On the other hand, the malleable casting, consisting also of crystals of iron, though very impure, has within its structure a net-work of free amorphous carbon particles called *temper-carbon* by the late Prof. Ledebur, the German authority on malleable cast iron. In other words the malleable casting is for practical purposes a poor steel casting with a lot of graphite, not crystallized, between the crystals or groups of crystals of the steel. This naturally makes the material weaker on a direct pull, but when it comes to shock, the blows will batter the face, but the compression of the cushions of carbon will effectually prevent the transmission of the force very far. The fact that the carbon or graphite is not crystallized in the malleable casting, as it is in the case of gray iron, explains why the former is so much stronger. The graphite found in cast iron represents planes of weakness, a distinct separation of the metallic particles, so that when pulled, only a very small portion of the iron holds together. In the case of *malleable* there are no such planes of weakness, and hence the small spaces taken up by the carbon present in its free, uncrystallized form do not interfere so much with the holding together of the particles of iron.

It may be said in passing, that as between the steel casting and the malleable, if the first is not properly annealed before being shipped there are always remaining serious casting strains which are bound to weaken the product. Hence the shipment of unannealed steel castings, except for use where great strength is not a factor, should not be countenanced. On the other hand, the malleable casting, when well made, is a finished product. The heat treatment received is ideal. Brought to red heat quickly, held there a fair length of time, and then allowed to cool gradually, all strains are removed. The material is in perfect equilibrium and can therefore carry its proper load safely. It must, however, be well made to do this, for when malleable is bad, it is utterly so.

Malleable cast iron being cheaper than steel makes it a prime favorite with the railroad man, for agricultural work, pipe fittings, and in all construction work involving a great number of pieces from the same pattern. Competition keeps the price of the malleable casting between the gray iron and the steel in the United States. In England the same condition exists. In Germany, however, where the steel casting industry has attained quite a prominence, and where the custom of machining cast material of all kinds obtains, as explained in the previous chapter, the malleable casting oftentimes commands a higher price than the corresponding steel section.

A study of the strength of malleable cast iron, carried on by the author for many years, and involving perhaps a hundred thousand physical tests and nearly twenty thousand chemical determinations, has not only given a fair insight into the remarkable improvement brought about by the better regulation of the methods of manufacture, but also shows what might be done were it possible to produce an absolutely uniform product, one casting identical in its structure with the other. Time and again concerns have started in business attempting to exploit some supposedly new method of shortening the annealing time, or in addition to this, recarburizing the skin of the casting to make steel (?), only to fail in the end. An almost unbroken series of runs would turn out successfully, or would be fairly so, and then would come a batch of castings with which nothing could be done, though these castings, when treated in the ordinary way, would anneal all right. Simply the lack of uniformity, due not only to the varying composition, but also the changes made in the proportion of scrap and pig iron were to blame. The latter cause will eventually be traced more clearly to oxidation of the metal to a greater or less degree by poor melting practice, or too great a number of remelts.

This lack of uniformity is more apparent in the heavier classes of castings than in the light. It is quite possible to make a line of thin cutting tools, such as wood chisels, hatchets, etc., case-harden them, and finish them for the market. Many a patternmaker and carpenter uses a chisel he fondly imagines to be made of the very best cast or tool steel, which in reality is only a case-hardened malleable casting. It is only when breaking the tool in its thicker parts that the "black-heart" characteristic of malleable cast iron appears. The reason for this condition will be explained later. In the case of heavy iron work, where it is necessary to work down to pretty close limits in the silicon of the mixture in order to get good results—so close, in fact, that the limit is sometimes overstepped, and burnt iron results—it is practically impossible to get material uniform enough with which to try metallurgical tricks. The result, therefore, must always be disastrous to an enterprise based on so insecure a foundation.

It is quite amusing to receive work made by such processes preliminary to a desired investment, and upon opening the package to almost invariably find a hatchet with the edge turned over slightly. Not only the shortening of the time of anneal, but the introduction of chemicals, gases, and what not, into the pots forms the basis of these inventions. The bright geniuses in question forget or do not know that it is perfectly possible, though not good practice, to anneal a hard casting of the proper kind in a few hours at a very high heat, as well as to get first rate results in the ordinary annealing process by packing the castings in brick dust, fire clay, or sand. Foundrymen should therefore fight shy of these inventors, at least until they can prove some new principle, and the possibility of handling the whole gamut of malleable work with uniformly good results.

Before taking up the question of testing malleable cast iron, a few more words should be said on the constitution of the material. Take a thick, flat piece of malleable and plane off the skin, say 1-16 inch deep, and gather the chips for analysis. The total carbon will be found to be, say 0.15 per cent, and occasionally even less. Cut in another sixteenth-of-an-inch, and the total carbon will have risen to, say 0.60 per cent. Now go down successively by sixteenths and the total carbon will be found to range from, say 1.70 per cent, successively up to the maximum amount originally found in the hard casting. This maximum amount will remain constant until the center has been passed, and the carbon decreases again.

For practical purposes, since the *temper* carbon, of which this total carbon consists almost entirely, will become combined carbon on heating high and quenching the piece, the skin of the casting may be considered something like wrought iron. It cannot be hardened by quenching, but can be satisfactorily case-hardened. The next portion of the casting is in reality a tool steel and can be hardened, and finally the interior is a cast iron, however, an iron but little short of the strength of the whole piece.

The portion just below the skin is interesting, for it is that part of the casting in which the crystals have arranged themselves at right angles to the surface. In the annealing process this arrangement may facilitate the penetration of oxygen from the scale, or air, to effect the removal of carbon—if the older theories are correct. The author, however, has always maintained, that once oxygen gets into a casting, as in *over-annealing,* it remains there to the detriment of the piece. He further holds that the carbon is removed by a species of migration similar to the wandering of the carbon from a high-carbon piece of steel into another low-carbon piece placed with it when both are subjected to a high temperature. The result of the crystal arrangement at right angles to the surface is a pretty sharp change from a lower carbon content to the full amount at the center where the crystallization is mixed in every direction.

An inspection of the fresh fracture of an annealed piece will show the founder, accustomed to this, a more or less noticeable band of material, lighter in shade, between the steely rim and the black interior. This is the zone of crystallization referred to, and it is this portion of the casting which is made use of for the cutting edges of chisels, etc., sold as cast steel.

There is a further deduction to be made from the above, and that is the utter worthlessness of any carbon determination made on a piece of this metal after annealing. Unless the sample is taken right out of the middle, or planed off as indicated, and the facts stated, the determinations made for carbon are of no use. Even boring right through the casting, gathering all the drillings, and using them all for the determination is only an approximation of the truth. To get some light on this point, it is necessary to take the total carbon of the casting before it is annealed, and then one may know what to expect from a heat which runs, say 2.85 per cent total carbon, as compared with one running 4.06 per cent.

There is but a slight variation in the quantity of the rest of the elements present before and after anneal, the carbon alone being affected. This is changed from combined carbon to *temper-carbon* throughout the mass, and partly removed in what is called the skin and a little further inward. Other characteristics of malleable cast iron will be described in connection with the processes involved.

III

The Testing of Malleable Cast Iron

MALLEABLE CAST IRON is tested for its quality in two general ways—by so-called shop tests, and by laboratory tests of bars cast from every heat and annealed with the castings. Apart from the *test-plugs* taken from the heat while this is going, and which will be described under the chapters on melting, the usual shop tests consist of bending occasional castings, twisting the longer pieces, making and breaking so-called *test-wedges* separate from castings and casting *test lugs* on the more important work. The latter, when broken off just before their final preparation for the market, show up the quality of the particular casting. These are in effect the *test coupons* of steel practice, but much smaller.

In testing castings taken at random from the pile of discards, as they come from the soft-rolling room, what is looked for particularly is that the heart is sound, black, and the white rim not too pronounced. The casting should bend well before yielding, batter out to show softness, and the skin should be clean, free from pin holes, with the edges sharp. The interior should not show sponginess or *shrinkage,* as it is called—(true shrinkage and not the contraction in melted metals from set to coldness erroneously called *shrinkage*). This *shrinkage* is a serious point with the malleable man, as it is the cause of most of the failures on the part of castings. To overcome this difficulty it is usually necessary to use chills in the molds at the danger points, as will be explained subsequently.

The test wedges used in the shop are about 6 inches long, 1 inch square for 3 inches of the total length, and then tapering down in thickness for the last 3 inches to nothing, but keeping the full inch width. This gives thick iron as well as thin on the same piece. These wedges are cast at the same time as the regular test bars for the laboratory, and are marked to correspond.

When the test wedges come from the anneal, being placed there with the test bars in the center of the pot which stands in the middle of the oven, the annealer breaks them on his anvil, striking a succession of short, light blows. The object is to see how much the thin end of the wedge can be bent before the piece breaks. After breaking, by simply holding the two parts together, and observing the bend, a very fair idea of the quality of the castings these wedges represent may be had. The break, by the way, is made to take place in the middle or rather toward the inch-square side of the wedge.

In marking the wedges as well as the test bars, the following method will be found well adapted for the purpose. Number the furnaces for example from one to ten or one to four as the case may be. Then number the heats in each. Thus heat Nos. 1, 2, and 3, if there are that many in one day. Next, designate the first part and the last part of the heat by one and two. Finally put on the date. Taking either the wedge or the 14-inch test bar, put the furnace items on the left hand end of the bar, and the date on the right hand. These numbers are obtained by pressing the ordinary steel figures, as used by the machinist, into the mold before closing.

Now take for instance the last part of the third heat of furnace No. 8, cast on November 15. This would appear on the test bar or wedge as follows:

8	3	2		11	15

Or the first part of the first heat of furnace No. 2, on March 8. This would appear:

2	1	1		3	8

This locates the bar and consequently the castings corresponding to it at once and trend can be kept of the quality as shown by the tests.

There is a further very important advantage to be derived by making test wedges. In the larger works it is almost impossible to keep track of the condition of the furnaces, more especially if the open-hearth type is used, unless the laboratory has the evidence at hand for the benefit of the melter, superintendent, as well as the manager of the concern. The tendency on the part of the shop management is naturally to get out the very last heat possible before repairing the furnace. This always means that the product suffers. Similarly, annealing ovens are run as long as they will keep from collapsing, with resulting underannealed work to the detriment of customer and works' reputation alike.

Unless the very head of the concern can, by casually stepping in at the laboratory, see exactly how things are running, and give the necessary orders to correct the trouble, much bad iron will go out. By building a little cupboard with about 20 shelves with 2½ inches or so clear space between each for the storage of the broken test wedges, these useful castings, after being broken and inspected, may be placed on the shelves in regular order of furnace number and heat, with the date chalked on the shelf. After having two or more weeks run on exhibition, by glancing down the shelves, the product made by each furnace can be readily traced, and its condition seen by the white rim of the castings.

Suppose the work of the establishment is heavy, and the open-hearth furnace is used, as this gives the best results, the silicon will be pretty low to start with, and with regular time on the part of the heats, the fracture of the wedges should show up normal. Suppose the ports of a furnace are burning away, the checker work is choked, or other troubles begin to appear, the first effect is to prolong the heat. It will not be gotten ready in the regulation time. The consequence is that the silicon burns out to a greater extent, and we get into what is technically termed *high* iron, that is, the silicon gets too low. The castings will not anneal well, and the first indication is a widening rim of white in the wedges and test bars. The trouble will increase, the iron not only being too low in silicon, but burning will develop. This will result in pin holes in the wedges, later big blow-holes and white rims ¼ inch wide. Finally the trouble gets so bad that the castings will not anneal at all, and the wedges are full of blow-holes, and entirely white, though not crystallized as the original hard iron. Long before this, the furnace should have been put out of commission and repaired.

The record of the wedges shows the trouble one week after casting, not before, and if the white rim is allowed to become quite broad, it is probable that at that very time, the castings being made, going into the anneal, are worthless. The annealing requires a week, and hence six days' castings are always a doubtful quantity when trouble is the order of the day. This accounts for the heavy losses when things are not going right. Formerly, castings thus made, were duly shipped out, but at the present day buyers are becoming wiser and owners more jealously guard their good name.

To induce prospective customers to purchase, they are oftentimes shown wrenches twisted several times, or ¼ inch flat pieces bent into circles, 6 inches in diameter. These are very nice to look at, but in reality not very serious problems in foundry work. Taking a twisted wrench, it will be noted that for every inch in length, but a very small curvature is given the metal. Similarly, in turning a circle with a flat piece, this is done by striking every part of it slightly, giving every half inch of it a little bend. A much more difficult feat is to take a heavy casting under the steam hammer and flatten it out without breaking, as for instance boiler nuts, and this can be done with good malleable castings.

It is, therefore, better for the manufacturer not to show too many of these freaks, as the customer is apt to try them himself with what he gets from that foundry. It is much better to invite the prospective customer into the laboratory and show him the testing being carried on. He will then realize that every precaution is being taken to turn out good work, and go away satisfied that he can do no better elsewhere.

The test lug still remains to be considered. It has long been the custom of the founder to add small chunks of metal to his important castings. These are broken off after annealing, and by the manner of their breaking, as well as the fracture exposed, indicate whether the casting can be safely shipped. The size of these lugs is always aimed to be large enough for easy handling, but not too large, so that in breaking off, the metal may not be torn out of the body of the casting. Thus, for work as large and heavy as car couplers, the test lugs, placed in several vital parts of the casting, would be one inch wide, 5/8 inch thick and one inch long. In the case of other castings, the lug might be 1/2 inch square and 3/4 inch long. Still other sizes would obtain the thickness approximating the section of the casting. In breaking these lugs off, they are to be struck on the outer edge with light blows, giving the iron a chance to bend and break off not too suddenly. A sharp, heavy blow will knock the lug off, but will leave a fracture that may be perfectly white. This is due to the tearing apart of the crystals of iron, thus masking the free carbon present. The same lug broken off a good casting, as above described, would leave the fracture a fine, velvety black. These test lugs, by the way, should be preserved for use in the soft rolling room, as they give up their graphite and polish the annealed castings nicely.

Manufacturers have always strenuously objected to leaving some of these test lugs on the castings they ship out, in most cases grinding away the fractured surface, so that it may not be known that test lugs were used. Customers, however, who are sufficiently important to enforce their demands, have in this method a means of satisfying themselves, that at least as to process of manufacture their purchases are correct, whatever may be the quality of the metal as revealed by the regulation tests.

Coming now to the regulation test for malleable castings, we find it customary to provide for two classes, the heavy and the light. Thus the one inch square bar represents work 1/2 inch thick and over, and a 1 x 1/2 inch section bar cares for the lighter castings. The bars are both 14 inches long. They should be cast at the beginning and at the end of each heat. About the fifth ladle from the start is generally selected for the first mold of test bars, and similarly the fifth ladle from the end, as nearly as may be gaged by the melter, serves for the last of the iron. Test bars and test wedges are cast from the same ladle, the molds being close to their respective furnaces. The idea is simply to have a record of all the metal cast from each furnace day by day.

The rectangular shape is used for test bars in preference to the round section, because the latter invariably shows serious shrinkage in the center, especially if the diameter is large. It is bad enough in the square bar, slightly so in the flat one, but in reality the sections, thus used, correspond to the castings it is customary to make of this material. A round section, unless in very light hardware, is avoided by the experienced malleable man, as he never knows but what the shrinkage in the center might have an outlet to the skin, and cause failure in service. The arguments in behalf of a round test bar for gray iron do not hold for malleable cast iron, as we deal here with an absolutely white iron, crystallized through and through. The complete change brought about in the structure through the heat treatment in the anneal, wipes out every trace of hardness, casting strains and even crystallization; hence the four hard corners and soft intermediate spots existing in the square gray iron bar are absent in the finished malleable casting.

Now about the interior shrinkage of the test bar. If a one inch square bar is pulled apart in the testing machine, there will be a slight elongation in one part, the break being at its center. This part, the elastic limit of which was exceeded, is very short, and hence it has become customary to take the elongation within two inches. Thus, the bar which is to be tested has pricked on one of its sides a series of center punch marks, each two inches apart, and when the break occurs, the elongation is measured between the nearest points in question.

Suppose the break occurred very close to one of the jaws of the testing machine. It is then possible to place the same bar minus its short end in the machine again, and get another pull. Occasionally a third test can be had from the same bar. This has actually been the case, time and again, during the investigations of the author, and the results have run, say 51,000 pounds per square inch for the first test, over 54,000 for the second, and 59,000 for the third. In the case of a more uniform material, like steel, where there is a stretching of the whole of the test piece before breaking at one point, the piece, if tested again, is considerably stronger than it was, a fact well known and nefariously used in the armor plate scandals now long forgotten. In the case of malleable, however, the test bar is not stretched except at the one point, the elastic limit being fairly close to the ultimate, and hence the bar, except at the very break, is in just the condition it was before the test. The first time it breaks at the place where the interior shrinkage is largest, the second time, at the next smaller shrinkage place, the third time, at the place still smaller, and so on, if this could be repeated indefinitely. All of which shows that but for this shrinkage problem some very great ultimate strengths could be obtained.

As a matter of fact, after the author gained his knowledge of malleable castings, and introduced the improvements indicated by his researches, it was by no means uncommon to get results for months where the ultimate strength of the daily runs averaged 58,000 pounds per square inch, and in one case the breaking strength of a bar actually went as high as 63,000 pounds per square inch. Be it said, in passing, that usually such strengths are to be deprecated, as they mean hard iron, while malleable is wanted soft and ductile. In the above case, however, some of the strong bars, tested transversely, on supports 12 inches apart (the customary method) gave deflections of 2½ inches, where ordinarily only ½ inch is expected, which would indicate extreme softness.

Now to look a little further into this shrinkage question. If a bar were to be sliced in two longitudinally, and the interior magnified, a regular series of cracks at right angles to the length of the bar would be found. These cracks, very marked in the center, extend outwardly only a short distance, as may be seen in observing closely the black fracture of a broken bar. The center shows up like a large snow crystal, the edges flaring outward in streaks, never very far, perhaps one-quarter the thickness of the casting. That these spots are actual breaks in the continuity of the bar is proved by the fact that occasionally these flaring edges of the shrinkage crack communicate with the skin of the casting through some small sand hole. The shrinkage, which looks so much like the snow crystal, will then be beautifully colored, showing the effect of oxidation by the entrance of air. While this is a common observation in castings which have sudden changes in section and no provisions taken to overcome the draw of the iron, it would not be so readily expected in well made, high grade test bars; but it is the case just the same, and every test bar, and for that matter every casting, may be regarded as a shell of fairly continuous metal with an interior of slight planes of separation at right angles to the surface.

Taking into account the heavy contraction of white iron this is self-evident, for as soon as the metal sets against the mold, and the source of supply is cut off, the setting interior will pull away section by section, beginning at the colder end. An exaggerated illustration of the longitudinal slice, above mentioned, would look like a rectangle with solid rims, the interior broken only by a running series of convex lenses from end to end, standing vertical when shown in section. The longitudinal section of the test bar is shown in the accompanying illustration.

It is important to remember this characteristic of malleable cast iron, as it forms the basis of many a mysterious failure in otherwise good looking iron.

In contradistinction to gray iron, the tensile test for malleable cast iron is very important. The ductility of the material allows it to be firmly and evenly gripped in the jaws of the testing machine, and hence the results are correct. The bars being cast either one inch square, or ½ x 1 inch, the calculations are easily performed. The elongation is taken in two inches.

The other test made is the transverse. The bars are laid flat on the knife-edge supports which are placed 12 inches apart, and pressure applied in the center. The removal of all the casting strains, etc., during the anneal, make it immaterial which side of the bar (cope or drag) is laid up or down. While the transverse test is going on, the deflection is measured by an instrument placed under the bar, and a reading taken at the moment of failure. From this transverse breaking weight or pressure, and the deflection, it is possible to get a value for the resiliance of the metal, or its comparative resistance to shock.

Longitudinal section and base of fractured test bar

Impact tests, much as they are to be welcomed, have not yet been perfected enough to cut any figure in the testing of malleable cast iron. It is only in the case of the malleable car coupler that elaborate drop tests were carried out, a standard machine as used for testing car wheels and modified for the purpose, being employed. This form of testing was ultimately abandoned as being unnecessary.

The history of the improvement of malleable castings is admirably reflected in the test records of any works that may be so fortunate as to have them for the last 20 years. Going back to the early nineties, the average tensile strength of malleable cast iron was about 35,000 pounds per square inch, with an elongation of about two per cent in two inches. The transverse strength perhaps, 2,800 pounds, with a deflection of ½ inch. Toward the close of the nineties things were different, and a fair average of the malleable castings then made would run about 44,000 pounds per square inch with an elongation of five per cent in two inches; the transverse strength, about 3,500 pounds, with a deflection of ½ inch as before. These, while average figures for the general run of the work, were greatly exceeded in establishments where special attention was given to the niceties of the process. The tensile strength here would run 52,000 pounds per square inch regularly, with seven per cent elongation in two inches. The transverse strength, 5,000 and over, with 1½ inches for deflection.

With the passing of the hard times, during which nearly all the improvements in the malleable process were applied, came a swing of the pendulum which carried the tonnage of this material far upward. The result was an immediate deterioration in the quality of the castings. Furnaces were pushed to the limit. Steel melters took the place of many conservative and careful malleable men, and the metal suffered before it went to the anneal. The result was a drop in the quality of malleable castings, which has not been overcome to this day. Witness the specifications for these castings modified in 1904, when it was found necessary to drop the required ultimate strength from 42,000 to 40,000 pounds per square inch. There is much good malleable made in every works, but on the other hand, the scrap heaps bought from the large consumers, when examined for specimens with trade mark and approximate date on them, reveal a deplorable and unnecessary inferiority in what should be a high class product. Charge this to the incessant chase after tonnage and high pressure production.

As an interesting side light on the tensile strength of malleable cast iron, there may be mentioned the results of experiments on drawing down round test bars of various diameters. These were heated red hot and handled exactly as crucible steel bars under the steam hammer to turn out the highest grades of tool steel. It was not possible to draw the malleable bars down very far, as the interior, on account of its high total carbon, cracked very badly. The surface, however, remained intact, and acquired a high finish for a hammered bar. The results of the hammered portions of these bars were surprising, running from some 80,000 pounds per square inch in the larger sizes to 123,000 in the smaller. If the cracked and worthless interiors were to be deducted from the area of the hammered bars, the remaining good portions would show up as good as high class rods of tool steel. In effect, the sound portions of the bars approach this in structure, as the result of heating and hammering.

In addition to the numberless tests made by the author on the product made in establishments with which he was connected, he had occasion to cut test coupons by the hundreds, from the product of practically every important producer of America, and subjecting them to tensile tests. The rise in quality, and subsequent deterioration can be readily traced from these records.

The specifications given below, formally adopted by the American Society for Testing Materials, are well adapted to secure reasonably good material. They were gotten up by a committee of well known malleable producers as well as engineers familiar with the subject. The specifications are introduced into the text because they will be recognized as eminently fair, and are the only official standard in existence. Every point in them has a reason connected with the manufacture of the castings, as will be seen from the subsequent discussions of the melting and annealing processes.

PROCESS OF MANUFACTURE.

Malleable iron castings may be made by the open-hearth, air furnace or cupola process. Cupola iron, however, is not recommended for heavy or important castings.

CHEMICAL PROPERTIES.

Castings for which physical requirements are specified shall not contain over 0.06 sulphur or over 0.225 phosphorus.

PHYSICAL PROPERTIES.

(1) Standard Test Bar.—This bar shall be an inch square and 14 inches long, cast without chills and left perfectly free in the mold. Three bars shall be cast in one mold, heavy risers insuring sound bars. Where the full heat goes into castings which are subject to specification, one mold shall be poured two minutes after tapping into the first ladle, and another mold from the last iron of the heat. Molds shall be suitably stamped to insure identification of the bars, the bars being annealed with the castings. Where only a partial heat is required for the work in hand, one mold shall be cast from the first ladle used and another after the required iron has been tapped.

(2) Of the three test bars from the two molds required for each heat, one shall be tested for tensile strength and elongation, the other for transverse strength and deflection. The other remaining bar is reserved for either the tensile or transverse test, in case of the failure of the other two bars to come up to requirements. The halves of the bars broken transversely may also be used for the tensile test.

(3) Failure to reach the required limit for the tensile test with elongation, as also the transverse test with deflection, on the part of at least one test rejects the castings from that heat.

(4) Tensile Test.—The tensile strength of a standard test bar for castings under specification shall not be less than 40,000 pounds per square inch. The elongation measured in two inches shall not be less than 2½ per cent.

(5) Transverse Test.—The transverse strength of a standard test bar on supports 12 inches apart, pressure being applied at the center, shall not be less than 3,000 pounds, deflection being at least ½ inch.

TEST LUGS.

Castings of special design or special importance may be provided with suitable test lugs at the option of the inspector. At least one of these lugs shall be left on the casting for his inspection at his request therefor.

ANNEALING.

(1) Malleable castings shall neither be *over* nor *under* annealed. They must have received their full heat in the oven at least 60 hours after reaching that temperature.

(2) The *saggers* shall not be dumped until the contents shall be at least *black hot.*

FINISH.

Castings shall be true to pattern, free from blemishes, scale or shrinkage cracks. A variation of $\frac{1}{16}$ inch per foot shall be permissible. Founders shall not be held responsible for defects due to irregular cross-sections and unevenly distributed metal.

INSPECTION.

The inspector representing the purchaser shall have all reasonable facilities given him by the founder to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made prior to shipment.

In addition to the records of the tensile and transverse tests, the founder can also get a comparative idea of the value of his material for resisting shock. The resilience of malleable cast iron, as this is called, is measured by the product of the breaking weight times the deflection at that point, divided by twice the weight of the metal between the supports. This will give an arbitrary figure, let us say 680. By watching this from day to day—the iron ranging from 500 up to 1,650 for example—a very fair idea of the manner in which the castings run will be had.

In concluding this general discussion of the testing of malleable cast iron, it may be said that for general purposes it is not altogether desirable to have a metal very high in tensile strength, but rather one which has a high transverse strength, and especially a good deflection. This will mean soft ductile metal which adjusts itself to conditions much more readily than a stiff strong product. It is not always that a strong and at the same time soft material can be produced in a foundry operating on the lighter grades of castings. The purchaser therefore, unless he requires very stiff material, should rather look upon the deflection of the metal coupled with the weight it took to do this bending before failure, than for a high tensile strength.

IV

The Pattern Shop

THE pattern shop is one of the most important departments of the malleable works. Malleable castings are comparatively light when considered in connection with the general run of gray iron work, and moreover are often made in enormous quantities from the same pattern. Hence, every refinement in pattern-making for light castings is found in this branch of the foundry industry. A modern pattern shop for this purpose would therefore be equipped with the usual woodworking machines, as well as individual wood trimmers and other labor saving devices for each bench, and also have every facility for metal patternmaking as part of the installation. Thus, a vertical universal milling machine will be found indispensable where accurate and quick work is to be turned out. The pattern shop, in fact, becomes a foundry for white metal castings, a tool room, machine shop and model works all combined. It naturally takes a high order of shop executive to conduct such a department successfully, and hence we find many a superintendent a graduate from the pattern department of a malleable works.

When a blue print or pattern comes in, a careful study is made to see just how much it will pay to spend upon the pattern end to turn out the job in the cheapest way. Every shop has its own experience in this regard, and concerns that send out patterns are sometimes puzzled to learn that their patterns are gated wrong, and are necessarily charged with the costs of the change.

Large consumers, therefore, have adopted the method of ordering their castings simply by blue print, the works to make and keep the pattern. This, while a little hard on the shop taking the order, is the most satisfactory in the long run, as it puts the whole matter strictly up to the management to make good. There is a good deal of give and take in this, and the result is sometimes a loss on the order.

For example, the author remembers having executed a contract for a great railway system by the terms of which blue prints would be sent in, and castings ordered at a certain price a pound, regardless of the number of castings, the works to make all the patterns. A very intricate job was made under this arrangement, the pattern work on which amounted to many hundred hours, but only seven castings weighing some 100 pounds apiece were required. The price paid was just short of three cents a pound. On the other hand, very many times under that same contract, an order called for 20,000 castings, some 15 pounds in weight, without change of pattern.

Another very good arrangement is sometimes entered into, and that is keeping stock for a customer until called for, under guarantee of taking over up to a given number of these castings in case of change in pattern. This enables the founder to fill up a day for the molder, or to put the job on in case of a dearth of orders, storing the finished castings in the warehouse. The consumer, on the other hand, if requiring quick deliveries for some rush job, finds his castings ready in part and is thus greatly accommodated.

It will be seen that this method of doing business necessitates a rather large pattern shop, and as practically all of the large works cater to railroads and other industrial enterprises which are continually improving their output, it oftentimes happens that some 35 patternmakers are required to keep 300 molders at work.

On the other hand, the makers of fittings, saddlery or other hardware, in which standard patterns can be kept, have gotten things so nicely balanced in their pattern systems, that they know to a dot just how many pieces can safely go on a card or plate; how the runners must be placed, their size, and how attached to the individual patterns. This work is now all metal, and the pattern store room of a modern large malleable works making a line of very small castings is very interesting and entails a heavy investment.

When developing a new article, say a journal box, rail joint, wagon skein, or what not, the patternmaker must practically live in the foundry. As the trial castings are made, he must measure them up with the pattern, make little changes here and there, try the matter out again, both before and after anneal, with iron from different parts of the heat, and thus bring out new points calculated to make the molding end easier, the difficulties from shrinkage less, and swing the job so that it can be carried on without difficulty. One, therefore, seldom finds the friction between molder and patternmaker in the malleable shop, so usual in the gray iron foundry, as the two departments are peculiarly inter-dependent. It should be the rule never to start an order for a quantity on the floor until the pattern has been tried out, the hard castings broken up for evidences of shrinkage, the necessary corrections made, and every one interested satisfied that it is safe to go ahead.

The above naturally results from the problem of the contraction of malleable cast iron. Contraction and shrinkage are two separate and well understood features of *malleable.* Whereas shrinkage is erroneously applied to the shortening of a casting in cooling in the gray iron froundry, in the malleable, *shrinkage* is understood to mean the tearing apart of the particles of iron in the interior of a larger section, close to a small one, leaving a spongy mass, naturally weak, which is highly dangerous to the life of the casting. Contraction, on the other hand, is simply the reduction in size incident to the cooling of a casting from the point of set to ordinary temperatures.

Now, in the case of malleable, this contraction in the hard casting is roughly ¼ inch per foot, or double that of gray iron. In the anneal one-half of this is recovered, and hence the net result is the same as in ordinary foundry pattern practice. It will be seen, however, that this big contraction causes the tearing away of the iron particles, above mentioned, wherever a heavy part remains liquid just a little longer than the adjacent light part already set. The result must be a void, unless liquid iron can be fed in, or else the heavy portions chilled and made to set while the lighter parts can still pass liquid metal. Hence the use of chills, so prevalent in the malleable foundry. Chills mean expense, leave an uncomfortable feeling that the shrinkage was forced to some other part of the casting, are in every way undesirable, but remain a necessary evil. Feeders can also be used on occasion to advantage, but mean an increase in the already high percentage of wasters, and hence are resorted to only when necessary.

As a matter of fact, the chill is a very serviceable article, even if expensive. At one time a certain knuckle (by the way, sold as steel), the section of which was three or four times as great as malleable, was successfully cast in sand, was extensively used and gave very good results. Breaking it revealed the black-heart of malleable. Observing the surface closely, quickly explained the reason for its quality. Chill upon chill could be traced by the contours left. Here was an example of what might be called a sandless casting, at least in part. Probably it cost more than the steel casting, and hence finally disappeared. The chilling, however, accomplished a result that could not have been obtained in any other way, as it was necessary to have the casting practically white in the hard in order to anneal at all. About the ethics of selling this, as well as many other malleable articles, for steel, quite a chapter could be written.

The contraction of the iron used in malleable work has been mentioned as practically ¼ inch per foot, with a return of ⅛ inch in the anneal. Hence the shrink rule of the regular foundry pattern shop is used. Now this ¼ inch contraction will vary from 3/16 to 5/16 inch, and occasionally a little beyond even these limits. This is caused by many factors closely associated with the constitution of white iron. Thus, the lower the silicon and hence the harder the iron, the greater the contraction. Again, the more sprues used, or the more steel used in the mixture, the silicon of the castings being the same, the greater the contraction. In the same heat, the first and last iron give different contractions, depending a good deal on whether the heat was *high* or *low* in the first place. Hence, the importance of careful attention on the part of the pattern shop in following up work having to pass inspection, or where castings are sold by the piece, and any excess iron is a loss. The composition and method of melting the metal having its effect also on the anneal, the castings may not recover the ⅛ inch, and again repeated annealing opens up the structure to an extent quite appreciable in measuring up the finished casting. Thus, the whole question is beset with difficulties, every case requiring individual treatment.

With rather thin castings the expansion after anneal may be so great that occasionally the whole of the contraction is taken up, and the casting is as large as the pattern. This is more particularly true with the higher ranges of silicon in the iron. Hence, as previously stated, particular attention should be given each case.

Nor is the subject closed here. Of late there has developed a tendency to add large quantities of steel scrap to malleable mixtures. This is copied from the steel additions in gray iron, where occasion-

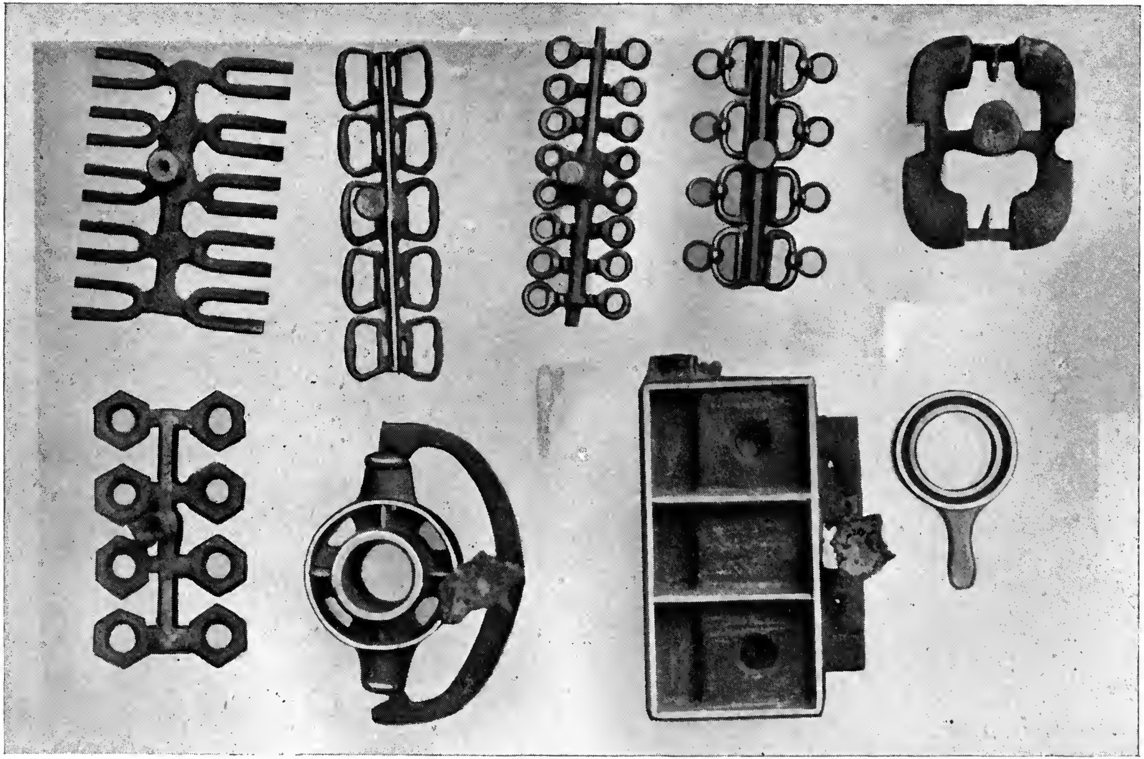


Fig. 1—Miscellaneous malleable castings showing methods of gating

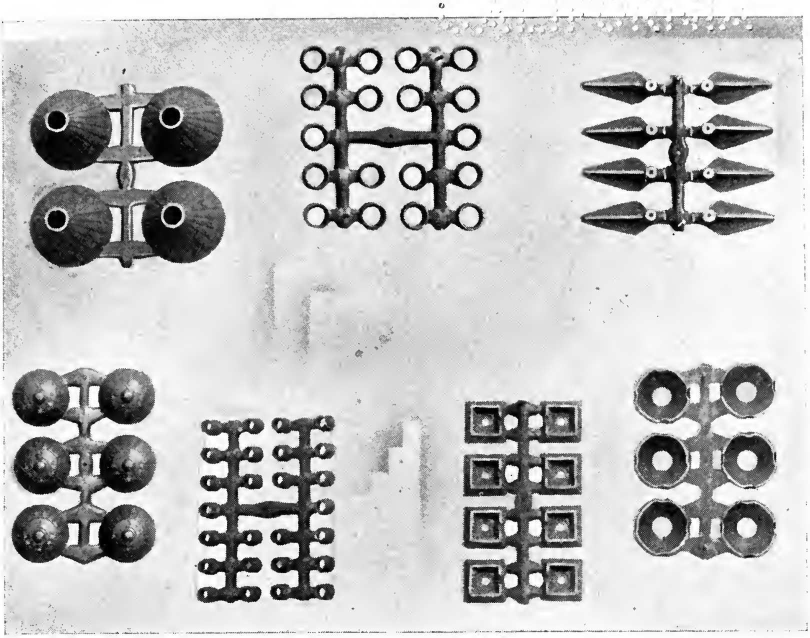


Fig. 2—Gated metal patterns for chandelier trimmings and other small castings

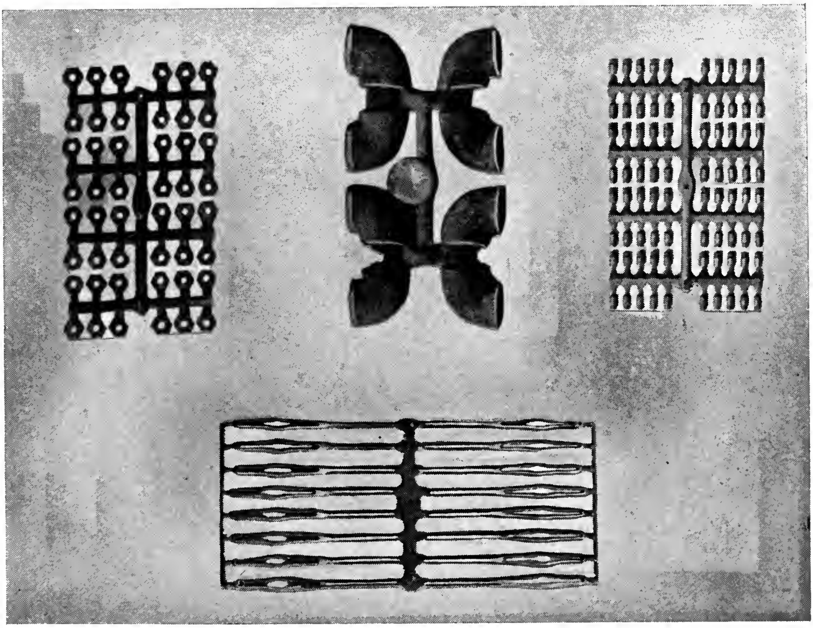


Fig. 3—Malleable castings showing methods of gating

ally as high as 40 per cent goes into the cupola. In the case of small castings, the bad effect of too much steel is perhaps not so noticeable as in the long or complicated ones, but not only will there be annealing troubles where more than 10 per cent of steel scrap is used in a malleable mixture, but there will occur serious cracking on the part of castings in the hard, especially where strains are likely to be set up. These cracks are not always discovered in the trimming room, unless practically each casting is struck to see whether it rings true. The result is that such castings are annealed and go out into service only to cause annoyance and trouble. Thus will result difficulties from experimenting beyond safe limits, whether this be in mixture making, melting, or in annealing temperatures.

In gating patterns it should always be remembered that we have to deal with a metal which chills easily, and hence must be poured very rapidly. Again, for the same reason, the number of pieces that can be run successfully is limited, unless the gates be made too thick, which in turn means dirty iron and a larger discount. The runners should be amply large, and the sprues heavy. The idea is to get a large amount of metal right in front of the gate for the individual casting. The rest will then be up to the molder to pour properly and the melter to give iron that can be satisfactorily poured.

The methods used for producing small castings in the malleable foundry are not different from the gray iron works, except in the gating, as above mentioned, and hence no space need be given to the matter further than to show a number of illustrations which tell the story sufficiently plain.

In the upper row, at the extreme left, Fig. 1, is shown a gate of 10 clevis castings made in one mold. These castings have just been shaken out and show very clearly the method of gating, the relative size of castings and runners, as well as the sprue. Next are shown 10 razor strap handles which weigh about ½ ounce each. It will be noted that each handle is gated at two points in order to insure free running of the iron without making the gate too thick, and thereby probably breaking the casting itself in knocking it off. Next are shown 16 eyes for the top part of a razor strap swivel. Next to this is the completed swivel, eight castings in a mold. The eyes and the lower part of the swivels are cast separately, the swivel part of the eyes being covered with shellac and sand, this portion of the eye practically forming the core when the lower part of the swivel is made in the mold.

The next view illustrates the method of gating four street elbows. In the lower left hand corner of Fig. 1 are shown eight bushings weighing about eight ounces each, properly gated. Next is a die stock weighing about nine pounds. This is gated as shown and allows the metal to flow very freely. A friction drive gear casting is shown next to the die stock, the sprue being unusually small. The casting weighs about 50 pounds. The other casting is used in connection with the die stock, and is also malleable.

Fig. 2 shows a number of metal chandelier patterns, the method of gating and the location of the sprues being clearly indicated. Reading from left to right we have first a card of chandelier patterns, then a card of smaller patterns, and a card of fence picket patterns. In the lower row, second from the left, is illustrated a card of 26 patterns on two runners.

Fig. 3 shows carded patterns for 48 lock nuts, each weighing about one ounce each; 16 patterns of a saw handle clip, each casting weighing about three ounces; the third carded pattern set is for 81 ⅛ inch pipe plugs, which weigh less than ½ ounce each. In the center are shown eight 1½ inch elbows just cast and not yet knocked off the gates.

Fig. 4 shows a mold for ¾ inch street elbows, made on a molding machine, a pattern plate having been used. It clearly shows the method of gating.

Fig. 5 is a similar mold, containing eight 1½ inch elbows. Fig. 6 shows a mold for making razor strap swivels, the eye of the swivel being shown in the mold. As previously stated, the shank is coated with shellac and sand. After annealing and tumbling, the eye can easily be rotated, but not so in the hard.

The match-plate is a very important factor in the malleable shop, great care being exercised in getting it right where much work is to be done. The subject is of course familiar to every foundryman, and hence only one view is shown herewith, in Fig. 7.

Here we have a varied lot of match-plates. At the top is shown one for molding razor strap swivels. Below at the left is shown a match-plate for the eye of the razor strap swivel and the handles. Next to this is the match-plate for another small section. Lastly, the

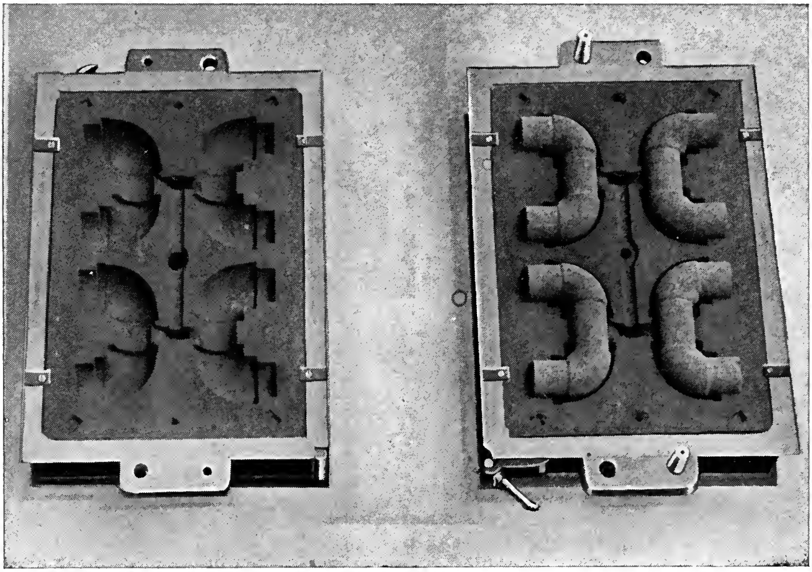


Fig. 4—Cope and drag halves of mold for $\frac{3}{4}$ inch, street elbow castings

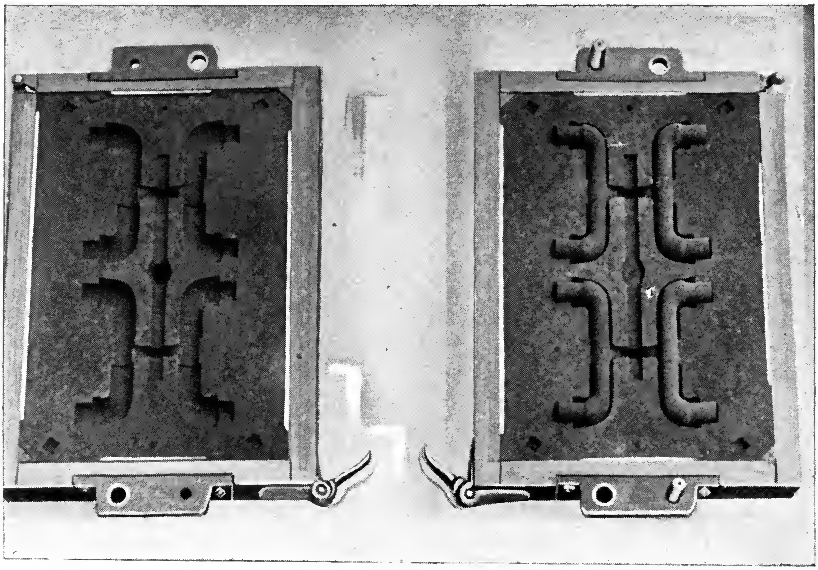


Fig. 5—Cope and drag halves of mold for eight small street elbow castings

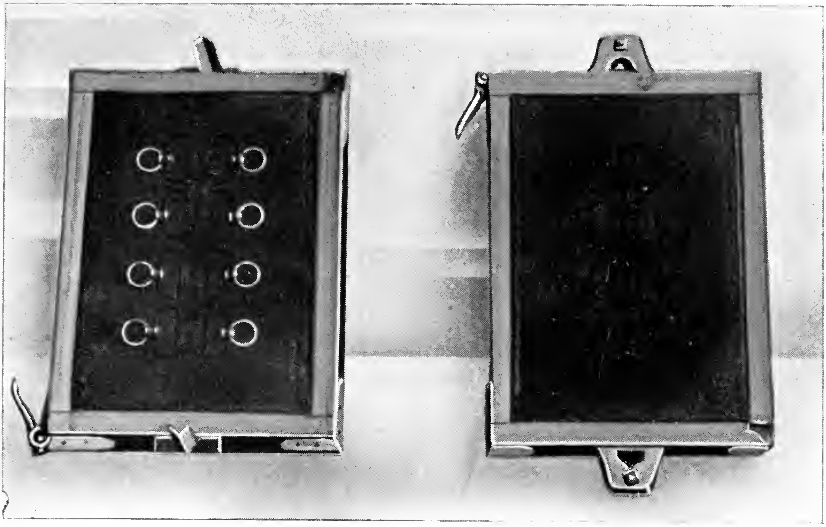


Fig. 6—Mold for eight small malleable swivels

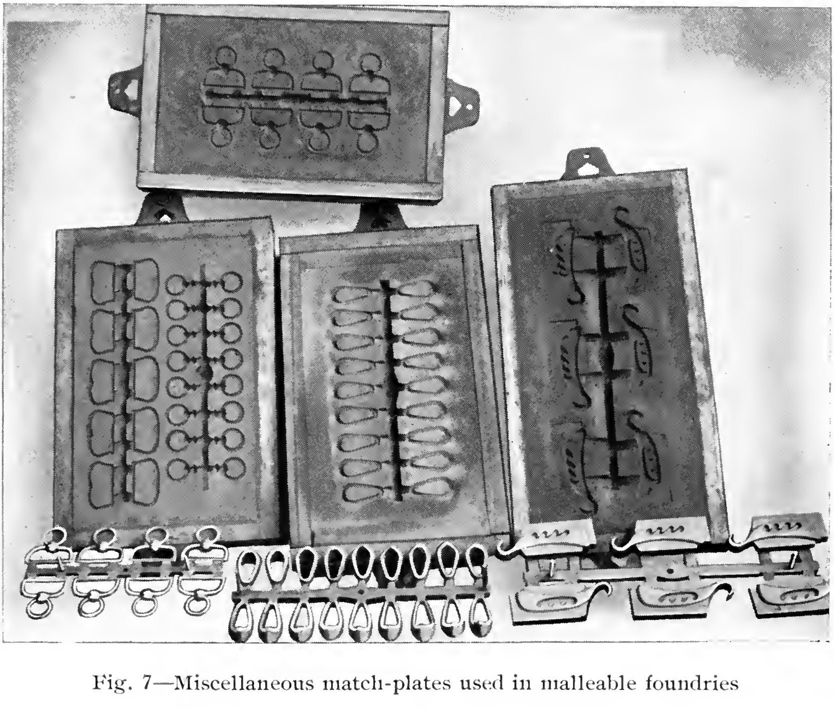


Fig. 7—Miscellaneous match-plates used in malleable foundries

match-plate for a saddlery hardware casting of a more difficult nature.

The matches themselves are made of sand hardened with litharge. Matches can, of course, be made of many products. Thus, common clay will do for a small job and will last for some time. Plaster matches are more generally used, especially if hardened with cement to insure better wear.

The subject of mounting patterns is a very important one, and numerous methods have been developed to facilitate this work. Practically every maker of molding machines now develops a method peculiarly adapted to his uses and much ingenuity is displayed. Attention is called to the paper on this subject written by S. H. Stupakoff and presented at a meeting of the American Foundrymen's Association, in which he describes a universal method of mounting patterns, using a jig plate, accurately bored, and allowing of the quick-placing of a number of patterns with great accuracy.

V

Molding Methods in the Malleable Foundry

MOLDING for the production of malleable castings differs but little from the ordinary proceeding for gray cast iron. The molder trained in the latter line of work has practically only to learn how to pour a mold for *malleable* properly, and ordinarily acquires the art in a few days. The points to be specially considered are based upon the differences in the behavior of white iron when compared with the gray varieties. White iron melts at a temperature several hundred degrees Fahr. lower than gray iron, and even if considerably overheated in the air or open-hearth furnace, not to speak of the cupola, is still at a lower temperature when at a scintillating white heat, than gray iron at a bright red. White iron, owing to the comparatively low silicon and manganese content, is very sensitive to burning when greatly overheated, as may be seen continually in any malleable shop. The brown smoke as well as the flaming effect on the surface of the ladle as it is filled at the furnace and taken away will convince any founder of this.

Burnt white iron is peculiarly sluggish when the temperature is lowered ever so little, as for instance in tapping into the ladle. Sluggish iron will not fill the mold as quickly as desired, if at all, and hence the molder must not only make his gates fairly large, but must practically throw the iron into the mold. Here are two variations at once from gray iron practice. On the other hand, from the fact that white iron is at a lower temperature, when melted, than the gray, comes the practice of using very little facing in a malleable shop. For very heavy work, where a smooth surface is especially desired, a very little facing is beneficial, but if too much is used, a very peculiar *grape-vine* effect results.

Most of the ordinary work is made in the snap flask, generally on the bench, occasionally on low horses, and the larger, though not

Fig. 8—Pouring malleable iron into molds

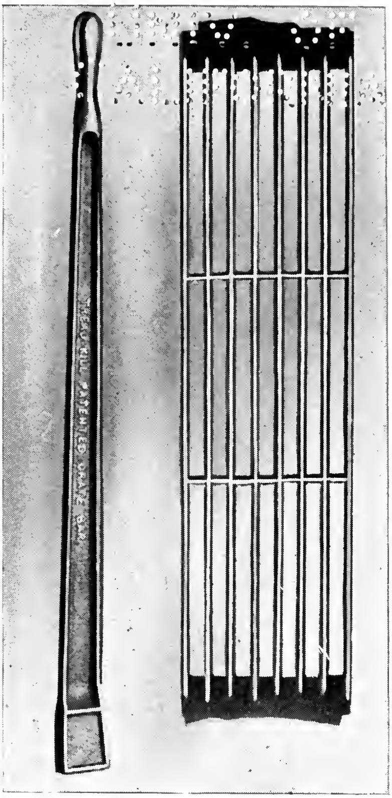


Fig. 9—Large malleable iron handle bar and core grate

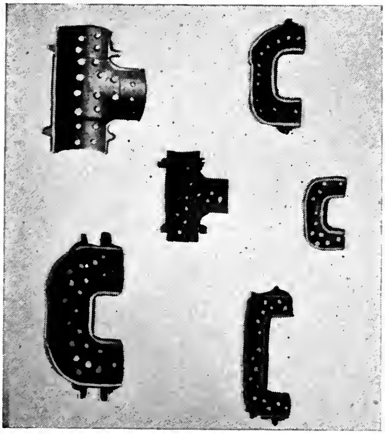


Fig. 10—Trays on which cores for malleable iron fittings are baked

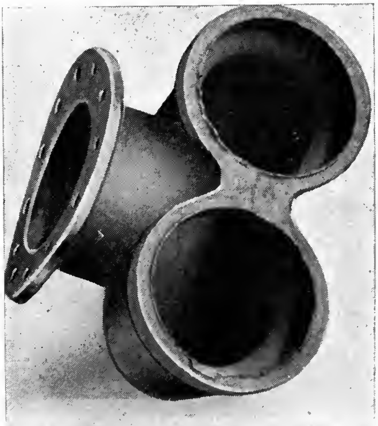


Fig. 11—Large malleable iron valve body

necessarily heavier work, in regular flasks on the floor. Fig. 8 shows the method of setting up a mold for pouring. The molds were made on the bench and simply set down on the floor with their bottom board. If safe to pour without a shell, they are only weighted, and then poured. A better practice is to insert iron bands in the snap flask when molding. This avoids the use of a shell before weighting and pouring, and leaves the mold undisturbed.

Long work, such as brake beam rods, or a casting as shown in Fig. 9, is preferably made in the snap flask, placed on low wooden horses. This takes less time than molding on the floor. Every shop naturally has its own methods and preferences, but the cost of molding in a shop making railroad work can be brought down to surprisingly low figures, while paying good wages. For instance, with average work, and pieces not too intricate, $5 a ton is not uncommon, and in exceptional cases this figure can be shaded somewhat.

When it comes to making large rings for heavy pressure gas pipe or railroad couplers, floor work is the order of the day, and it is important to arrange the daily heats so that several pourings, at uniform intervals, keep the floors within reasonable limits of size.

The sand is tempered in a manner similar to that pursued in the gray iron foundry. Preferably the night gang shakes out the last of the work remaining in the sand, and cuts up the sand heaps, the new sand having previously been brought in. When the molders come in the morning they can begin to mold at once, and a goodly array of molds should await the pouring of the first heat.

The quality of the sand varies with the lightness of the work. Too little attention, as a rule, is given to this subject, and hence some very rough castings must depend upon a sort of scaling off process in the anneal to make them presentable. Fig. 9 shows a skeleton core plate or grate on which cores are set on trays, Fig. 10, to be dried, and are set upon shelves in the core cars. A large 70-pound relief valve body for tank cars is shown in Fig. 11. It incidentally shows the gating at two points. Chills are used on the heavy parts of this casting.

While the bulk of malleable castings are made in the snap flask, on account of their small size, all the larger class of castings, such as couplers, rings, and many car castings, are made in the ordinary flask. Where a foundry is supplied with steady orders for the same castings, it pays to make the flasks of malleable cast iron. Special side and end pieces are cast, duly bolted together and bored for the customary flask pins. The castings are fairly thin, but well flanged for resistance to bending, and are filled with perforations for lightness and venting purposes. Where the works have a specialty, these flasks may approach the contour of the castings in question, so that a minimum amount of sand only need be handled. These iron parts are made in stock as occasion offers, and are put together when wanted.

Other castings that are made in stock in a malleable foundry are the core trays, Fig. 10, as well as the stars for the hard rolling barrel. These castings, both core trays and stars, however, are not annealed but remain white and hard. Core boxes, which are always best when made of iron, are made gray, as they require machining. The chills required are made of the regular malleable mixture, and left hard. They are provided with nails, if they are to be held in the cope, and are duly oiled before use.

If there is any place where a molding machine is useful, it is the malleable shop. The work being all practically in quantity, it remains only to select the right machine for the particular class of castings in hand. The squeezer was one of the first machines introduced, but prejudice on the part of the men, and indifference on the part of the foremen to the savings possible with these machines, prevented the management from realizing handsome profits. The pendulum has, however, swung the other way and molding machines of the most advanced types are being installed in all modern plants.

The time was not so long ago when molding machines were tried, discarded and sent through the cupola. Since then it has been realized that castings may be divided into classes, some, but not all of which are best handled by a particular make of machine. Hence, foundry owners can do no better than attend the great exhibitions of molding machines at the foundrymen's conventions, and there see just what machines will do their work most advantageously. Apart from the increase in production, the castings are better and uniform in weight which, in most cases, means a saving in iron.

Wherever molding machines are introduced, there is usually required a complement of sand handling machinery. In fact, one of the weaknesses of present foundry practice is the introduction of great molding capacity by machines, without supplying the facilities for handling sand, etc., in like proportion. As the requirements of the situation become better understood, this will be remedied, and it is important that with the introduction of sand handling machinery, the question of sand preparation be not forgotten. Attention need only be called here to the desirability of applying methods which rub the clay portion of a molding sand intimately against the silicious part. This allows the use of the least amount of clay matter in a sand and hence keeps it very open while holding the bond. Where such a system is adopted, the ordinary molding sands may be mixed with much sharp sand, and a corresponding benefit in venting derived, while it is still strong enough to hold up properly in the mold, and when pouring the iron.

It will be seen from the above that the differences between gray and malleable practice, so far as the molding is concerned, are slight, and hence it requires no further discussion at this time.

Unless the principles underlying the use of the iron mold are well understood and the mold itself properly built and used accordingly, the subject will remain an *ignis fatuus* in the foundry business. As in the case of the molding machine, the malleable shop offers the best chance for the iron mold, for the characteristics of white iron, with its subsequent annealing, are such that the strains found in gray iron, cast in this manner, are fully eliminated. As attention is now being directed to this subject again, the tests made by the author may be of value. He has always believed that there was a great field for the sandless mold in the malleable shop, and at one time was instrumental in having the matter tried out with a very large casting. Some 800 or more of the casting in question were made from time to time in the same mold, and after anneal went duly into service. Then the natural opposition to this method of preparing castings caused the mold to be discarded, otherwise a more complete record of the life of the mold might have been established. Tests on the product showed a slight decrease in the strength of the metal, probably due to a more distinct setting of the crystals of iron at right angles to the metal mold, instead of having an indeterminate mixture of the crystals which is better adapted to secure all around strength in a casting. The castings themselves weighed some 275 pounds each, and the preparation and continual use of 50 of these molds would have allowed 250 men in the shop to apply themselves to other more useful vocations.

The iron mold, as compared with the sand mold, has two objections which must be overcome. First, the excessive contraction of white iron, especially when cooled more rapidly than in sand, must be provided for; and second, the cooling of the metal should be made to take place as nearly the same in the metal mold as in the sand. If these two points are observed success is assured, and only then.

In the early experiments with iron molds, very easily crushed cores were placed where the contraction of the metal could not be given full play otherwise. These particular spots were found by observing the castings poured into the mold without this precaution. The metal was found torn apart at these points, and the judicious use of cores remedied this trouble without difficulty. Another and better method, being used now, is to construct the mold so that the contraction of the iron opens the parts automatically. By making the molds in a number of parts to suit the requirements of the case, this spoiling or injuring the casting is avoided.

The other point is to heat up the mold to a point that the cooling of the molten metal is effected as slowly as possible, thus closely approaching the sand mold.

In the experiment above cited, this was done by pouring metal into the mold, allowing it to remain long enough to heat up well, dumping the casting for scrap, and then going on with the regular work. The castings are taken out of such metal molds as soon as set and placed into soaking pits where they can cool very slowly, be inspected and go directly into the anneal, the hard rolling being eliminated. The molds are filled as often as it can safely be done without burning the pouring basins. It is possible to place the necessary cores into the molds, which should also be coated with a wash of graphite in a heavy paraffine oil.

The preparation of cores offers nothing different from gray iron practice. The same mixtures and methods are employed. In the evolution of the business the customary mixtures of sharp and bank or molding sands with flour and rosin as binders are gradually giving way to the prepared binders thoroughly mixed in with the sand by machines especially built for that purpose. This last point is important, inasmuch as by mixing by hand, a core binder may give satisfaction when used 1 to 40 of sand, while with mechanical mixing, especially when plenty of time is given to the work, 1 to 90 has given fair results. It is simply the old principle of rubbing the binder on the grains of sand uniformly and in a thin layer so that a good bond with good venting may result.

In the malleable shop, practically everything is cored, and hence the core room is one of the most important adjuncts, also one of the most expensive. As a rule, the shop orders call for 10 per cent over the castings required, though with a close connection between molding room and core department, the making of too much stock can be avoided. Plenty of shelving is necessary to store cores, and facilities for bringing in sand, taking out cores, and straightening out the rods used should be arranged for. Even the repeated use of the larger wire nails, by hand straightening, by some old pensioner acting as a minor gate watchman about the works saves just so much money.

Where the cores are very large, in fact form part of the mold itself, the unburnt portions should be reground and used over again. The best of core ovens are only just good enough, for what is desired in core baking is first a temperature sufficient to drive out the water when drying, and then an increase up to about 350 degrees Fahr. for the actual baking. In the days of flour and rosin, great care had to be taken with the ovens because of overheating and frequently insufficient time was given to the baking. The result would be either burnt cores or they would be wet inside. The construction of the ovens, usually built on the premises, would frequently prevent the exit of the moisture freely, and when opening up a large oven in the morning a pool of water would be found on the floor. This always meant returning a lot of the cores for baking over again. Unfortunately, in every core room where flour is used to any extent, a close watch has to be kept on supplies smuggled in surreptitiously. The men or girls, as the case may be, will reach under the bench for additional flour to mix quickly with the sand given them and thus get out their day's allotment with the least trouble to themselves. Swollen cores, and life a burden in the casting shop, result.

Many other binders have been tried and are being used for making cores. The author remembers having used a great many cores made with cement in the proportion of 1 to 10 of sand. The results were most excellent. The cores had to be handled more carefully while being made, but required no baking, being allowed to set like concrete, as they were made fairly dry in the first place, and would keep indefinitely. The only objection was that the cement hurt the hands of the operatives.

Coremaking machines are very much needed in the foundry. A beginning has been made in this direction, though confined more particularly to the easier classes of work. What is wanted badly is a variety of molding machines for coremaking both in green sand and the ordinary way.

VI

Melting Processes

IRON for malleable cast iron purposes is at present melted in the crucible, the cupola, the small Bessemer converter, the air furnace, and the open-hearth furnace. The *pros* and *cons* of each method will be discussed at length.

The crucible method, the most ancient, undoubtedly gives the finest material. It is also the most costly, and hence may only be found at the present day in parts of Europe, where a production of 500 tons a month is considered very large. The superiority of the material obtained by this process is due to the melting conditions, which are ideal. There is no contact with and hence contamination from the fuel. The charges placed into the crucible are taken out in the melted form without refining or any other change than uniform mixing. Hence, if sufficient steel is added to reduce the total carbon to, say 2.75 to 3.00 per cent, a very strong and clean product results.

The high cost of the process unfortunately puts it out of question in this country, for with care in the air furnace and open-hearth an equally good and cheaper product is produced. However, we have in the crucible process the ideal condition of putting into the charge what we expect to get out without refining, but simply heating up to the desired temperature for pouring. Naturally, the small amount of metal melted at a time has limited this process to the production of the smallest classes of work only, and as there is no likelihood of the process ever being revived where abandoned, no more need be said.

The cupola process for making malleable differs from the ordinary gray iron foundry practice only in using a very high proportion of fuel to iron. As a rule it is four of metal to one of coke or anthracite. It is necessary to have extremely hot iron to run the fairly light work made by this process and hence the very low efficiency of the fuel. The stream is run from the cupola practically continuously during the melt and hence the tuyeres are set very low, so that the metal may not be unduly cooled in passing through a bed of fuel at a lower temperature than the melting zone. Where anthracite is used in part, it is best placed for the bed charge, and coke thereafter, above. The charges of metal and sprues are made as small as possible, and with the very smallest range of variation in composition, so that the metal tapped out may be quite uniform. By having small charges, the position of the melting zone is not interfered with to an appreciable extent, and hence the metal is not apt to get below the proper point, which would mean burning.

The advantages of the process are the cheapness of the installation and operating expense, the ease with which it can be carried out, when compared with the air or open-hearth processes, the comparatively small melting loss, as only 0.25 per cent silicon is burned out, and carbon from the fuel, if anything, added; the ability to drop bottom in case of necessity, and the ease with which the metal is secured and distributed as fast as melted.

The disadvantages are very marked. The chief difficulty arises from the contact of the metal with the fuel, making it peculiarly liable to burning, which means sluggish iron, castings full of pin holes, and trouble in the anneal. Again, even with perfect conditions during the melting, the metal made in the cupola is of such a physical constitution that it requires an annealing temperature several hundred degrees higher to properly anneal it, over that for air or open-hearth furnace iron.

For this reason, and the fact that the metal made from the cupola is somewhat weaker, it is only used for those castings which are light and require strength less than the property to bend readily. Pipe fittings are the best example of this class; in fact, these castings form the bulk of the work made from cupola iron.

But little *malleable,* that is annealed scrap, can be used in the mixtures, as the danger of burning is so great, and steel is likewise seldom added for the same reason. The silicon of the castings usually runs between 0.75 and 1.25 per cent, probably averaging 1.00 per cent in most works using the cupola. Hence in the mixture calculations, 0.25 per cent is added for burning out. The pig iron is used in fairly small pieces, and this with the sprues is charged in very small amounts at a time, with the corresponding coke between. The blast pressure is preferably kept low, say not over 7 or 8 ounces, and the cupola filled up to take advantage of all the preheating of the charges possible.

Every malleable works has a cupola intended for melting iron for pots. The very fact that cupola iron requires over 200 degrees more than the air furnace castings to be packed in these pots to anneal them, makes this class of iron well adapted for the purpose. While convenient to use the left over metal from the furnace for pot purposes, as it has the proper composition, this should not be made a custom. In pot making, as in regular malleable work in the cupola, care should be taken to have the charges small so that no burning may take place. A pot made of burnt iron, while a good way to get rid of that kind of metal, will not last very long in the annealing room.

The modern tendency is toward air furnace or open-hearth iron, and rather away from cupola metal. Hence, nothing further need be added. However, where the cupola is used, the wisest course to pursue is to run it very light and if anything to look toward continuous melting as giving the best all around results.

Taking next the Bessemer converter process for making malleable castings, we find this a rather new line, and so far only used in some parts of Europe, where the fracture of an annealed malleable casting is similar to that of steel. The quantities blown at a time are very small, say one-half a ton to three tons, and the process is no different from the ordinary baby Bessemer process now used, except that it is stopped before the silicon gets too low. In other words, it is necessary to first melt the charge in the cupola, run the molten mass into the converter and blow until the silicon has been estimated to have dropped low enough. Then a sufficient quantity of aluminum is added to insure sound castings, and the metal is poured.

The advantages of the process would seem problematical to American minds, as there is nothing in it which cannot be done by the ordinary cupola process. It emanates from the mistaken idea that it is necessary to refine the metal to make good malleable castings. This is not the case, as the burning out of silicon, manganese, and perhaps a little carbon, which takes place in any of the processes for making *malleable,* is that which is unavoidable in the melting and the raising of the metal to the proper pouring temperature. In other words, if it were possible to simply melt without changing the composition whatever, the ideal melting condition would be obtained, as any strength gained by the reduction of the silicon and the carbon can be more easily and better obtained by charging steel scrap in the mixture. Hence, in discussing the Bessemer process for making these castings, the reduction of silicon is not necessary except to get heat, and this can be attended to in the cupola just as well. The reduction of the carbon can similarly be accomplished by charging steel, and any trouble that follows can be corrected by adding aluminum in the ladle, just as has to be done with the converter. The advantages do not therefore seem to be manifest.

Now as to the disadvantages. Melting a comparatively high silicon mixture in order to blow silicon out of it afterwards, means throwing money out of the window. The melting loss of the process, on account of the previous melting, cannot be less than 15 per cent, and may be much more. Aluminum is not a good thing to use on malleable work on account of its action on the carbon present. Large quantities throw out graphite easily, making a white casting gray and unfit to anneal. There must, furthermore, be an uncertainty as to how much silicon is blown out before the process is stopped, and finally the tendency to burn the metal is greatest on account of the direct introduction of oxygen into the metal, which should be avoided at all hazards.

Mention is made of the process at this time, because the number of baby Bessemer plants is slowly increasing in the United States, and there may be a temptation to use an existing plant for malleable as well as steel castings.

VII

The Construction and Operation of the Air Furnace

THE air furnace process is probably the most important in use today, and will likely continue so, as its advantages are numerous, and the product excellent. Briefly summarized we have the following conditions: The air furnace is comparatively cheap to build, and is easily maintained. Its operation does not require the skill necessary in the operation of the open-hearth furnace. The air furnace may be built in very small units, as low as three tons capacity, and still have a high efficiency. On the other hand, its size is only limited by the ability to get the metal away and poured before it deteriorates through being held in the furnace too long. The air furnace can be started up from a cold condition and make good iron. Successive heats can be made from it without renewing bottom. Air furnaces can be scattered about the shop as required, as no gas flues, extensive excavations, and charging platforms are necessary. The iron made is of the finest quality, if the furnace is run properly. The consumption of coal is fair, if fired right, and of good quality. The furnace is quickly cooled and easily repaired. It can be built by inexpensive workmen and kept in good shape cheaply, when compared with the open-hearth furnace. It requires no gas-making plant, and can be shut down indefinitely without abnormal deterioration.

The disadvantages may be summed up as follows: It takes at least an hour longer to run a heat in the air furnace, than it does for the same tonnage in the open-hearth, because the furnace is comparatively or altogether cold when charged. This has a bad effect on the metal. The coal consumption is greater than that of the open-hearth furnace. The form of the bath leaves a thin layer of iron near the stack, which is the metal coming out last. This metal is very often burned before it is poured into castings. On account of the longer time required to melt, and the difficulty of holding the metal long in the furnace after it is ready, the air furnace cannot be made as large as an open-hearth furnace, unless quality is to be sacrificed. The flame striking over the top of the bath and in the melting actually cutting through the charge, necessarily imparts much of the sulphur from the coal to the metal. Iron with 0.05 per cent sulphur in the charge has frequently had the sulphur content increased to 0.34 per cent when the coal contained over 3.00 per cent sulphur. In the open-hearth this is not so noticeable.

Taking the advantages with the disadvantages, it will be seen that the air furnace is probably the best all around melting medium that the ordinary plant can install. Hence it will be found in the great majority of American malleable casting foundries. It is only in the very large plants where malleable castings are contracted for by thousands of tons at a time, that the open-hearth furnace is essential, and further, an open-hearth plant should be used even by smaller concerns where the work is continuous throughout the year, day in and day out. Therefore, it is good practice to have both furnaces in a plant, the steady work going to the open-hearth, and the intermittent as well as lighter castings coming from the air furnace.

Essentially, the air furnace is simply a covered basin of refractory material, into one end of which there is forced a big volume of flame, and the products of combustion are permitted to escape from the other end. It is in the design of this basin, the details of directing the flame, and the way this is made to do its work that the efficiency of the fuel used, depends.

Fig. 12 is an illustration of a typical air furnace in outline. This is an English furnace, and is taken from *Modern Iron Foundry Practice* published by Van Nostrand. It is rather exaggerated in the contour of the roof, and presents a bad spot where the stack and furnace body come together, the brick at that point cutting away very rapidly. However, the bath is shown as well as the sloping bed, with the thin feather edge of metal toward the roof which is sure to be burned no matter how carefully the furnace is run. The firing end, with bridge wall, grate, and ash pit, gives a fair idea of the form of an air furnace for malleable casting purposes. It will be seen that the roof slopes downward just behind the bridge wall, the intention being to force the flames into the metal stacked up on the bottom, when melting begins. It is over this bridge wall, that the usual practice of placing air pipes exists. These pipes allow air to be blown into the flames, promoting more perfect combustion and sending the hot gases into the mass of metal below. The arching of the crown of the furnace allows the heat to be deflected downward, and is very essential to a furnace of this type.

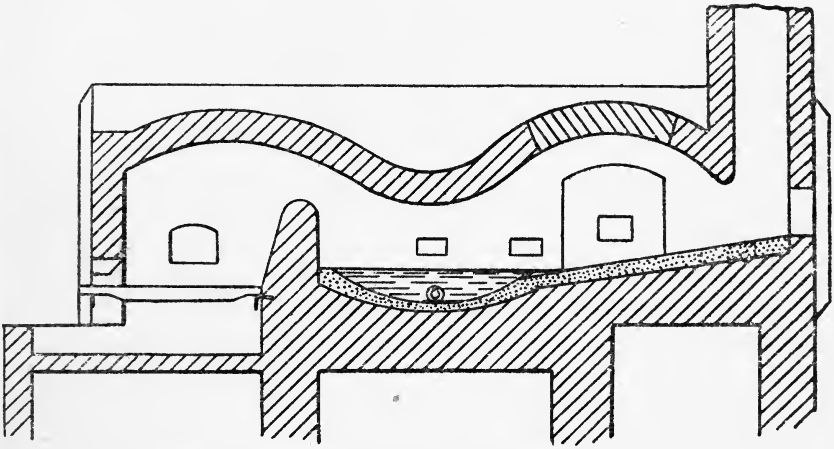


Fig. 12—Longitudinal section of typical air furnace

Fig. 13 shows a sectional view of an air furnace of much better design. The sand bottom is not shown in the illustration, being put in after the furnace is built. This furnace plan was loaned by the Morse Iron Works, Erie, Pa., where the furnace is in successful operation. Fig. 14 shows a bung, a number of which go to make up the roof. Some of these are removed after every heat, to allow charging. The furnace in question has a length of 35 feet, and is 5 feet wide inside. The top blast in this instance has been placed a little distance away from the bridge wall, to get the greatest combustion directly

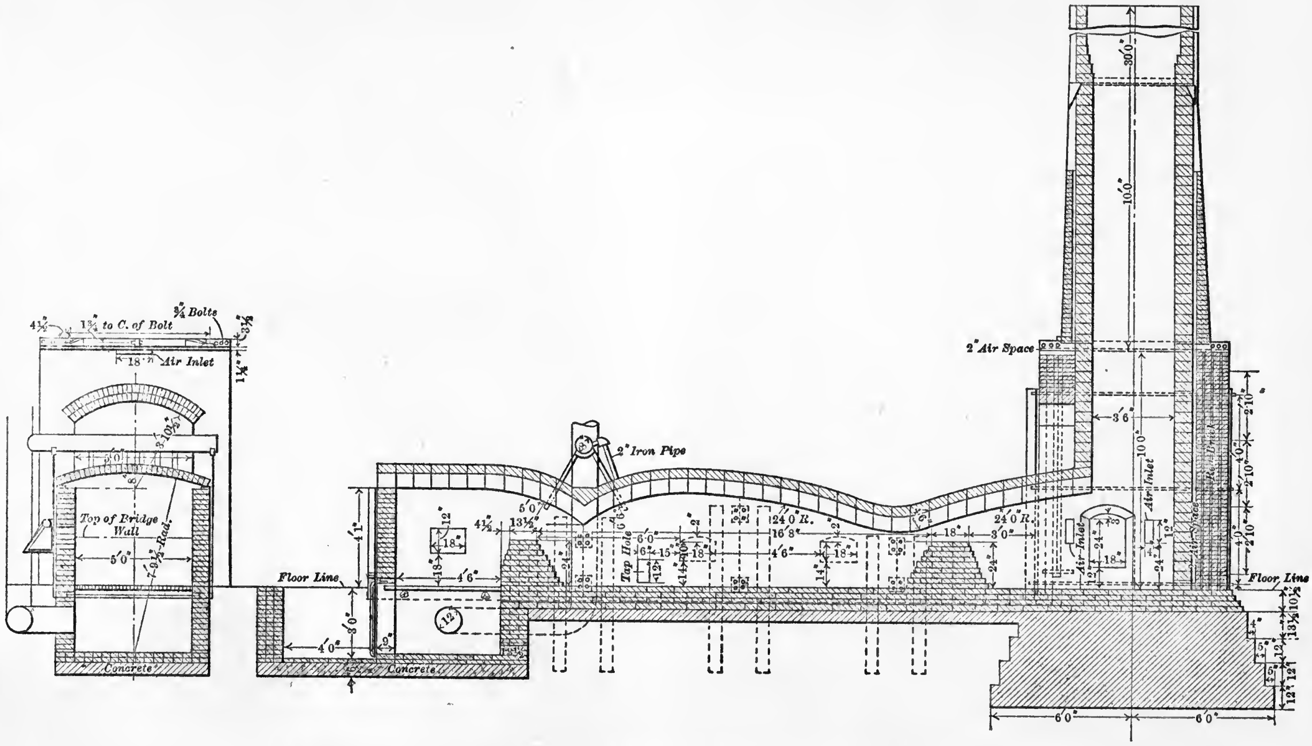


Fig. 13—Sectional view of well-designed air furnace for melting malleable iron

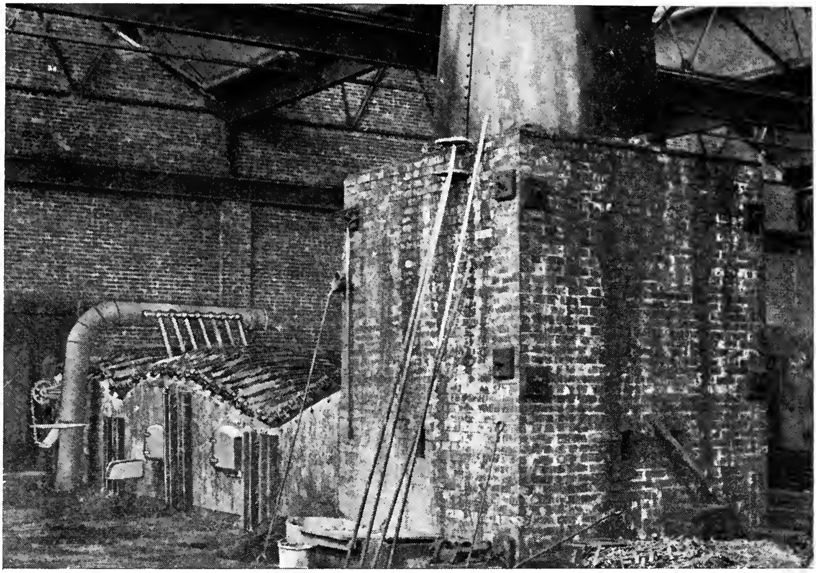


Fig. 15—Typical air furnace for melting malleable iron

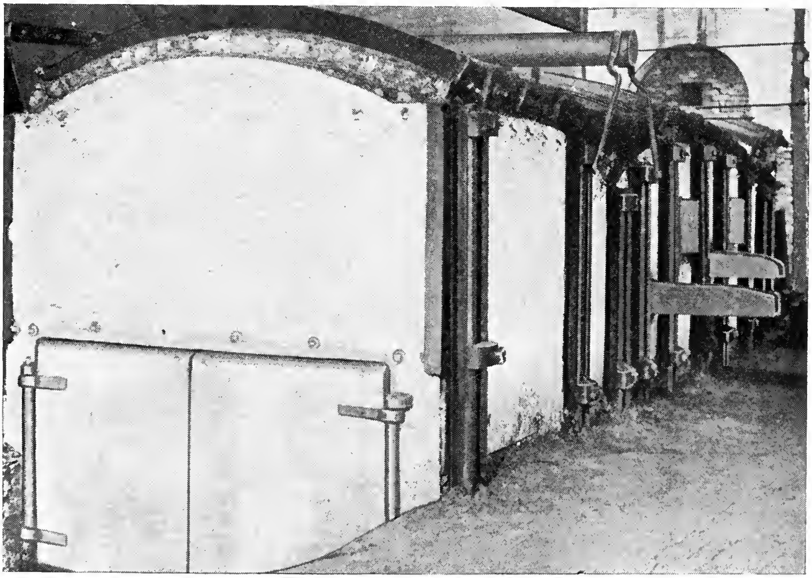


Fig. 16—Air furnace for melting malleable iron equipped with two tapping spouts at different levels

over the tapping spout. Otherwise the furnace is typical of existing ones in practically all other plants. It also has two doors to facilitate charging, something which is not always found on other furnaces. Fig. 15 shows this furnace erected in the foundry.

Fig. 16 shows another air furnace, at the works of Pratt & Letchworth, Buffalo, in which a peculiar arrangement of the tapping spouts is shown. These are on different levels, and allow the top iron, which is the hottest and most likely to burn, to be drawn off before the lower level of metal is tapped. In this way the capacity of a furnace can safely be increased without danger of burning the extra metal. This arrangement was designed by the author and applied by him at his works in Pittsburg, from whence it was adopted by others. In his own case, however, he employed three spouts at different levels, and thus got the same results as would be had with a tilting furnace, at a much lower first cost. This arrangement will be shown to better advantage later in discussing the open-hearth furnace.

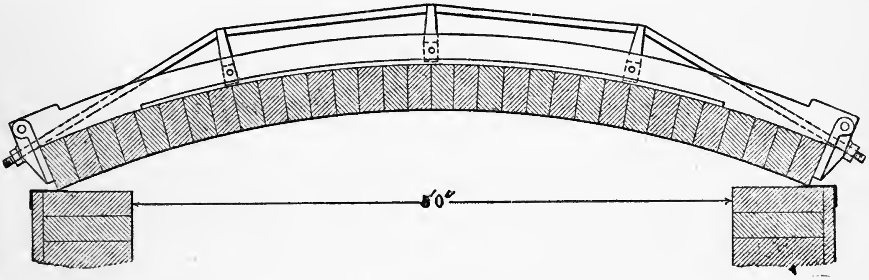


Fig. 14—Air furnace bung

Fig. 17 shows the general construction of a 10-ton air furnace, built by the Whiting Foundry Equipment Co., Harvey, Ill. Fig. 18 also shows an air furnace of 10 tons capacity, built by the S. R. Smythe Co., Pittsburg. Both of these are excellent furnaces, and give a high fuel efficiency and first class iron when handled properly.

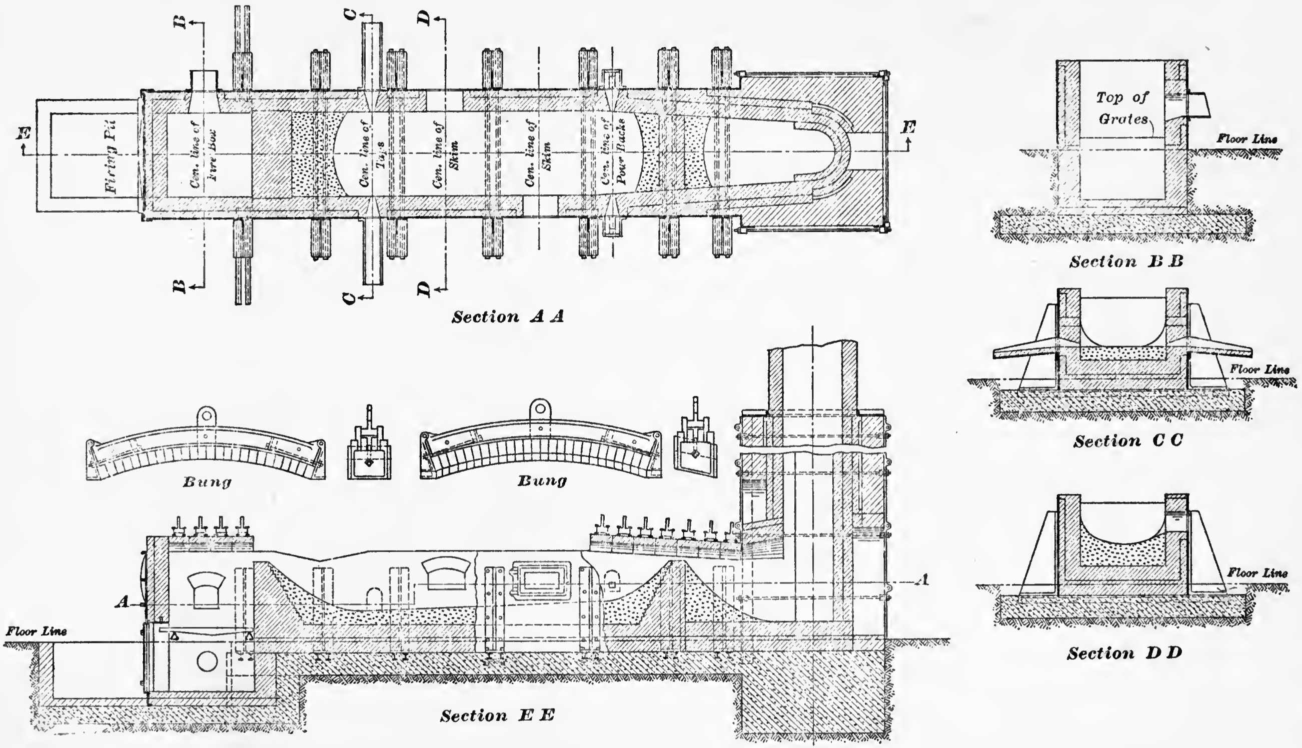


Fig. 17—Type of air furnace for melting malleable iron built by the Whiting Foundry Equipment Co., Harvey, Ill.; capacity, 10 tons

In melting iron for making malleable castings, it should be remembered that as little refining as possible is desired. A short melt, making iron at the highest safe temperature for metal and furnace, is the *desideratum*. Refining, while reducing the silicon and getting added heat by this means, always results in oxidation, the effect of

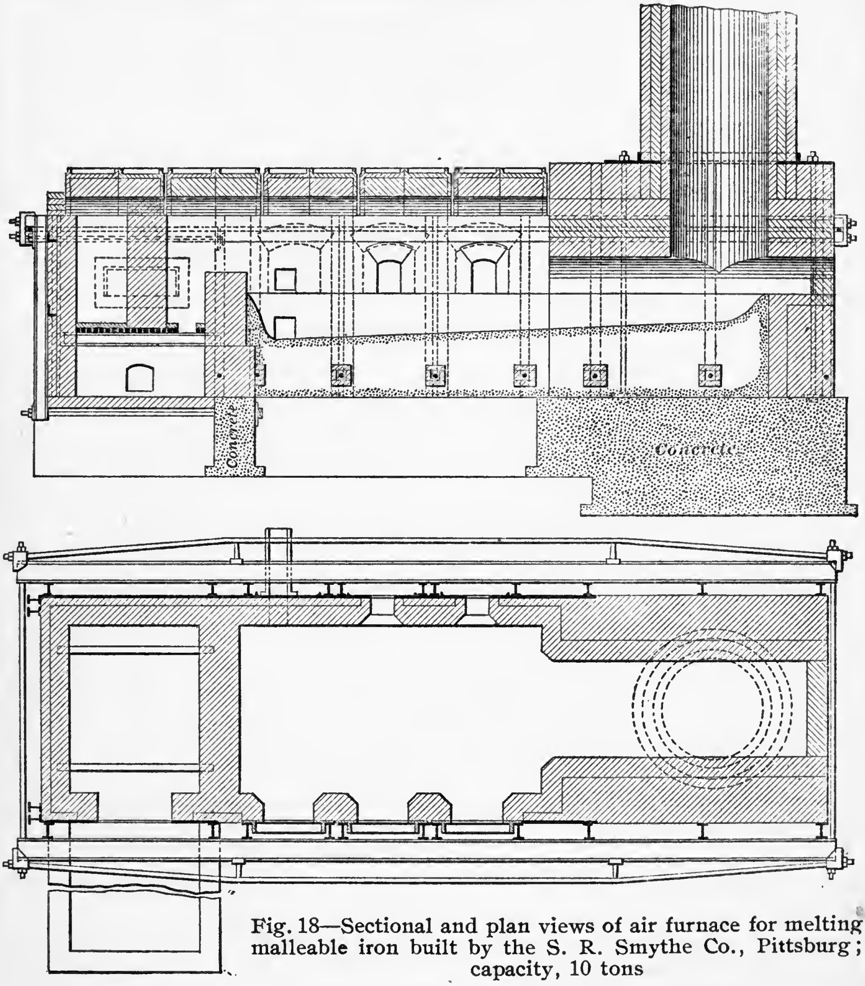


Fig. 18—Sectional and plan views of air furnace for melting malleable iron built by the S. R. Smythe Co., Pittsburg; capacity, 10 tons

which has become more noticeable since the charcoal irons were abandoned, and coke irons substituted therefor. It is, therefore, better to use coal or gas for fuel than silicon, besides, it is less expensive. The additional strength obtained by refining as it was formerly carried on, is best obtained by changes in the mixture, as previously explained.

It is, therefore, necessary, in designing a furnace, to provide for an easy method of charging quickly; to get the most out of the fuel in the shortest space of time, even at the expense of efficiency, if necessary, and lastly, to tap out the metal in the shortest possible time.

In the olden days of malleable practice, it was customary to take off the top bungs, charge and when ready to tap, have the molders catch their ladle full of metal at the spout, and then file up on a platform to pour it back into the bath. This heated their ladles, and did not waste any iron. This very praiseworthy method seems to have been abandoned at the present day, and unfortunately nothing takes its place. Rather elaborate experiments made by the author have demonstrated, that while the top and bottom of a bath of *malleable* usually have a composition so nearly alike that the difference may be classed as within the limits of error of the analyst (presupposing that the bath has been thoroughly rabbled by the melter throughout the heat), the temperature of bottom and top of this molten metal is by no means alike. This is best shown by the following test: The composition of the bath for silicon was 0.73 per cent at the top and 0.75 per cent at the bottom, where the metal was taken from the first ladle tapped, and was dipped out at the surface at practically the same instant. Molds were made with a pattern stepped up from a plate 2 x 2 inches and 1/8 inch thick, to similar plates 3/8 inch, 1/2 inch, 3/4 inch, 1 inch, 1 1/2 and 2 inches thick. All plates connected to form one casting, 2 x 14 inches, with the thickness in steps. After the metal had set and cooled, the castings were taken out and the plates broken off, one by one. The metal taken from the very top of the bath showed white until the plate, 1 1/2 inches thick, was broken from the one 2 inches thick. This metal was mottled. The casting made from the first ladle tapped, on the other hand, had that particular heavy piece show a perfectly gray fracture.

When pouring, the same thing will happen, the first of the tap is undoubtedly colder than the top of the bath at that same instant, and hence much judgment must be used to pour the first iron into work which is fairly thin and will give the iron a white fracture. Spouts placed at different levels overcome much of this, taking away the hottest iron first, instead of the reverse.

In designing an air furnace, the shape of the bath is important. The deepest portion is always put next to the bridge wall, and the bottom slopes upward to the throat of the furnace. In melting, this always leaves a thin or feather edge of metal where it is affected by the waste gases, and therefore, badly burned. This may be avoided by cutting downward into the bottom, so as to leave the metal some two or three inches deep at the end. This, together with the covering of slag that usually remains there, effectively protects the metal from undue oxidation.

Where the furnace ends and the stack begins, there should be a curve upward, allowing the gases to sweep into the stack without any sharp turn. This saves bricks and labor. Doors should be provided, so that the melter can rabble the heat thoroughly during the melt. For large furnaces, tap holes on both sides, and if necessary two of them on each side, will help to get the metal away faster. The philosophy of this will be seen from the fact that when a test plug is taken from the top, or at any rate from a point not very far down in the bath, and it indicates that the heat is ready to tap, it is oftentimes an hour or more, before that top metal actually gets out of the furnace. This should not be, for an hour's exposure of such hot metal to the gases passing over it, is sure to have a deleterious effect. Hence the importance of getting the iron out quickly.

On the firing end, of course, it is necessary to have plenty of combustion space, grate bars through which blast can penetrate, clean ash pits, kept as cool as possible, and a clean and not too thick fire. The great *desideratum* at the present time is the application of a stoker to the air furnace. Experiments made years ago resulted in failure simply because the wrong type of stoker was tried. Recently, however, the stoker has been successfully applied to air furnace melting, but the conservatism of the industry holds back the desirable spread of this improvement in practice. So much depending upon the man in hand-firing, as in boiler practice, mechanical stoking will eventually become a necessity.

To get an even fire, keep the grates free from clinkers, so that the maximum of air forced through from below may burn the coal quickly to obtain an abundance of gas of even quality as the result of a thick, open bed of incandescent fuel; all these things are far easier obtained with a good stoker than by hand, for with the machine the work is continuous, but hand labor of this exacting kind is intermittent. Once the stoker application to the air furnace has been perfected, some shops will have a different story to tell.

In starting up a new air furnace, supposing the brickwork to have been completed and the furnace dried out by fire, it is necessary to make a sand bottom. The best method is to apply layers of fire sand, with a little clay for the under layers, in thicknesses of two or three inches. Burn in the layers of sand by firing. Keep this up until the top layer, where clean fire sand is spread without clay. When charging, the sprues go in first, simply shoveled in and spread evenly on the bottom. The pig iron should go in next, and be nicely piled, one-half of the charge at each end, not thrown in promiscuously. As the sprues melt and the piles of pig begin to soften, the melter can introduce his iron bar, and push down pig after pig into the central bath, thus keeping liquid iron there all the time. In this way all the pig iron is gradually melted, and the slag comes up readily to the top. Where the metal is thrown in haphazard, the whole pile melts down together, the melter cannot handle the charge to advantage, and the melting is prolonged possibly half an hour or more. Moreover, the metal suffers accordingly.

Malleable scrap can be charged with the sprues, but steel scrap should be introduced after the charge is melted down, and a layer of slag collected on the bath. This prevents the steel from burning before melting down.

After the bath is liquid, and the slag is well up, this should be drawn off, and the metal given a chance to heat. Usually it is necessary to skim again, and oftentimes a third time. Test plugs are taken from time to time as the heat nears completion and the character of the metal and its temperature judged from the appearance of the fracture. The diameter of this plug should be as large as any section found in the castings to be made. One and one-half inches is a usual diameter where the heavier class of castings are made. This plug, after setting, is held in water until cold enough to break without coloring the fracture. Then it is broken, the extent or absence of mottling noticed, and the length of time still to be given the heat before tapping determined upon.

Briefly, it may be stated, that such a test plug should show only a slight amount of mottling. The white crystals should be clear and large, the rim should not show pin holes, and the structure should not be mushy. If there is excessive mottling, the bath may be either too high in silicon, or the temperature not high enough. In that case, continue the melting. If the plug continues to show mottling, a little low silicon pig had better be thrown in. If the plug is clear white and thin castings are to be made, some high silicon pig, or ferro-silicon with say 20 per cent silicon, should be added and the heat well rabbled. This will bring out the heat as wanted. If the rim of the plug shows pin holes, the heat has been burned, and it is then up to the judgment of the man in command whether to add high silicon iron and pig the heat, or to take chances. Probably the best way to judge is to pour some of the iron into molds. If it pours all right, and the ladles do not skull, the iron may be used, but if these symptoms appear, pig the heat. In any case, where the test plug shows pin holes due to gas in the metal, no important work, or where pin holes in the casting cannot be tolerated, should be poured.

In general, the efficiency of an air furnace should be four pounds of iron to one pound of coal, the latter to be of very good quality. The length of the heat would be somewhat as follows: For a 10-ton heat, after charging is complete, about four hours should see tapping commence.

The author has known heats of that size to take from five to ten hours before they could be tapped. This is very bad practice, and though the castings may not have shown many surface defects, they were not up to strength as they should have been. Again, some furnaces only melt two pounds of iron to one of coal, instead of double that amount. This is a case of bad design or poor handling. The author has been told repeatedly, when making statements regarding the efficiency of air furnaces, that this high ratio is only obtained once in a while, but not regularly. The only answer that can be given is that a plant should be kept up to the point where this efficiency is always maintained. Some one should be held responsible for it as a simple matter of shop economy. It pays to keep everything about a malleable shop up to the highest standard, for when it begins to deteriorate, it does so very rapidly, and returned castings are bad things to have about.

VIII

Construction and Operation of the Open-Hearth Furnace

CONSIDERING finally the open-hearth furnace for malleable practice, we find the advantages as follows: Short heats, very hot iron, high efficiency, production of castings of the best quality and ideal melting conditions.

The disadvantages are: High first cost, skill required to operate properly, continuous operation, frequent and heavy repairs and use of gas direct instead of coal. As an additional advantage it may be said that with an acid open-hearth furnace, alternate heats of malleable cast iron and acid steel can be made, if desired, and at least one plant is doing so today in this country.

An open-hearth installation represents the highest type for melting so far devised. Gas, the ideal fuel, must be used. If of the natural and rich variety, matters are simplified very much; if this is not available, a gas producer plant must be added to the installation. On the other hand, fuel oil can also be adapted for this furnace, and is fed either with superheated steam, blown in with compressed air, air at low pressures by fan, or simply dropped on a tile on the hearth. The oil is instantly gasified and the regular process obtains.

Essentially, the open-hearth furnace consists of a steel basin in which there is put a heavy lining of fire brick, and this is coated with successive layers of fire sand burned on, one after the other. This basin is arranged to be tapped from without to draw off the molten metal. Below this steel basin or hearth are four large chambers filled with checker brick, the function of which will be explained later. Over the basin or hearth comes the crown, and at the two ends the port arrangement for the gas and air. The whole is well tied up with beams and rods, is provided with charging door and gas and air valves, a charging platform and stack. A 20-ton furnace may mean the expenditure of some $10,000.

The open-hearth furnace is designed to utilize all the heat possible from the combustion of the gases with the air supplied. Reference to a section of such a furnace will show that the gas, on passing through the gas valve, as well as the cold air passing through the air valve, each first go through their flues into the respective chambers filled with checker brick—let us say on the left hand side of the furnace. They come up and pass through the ports, the gas catching fire as it enters the combustion space over the hearth. In burning, the furnace is heated. The products of combustion now pass into the opposite ports—those on the right—pass down the flues into both the gas and air chambers filled with checker brick, heat this brick, and having given up considerable heat, they pass out through the lower flues, through the gas and the air valves and out of the stack.

This process is continued for about 20 minutes in the ordinary furnace, and then the valves are reversed. The gas and air now come through their respective valves, which by the reversal have cut off the connection of the flues with the stack on that side, and passing through the heated flues go into the hot chambers, become highly heated, then passing through the ports into the melting space, the gas burns and the products of combustion come out through the checker chambers on the other side and out of the stack again. In this way, alternately on one side and then the other the ports, chambers, and flues of the furnace become highly heated from the passing products of combustion, while on reversal this heat is given up to the air and gas allowed to enter cold. The result is that gas and air arrive at the point of combustion very hot, and the temperature of the furnace is very much higher than it would have been had the heat, thus utilized, not been saved. In fact, unless this method is followed, it is impossible to get enough heat to melt the metal.

It will be readily seen that with cold air and gas passing through chambers full of checker brick, say at 1,000 or more degrees Fahr., it will not be long before the temperature of these brick will be sensibly reduced, and by the time they have dropped to 500 or 600 degrees Fahr., it will no longer be economical to work that way. On the other hand, as the hot products of combustion pass through the checker chambers on the other side, the brick there are raised from the 500 or

600 degrees Fahr. at the time of reversal to nearly the temperature of the gases passing out. Keeping this up any longer would be wasteful, for no further heat would be given up, while at the same time on the other side there would be little heat for the air and gas to take up. Hence, experience has shown that a certain number of minutes between reversals of the system give the best economical results. Attention to the temperature of the stack is the best criterion of what is going on within the furnace. It takes 500 or 600 degrees Fahr. stack temperature to give enough draft for operating the furnace. This is the minimum, and will be found there a few minutes after the valves have been reversed, the products of combustion passing through checker chambers thoroughly cooled by the cold air and gas. On the other hand, from that time on the temperature of the stack will gradually rise, the checker brick getting hotter, and hence will let more heat pass out with the escaping products of combustion. When a point is reached where the stack temperature is nearly 1,000 degrees Fahr., or better not over 900 degrees Fahr., it is time to reverse, otherwise loss in fuel results.

As a result of this practice a fuel efficiency of one pound of coal to six of iron melted is attained. This is not quite as good as in cupola practice for ordinary gray iron castings, but there is a big difference in the quality of the work made.

The air allowed to be drawn into the furnace, for everything depends upon the stack draft, must enter cold. This is necessary for the reason that hot air contains too little oxygen for a given cubic content to properly support combustion. Very frequently, with open-hearth furnaces not giving good results in a hot shop, changing the point from which the air is drawn into the air valve of the furnace makes a big improvement.

In open-hearth practice in this country we have to deal with natural gas, producer gas from bituminous coal, and oil gas from fuel oil. In the case of natural gas, with its very high heating value, it is not necessary to regenerate it for ordinary melting. So in this case the two checker chambers on each side of the furnace are used for the regeneration of the air, the natural gas being introduced through several 2-inch pipes through the ports on each side. The two valves controlling the gas are brought to one end of the furnace, so that the melter can turn one off and the other on without trouble,

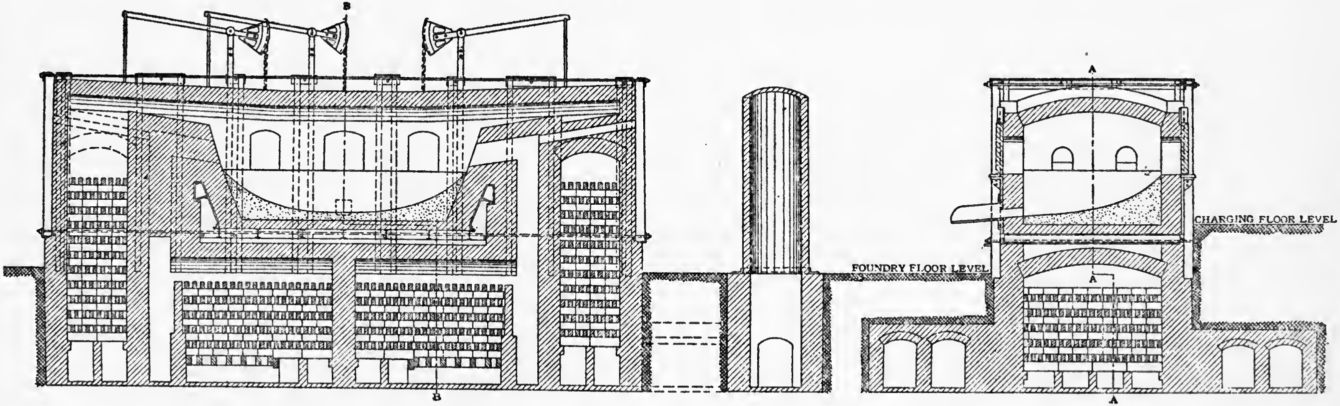


Fig. 19—Sectional views of open-hearth furnace for melting malleable iron; capacity, 10 tons

when reversing his air valve, no large gas valve similar to the air valve being required in this case at the stack entrance. While it is not necessary to regenerate natural gas for malleable work, it can of course be done, and the author remembers doing so for some time, and getting 10-ton heats in as low as one hour and 58 minutes from the end of charging to tapping. The furnaces, however, got so hot that they practically *ran away*, and the iron, though intensely hot, suffered considerably. Hence the return to regeneration of air only was necessary. As a little point to be observed it may be stated that where natural gas is regenerated, the pipes close to the furnace, or the gas box, if this is introduced between pipes and gas valves, and in fact the large gas valve itself (for which regeneration of gas this is required) get so hot that carbon is deposited within them, and trouble soon ensues. To obviate this, a ¼ inch steam pipe is attached, and a little steam is allowed to pass in with the gas, thus effectually preventing this carbon deposition.

Natural gas for the open-hearth furnace not only gives magnificent results, but is very easy to handle. Enough should be used to just show a little smoke at the top of the stack after reversing, and also puff out of the cracks of the furnace doors occasionally, showing that a reducing flame is within. Too clear a flame, that is one having a sufficiency of oxygen, may tend to burn the iron, and while this may be quite economical so far as gas consumption is concerned, the loss of castings and metal burned is greater than it should be. The gas should not come in at over five ounces pressure. Preferably it should be regulated for constant pressure, and come through large pipes. It should roll over the hearth lazily, and enter fairly low, the air coming in above it. This gives the best results for melting. With everything going right, in malleable practice, a 10-ton heat should not take more than 2½ hours between the end of charging and tapping. A 20-ton heat will take four hours. Where this time is exceeded it will be well to look into the method of handling the furnace, or to ascertain whether the charge was properly figured.

An open-hearth furnace built by Wm. Swindell & Bros., Pittsburg, is shown in Fig. 19. It differs only from the accepted type of furnace in having one checker chamber on each side placed at the side instead of under the hearth. The opening for the introduction of natural gas, or oil for that matter, is shown plainly on the right hand

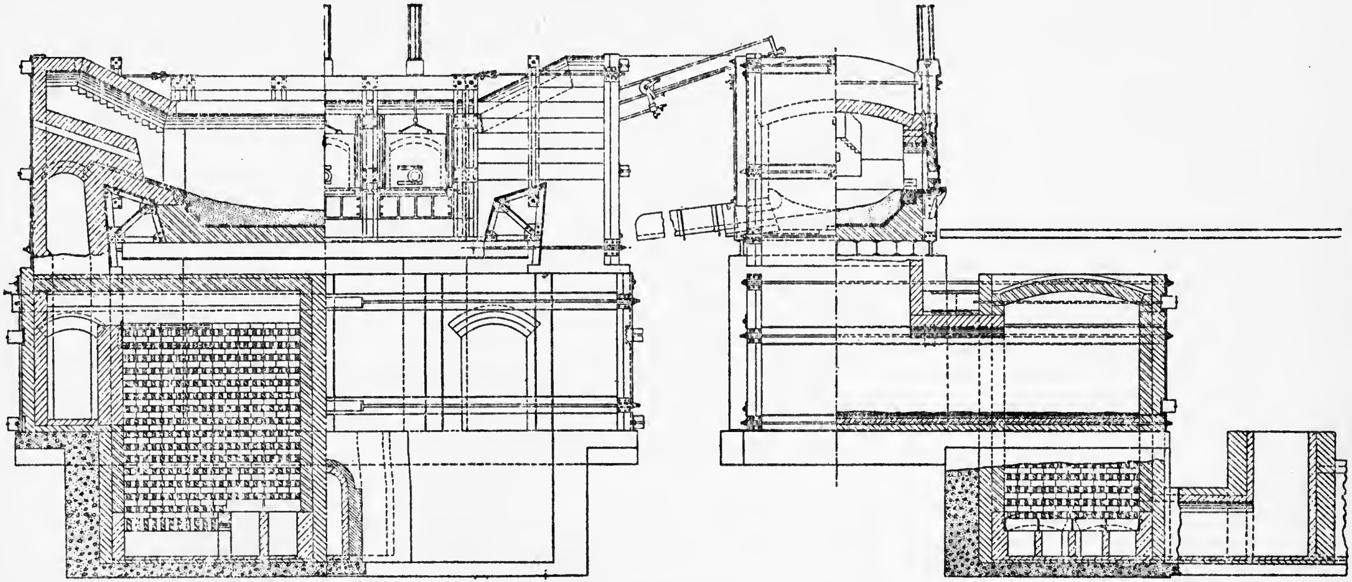


Fig. 20—Sectional views of open-hearth furnace for melting malleable iron; capacity, 10 tons

side of the longitudinal section. Both chambers on each side of the furnace are in this case intended for the regeneration of air only.

Where oil is to be used for fuel, all the checker space is also used for the regeneration of the air only, as the gas made from oil is very high in heating value. A 10-ton furnace of this kind, designed by W. M. Carr, is shown in Fig. 20. Here the checker chambers are very large and are placed below the hearth in the usual way. The oil is made to come in at the end, as shown.

The author has always preferred to have oil come into his furnaces, when he used this fuel, from the side, the pipes being placed at an angle and downward, so that the flame came from the side, front and back, and pointed toward the middle of the hearth. Reversal of the air valve meant the shutting off of the oil from one side and turning on of the other. Hence there were four pipes in this arrangement, two on each side, each provided with a small steam jet, to allow a little steam to pass through the pipes into the furnace when the oil was turned off. This prevented the burning off of the pipes when the heat struck them. Whether superheated steam, compressed air or wind from a fan, each coming through properly proportioned pipes, was used, or whether the oil was allowed to drop from the crown of the furnace on a tile at the end of the hearth, the result was an efficient flame which did the melting excellently. It must be said, however, that no fuel is as hard on a furnace as oil, especially, if for any reason the oil finds its way back into the ports and down into the slag pockets. This is usually disastrous. A roaring furnace results which melts the brick, iron and everything else indiscriminately. This is usually not noticed until that portion of the crown drops in, and then repairs are in order. Fortunately for open-hearth furnaces, the price of fuel oil is kept at a point which usually makes its use prohibitive for large installations.

The experience of the author with the various methods of using oil for melting have developed the following as the best system: The oil taken from the cars, passes into an underground tank, provided with a steam coil to keep the sludge, that will be found in the oil, liquid in winter weather. A pumping system is installed which, by a suitable regulator keeps the oil at a pressure of 40 pounds, and distributes it to every part of the works where it may be used. Just before it passes into the furnace the pipe is enlarged to allow the introduction of a strainer, which prevents sand or scale from the pipe from getting into the valve and causing trouble. This oil pipe, again reduced, passes through a larger air pipe into which a fan blows air at about three ounces pressure. This air can be shut off by a gate. The air blows the oil into the furnace, where it is entirely consumed, no gas carbon is formed, and the evils of local combustion are minimized as much as possible.

Fig. 21 shows a 20-ton open-hearth furnace built by S. R. Smythe Co., Pittsburg, for the Pennsylvania Malleable Co., McKees Rocks, Pa., in which the author was interested at the time of its installation. It also shows the three-spout arrangement which proved so successful in use. The first heat is being taken off at the time the picture was made, in 1900, and was carried away in 6-ton ladles for distribution in the plant. Natural gas was used for melting, as it was plentiful at the time, and excellent results obtained.

Producer gas is used for fuel in the open-hearth furnace, and as this will be the only fuel in the future, it is well to look into this question more closely. This gas must be regenerated as well as the air, otherwise trouble is certain to follow. Those who have been induced to try the other arrangement know this to their sorrow.

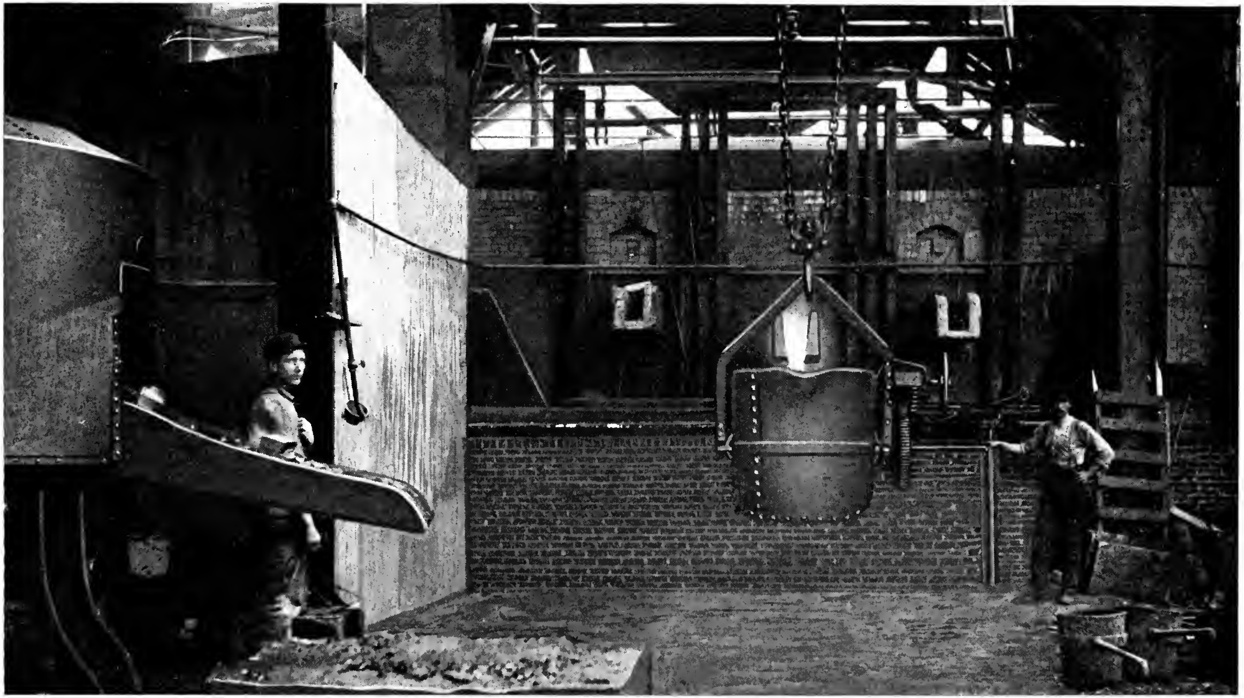


Fig. 21—Open-hearth furnace for melting malleable iron provided with three tapping spouts; capacity, 20 tons

IX

The Use of Gas Producers in Malleable Foundries

AS has been previously stated, the operation of the open-hearth furnace, which should not be larger than 20 tons for good practice, is dependent upon the use of gas as fuel. Whatever material is to be burned, it must first be gasified in some manner. The earliest attempts in this line were made by Siemens, and the gas known by his name is today still the best for metallurgical purposes, though no longer made on account of its rather high cost. Still, the composition—half carbonic oxide and half nitrogen—makes it more valuable than the gases with low carbonic oxide, and high hydrogen, for the purposes of practical steel and iron-making.

With the introduction of the steam jet for blowing air into a gas-producer, and at the same time holding down the temperature within reasonable limits, there came a new era for the open-hearth furnace. Enormous quantities of coal could now be turned into gas in comparatively small producers, and if close attention were given the installation, very uniform results would obtain.

The author had one of the earliest American producer plants in his care, and hence went through a lot of the kind of experimenting which is usually so costly, but of great benefit to those who later make similar installations. In the discussion of the subject, therefore, a number of points will be brought out which have the merit of being gotten by some years of very strenuous life. The plant consisted of 14 producers of an early type, which would convert four carloads of good Pittsburg gas coal into producer gas every 24 hours. These producers were all connected to a system of underground flues which delivered the gas to the melting and annealing furnaces of the plant. The gas for the open-hearth furnaces entered a steel box provided with a safety door in case of explosions, before entering the regulation furnace gas valve. For the annealing ovens a special gas box was constructed, after much experimenting, in which gas, and air for burning it, were so handled that most excellent results were obtained. Man-holes were placed at regular intervals, as well as stack connections, so that the periodical burning out of the flues, and the consequent removal of soot could be arranged for. As this gas has a very large volume and very low heating value, it becomes a question of pipe, not in inches, but feet diameter, and hence all overhead flues and connections were made of riveted sheet steel plate, lined with a grade of fire brick which would withstand about 1,200 degrees Fahr. successfully, which means a brick a little better than the common red variety.

Underground flues are usually of red brick with a lining of this same flue brick. The disadvantages of any underground work are, however, so great, that as little of this should be done as possible. The expansion and contraction of the flues—usually built like conduits, and often 4 feet wide and 5 feet high—is such that the entrance to connecting flues or branches is partially cut off, and the brickwork badly damaged in short order. Furthermore, where such a flue traverses the foundry floor, it is very hot to work upon, and men as well as the sand heaps suffer correspondingly. It is, therefore, advisable to carry the conduits for the gas overhead as much as possible, preferably on the lower chord of the roof trusses, after these have been strengthened suitably.

The gas producer itself, as used today, is undergoing rapid changes, principally in Europe, where it is essential to use fuels which would not be taken from the mine here. The advance in practice may be seen from the fact that in some localities in Europe, gas is being made from fuel with only some 25 per cent carbon content.

While for the purpose of this book one of the best of American producers is shown, this is by no means the most advanced type. The better types have not yet reached this country where we have so much better fuel. Briefly, gas producers, other than the old Siemens' type, may now be divided into two classes, those using the steam blast to draw in the required air and to keep the installation cool enough for proper action, and an entirely new type in which no steam whatever is used and the fierce combustion resulting from the blast of air introduced is allowed to melt the ash into a slag, with lime and other fluxes added to the coal as found best suited, the slag being tapped off just as in a blast furnace. The latter type seems to give a splendid gas,

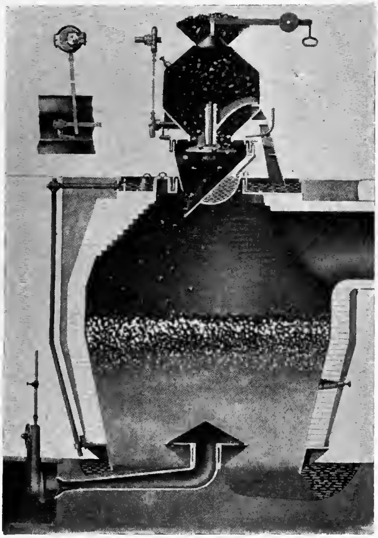


Fig. 22—Sectional view of continuous gas producer equipped with automatic feed

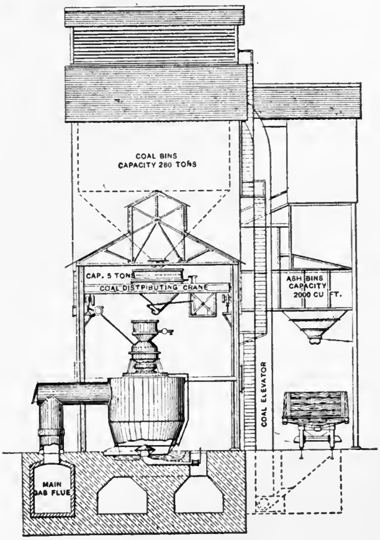


Fig. 23—Gas producer plant showing coal and ash-handling equipment

so far as composition is concerned, and the near future will see its introduction in the United States.

Fig. 22 is a sectional view of an excellent gas producer of the first type, previously mentioned. It differs from the later European producers of this type only in one respect, and that is in the grate arrangement. Revolving grates are now used equipped for the automatic removal of the ash, all clinkers being crushed, obviating excessive poking and reducing the labor cost.

The producer shown consists essentially of a steel shell lined with fire brick of the best quality. On the top of this shell is the floor, water-cooled, so that men may work on it with some degree of comfort. Poke holes are provided on the floor and in the side, for insertion of rods to break down the fire when required. The charging head is placed in the center of the floor, and is arranged with a bell and hopper, so that coal may be placed in it, and allowed to drop, without escape of gas. The illustration shows an automatic device for feeding, which assists materially in making for regularity on the part of the apparatus.

At the lower part of the producer there will be seen the air inlet, the cap of this practically serving as a grate or rather deflector for the fuel. This keeps the air inlet free. Steam is allowed to enter this air inlet, as shown, and in rushing in through a very small orifice, a large volume of air is drawn in, air and steam entering the incandescent fuel in the producer together. A water seal holds in the gas under pressure of a few ounces, and allows a ready means to remove the ashes without in any way disturbing the continuity of the process.

It will be noted that the bed of fuel is very thick. This is necessary, as the chemistry of the process will show. The air entering the bed of incandescent fuel is at once converted to carbonic acid with nitrogen from the original nitrogen and oxygen. As this passes upward the carbonic acid dissolves more carbon and becomes carbonic oxide. This is the real fuel gas. The nitrogen goes up through unchanged, and is the unavoidable and inert diluent of the gas. Now it takes a little time for this extra carbon to completely change the carbonic acid gas to carbonic oxide, and hence, unless the bed is thick enough, the process may not have been completed when the gas emerges above the surface of the fuel. In the chemical examination of the gas, therefore, if the amount of carbonic acid exceeds 4.5 or 5 per cent, the low point of the process, the bed of fuel has been allowed to get too thin. Further, any lack of uniformity in the fuel bed, such as clinkers, solid masses of fuel, or again large voids through which the gas may pass without getting fully in contact with incandescent carbon, means uncombined oxygen in the fuel gas, and is due to inattention on the part of the men to their work.

All well-regulated works in which producer gas is made, should have an analysis of the gas at least twice in 24 hours, so that the day and the night shift are checked up. The typical gas from this type of producer should be about as follows:

	Per cent.
Carbonic oxide	23.50
Hydrogen	14.00
Oxygen	0.50
Nitrogen	57.50
Carbonic acid	4.50
	100.00

This is obtained by the rapid method which does not go into the refinements of the hydrocarbons present, but gets them practically as hydrogen, etc.

The use of the steam jet is, as above stated, not only for drawing in the air, but also for reducing the temperature of the incandescent fuel to a point which will allow a continuous performance. In this type of producer were air alone to go in, the temperature of the mass would go up so rapidly that the whole apparatus would melt down in a short time. If, on the other hand, steam were allowed to go into the fuel made incandescent by the preliminary stack draft, as steam alone, the whole mass would rapidly cool down, as in the case of making water gas with anthracite. Hence, a happy medium, which allows just as much steam as may be necessary to hold the temperature right to enter.

Discussing the analysis of the gas further, we note that for practical purposes, the percentage of oxygen and carbonic acid—the deleterious ingredients—are a sufficient guide to observe in order to ascertain whether the producers are handled right. The percentage of hydrogen should be held as low as possible, for while the heat value of this element is the highest in the gas, unfortunately in burning hydrogen an intense local heat is generated and water made as the product of combustion. This water vapor, in passing along in the furnace is disassociated and again forms hydrogen and oxygen, with the absorption of much valuable heat. Then the two elements recombine, giving up their heat, and so on until the stack or such a point is reached where the temperature is too low to allow this disassociation of water vapors. The result is a very unsatisfactory condition of affairs, and hence, the lower the gas in hydrogen, with a corresponding increase in carbonic oxide, the better the steel and iron founder likes it.

As previously stated, the higher the carbonic oxide of the gas, the better. The quicker the hydrogen gets down to 14 per cent and lower, and the sooner the carbonic oxide gets up to 23.50 per cent and higher, the better. It is for this reason that the old Siemens' gas with 50 per cent carbonic oxide and no hydrogen was so well liked, though too slow and expensive in the making.

There is a further point to be observed in watching the gas-producer, and that is the ash. It will be seen in Fig. 22, that from fresh fuel at the top the mass in working downward—while burning out the 88 odd per cent of carbon, moisture, sulphur anud volatile matter—is left the 10 to 12 per cent of ash. This gradually accumulates at the bottom in the pan filled with water, and is drawn out without allowing air to enter. This ash, if the producer is handled with intelligence, and the plentiful use of muscle at the bars through the poke holes, should be a clean white, and free from practically every trace of carbon. If coke and half consumed coal come through, the regulation of the process has been imperfect, and attention should be given the plant at once.

Hence, with an inspection of the ash daily, the taking of analyses, and the other manipulation of the plant, such as burning out the flues, etc., very good metallurgical gas should be made.

It may further be stated that the producer furnishes the means for making use of inferior coal in regions where good coal is expensive. Good gas will result, unless, of course, the sulphur content is too high. Still, even this gas, when used for power purposes, is excellent, and may be the means of utilizing the enormous bodies of poor coal now left in the mines, when the transmission of power from mine to manufacturing cities becomes the order of the day.

It is a well understood fact, that in annealing practice, a steady supply of gas, well-regulated and burning easily with a minimum of draft, gives far better results than a coal fire which is disturbed periodically and requires an excess of air for combustion of the proper kind.

Producer gas is very low in heating value, perhaps one-tenth of natural gas; hence, immense volumes must be made, and if possible kept at as high a temperature as the producer will make it, without, however, running up to a point where an excessive amount of soot is formed by the decomposition of the hydrocarbons present. The plant itself is usually installed with coal and ash-handling apparatus, so that the cost of the gas drops down to the minimum. Fig. 23 shows such an installation.

X

Mixing the Charges for Malleable Iron

THE proper mixing of the irons going into a charge for malleable castings is of course the foundation of the whole subsequent work. With a mixture properly made, it then becomes a question of regularity in melting and annealing. It is a well known fact, that with everything in this connection running properly, a malleable mixture can stand some additions of odd gray iron scrap, steel shafting, old files, etc., and not run *off*. When, however, the mixture is just on the line between good and bad, it takes the most careful nursing to recover normal conditions. This is due to the large proportion of sprues and scrap hard castings that must be cared for, and which carry to each successive heat all the bad characteristics of previous melts which may have been damaged. Before the science of mixing was understood, it was customary to remove every piece of hard scrap from the foundry when trouble occurred, and to begin all over with a heat of all No. 2 pig irons. This was pigged and then used in place of the sprues for the mixture in the regular way. After a few heats, the old troublesome sprues were then fed in very carefully, or else used for making annealing boxes by running them through the cupola.

It is first necessary to discuss the various materials entering into the mixture. These include pig iron, sprues and discards, annealed scrap made by the establishment, annealed scrap bought or taken in trade, steel scrap, wrought iron scrap, borings, cast iron scrap and the ferro-alloys.

As all these materials have their bearing on the finished casting, and should be used only as they affect this, it will be desirable to give the composition of good malleable castings at this time. This is as follows:

	Per cent.
Silicon	from 0.45 to 1.00
Manganese	0.30
Phosphorus	up to 0.225
Sulphur	up to 0.07
Total carbon	above 2.75 (in the hard)

This is normal malleable for American practice. In special cases, especially for very small castings, the silicon may go up as high as 1.25 per cent, while for very heavy work it may drop down to 0.35 per cent with very good results. In the case of charcoal iron this figure gives the strongest castings. With coke irons, however, especially when steel scrap additions are the rule, 0.45 per cent should be the lower limit, and 0.65 per cent is the best silicon for all around medium and heavy work, such as is the case for railroad castings.

The manganese may go up a little, but this is not generally advisable, because manganese burns out first in a mixture, and costing money as iron when bought, simply adds to the melting loss. Moreover, with high manganese, there appear annealing difficulties. The above is written advisedly, for one hears many stories of 2 per cent manganese pig iron used successfully in the malleable foundry. Investigation always shows only a limited amount going into the mixtures, the consequent dilution through a large bath, poor in manganese, wiping out this apparent excess. It may be claimed that high manganese neutralized some of the sulphur by removing it into the slag, but it is far better to begin with low sulphur in the first place, as prevention is better than cure.

In phosphorus and sulphur we find the line demarking American from European foundry practice. Whereas we require our phosphorus not to exceed 0.225 per cent, and prefer it as low as we can get it without, however, paying for specially low amounts, European practice has this element as low as we do for acid steel castings. When the first coke irons were introduced into malleable foundries, it was a question whether the comparatively low phosphorus they contained would not militate against proper fluidity on the part of the heat. This proved not to be the case, and hence the irons with phosphorus somewhat above the Bessemer limit of 0.10 per cent, are the rule today. As charcoal irons, however, run up as high as 0.225 per cent and are first class for malleable work, the upper limit is as given.

In the consideration of sulphur we find the surprising fact that Europe makes malleable castings successfully with this element as high as 0.40 per cent, whereas we aim at one-tenth that amount, or 0.04 per cent. Nevertheless, if the sulphur runs as high as 0.07 per cent in the castings we let it pass, and instances have been known in this country of castings being shipped with 0.23 per cent sulphur, but they were certainly beneath all comparison with honest malleable.

We, therefore, call for not over 0.05 per cent sulphur in our pig irons, in order that in making our work we can anneal to the black-heart. This is impossible with the European high sulphur irons, where a long anneal at very high temperatures brings about the removal of the carbon by the entrance of carbon monoxide to carry it off, as shown by Dr. Wuest, a German authority on malleable practice. With us, the carbon passes out from the outer portions of the casting in probably another way. The high sulphur in European malleable also accounts to some extent for the comparatively low strength when contrasted with our product. Their castings being all very light, so long as they bend and twist properly, the purpose is served, and hence until heavier castings become the rule instead of the exception, *white-heart* and steely looking fractures will remain the characteristic feature of European work.

Total carbon is placed at 2.75 per cent in the hard casting, as below this point there is likelihood of difficulty in annealing. The exact point will naturally vary with conditions. Thus, with high percentages of pig iron, the total carbon can drop a little, while with heavy scrap and sprue ratios, 2.75 per cent cannot well be lowered and give safe results. The dropping of the total carbon being entirely accomplished by steel additions carried through a succession of heats, a line can be kept on the work, and the mixtures held within safe limits. For that reason it is not necessary to specify total carbon in pig iron for malleable purposes, a scrutiny of the other ingredients quickly showing whether an iron is an *off* grade. Such irons have no place in the malleable foundry even as a gift, if the highest grade of castings are to be produced.

The specifications for pig iron would therefore run as follows:

	Per cent.
Silicon	0.75, 1.00, 1.25, 1.50, 1.75, 2.00, as required.
Manganese	not over 0.60
Phosphorus	not over 0.225
Sulphur	not over 0.05

The lower the sulphur the better. Manganese should run about 0.40 per cent, not very much lower and not above 0.60 per cent, unless purchased with a knowledge of its analysis, and one should see that no more gets into the mixture than will give an average of not more than 0.40 per cent when charged.

Works making heavy castings almost exclusively, specify their silicon to include 0.75 up to 1.50 per cent. Makers of very light work take 1.25 to 2.00 per cent. It will probably be safe for every one to have all the above silicons, but in quantity only as needed. The upper and lower limits, though perhaps not needed once a year, are desirable for emergencies, and need only be kept for that purpose. The time for the large malleable establishments to carry thousands of tons of metal in reserve for such occasions has passed away, except perhaps for those who have not yet learned to mix by analysis. They will keep on paying out good interest on their metal which rusts in the yard.

In receiving pig iron from the furnace, as a general rule only the silicon and sulphur need be watched closely. The manganese and phosphorus run pretty steady so long as the furnace is burdened the same way. The author desires to pay tribute to the furnaces whose products he has used to the extent of hundreds of thousands of tons, never having had to reject a carload. Occasionally the analysis would be not what was desired, but an adjustment of price was quickly made, and the iron went in, a few pigs at a time, scattered over many heats.

Once, therefore, a furnace has been found to send reliable analysis cards with each car, the iron is piled in its respective place and used, pigs being taken for analysis while this is being done. The silicon analysis is made from these and at given intervals, the sulphur also. Manganese and phosphorus are taken only occasionally, unless the shipments are seen to be abnormal due to the furnace running *off*. In that case, attention must be given to everything. This, however, rarely happens, and the furnaces are particularly careful not to sin by shipping bad iron to a works with a laboratory and brains behind it.

It will be seen that by specifying everything within an upper limit except silicon, and giving that exact, the piling of the iron and its subsequent use becomes a very simple matter. Take for instance a foundry which specifies 1.00, 1.25 and 1.50 per cent only, though having a small amount of other grades of iron on hand for emergencies. This foundry will only have three general piles for every brand it purchases. It is no longer necessary to keep every carload apart, in fact the author holds this to be very bad practice in the malleable foundry. Say a carload of iron comes in with 1.35 per cent silicon. This should go on the 1.25 per cent pile, the pigs being laid on the ground in a long row, or several rows, as space permits. The next car may contain 1.55 per cent silicon. This would similarly go on the 1.50 pile. Then a car is received with 1.15 silicon. This goes on the 1.25 pile again, the car being spread over the first in a row as before. Gradually, as the cars come in, about 10 points being allowed below the desired figure, and 15 points above, the piles grow in height, and in drawing from the end for charging purposes, an exceedingly uniform metal is obtained. The silicon of the individual cars is determined, meanwhile, just the same, and should differences arise, the proper correction can be made for mixture calculation purposes, and the attention of the blast furnace operator called to the discrepancy, so that subsequent shipments may be more nearly correct.

As above stated, each brand should have its separate pile, but the silicons of each may be arranged as outlined. This limits the piles. Care in marking avoids errors often made, especially as every pile should be designated by the letters of the alphabet and not by names or car numbers. Furthermore, a record of the amounts taken off can be kept in the office, showing at a glance what is left from each respective pile, and how deeply each silicon has been cut into. This will prove of value when placing subsequent orders for pig iron.

It is always good policy to have three or four brands in stock of the silicons required. Occasionally, however, special reasons preclude this, and one brand only is available. With the piling, as indicated, a heat does not get the iron from only one or two cars, but from 25 cars, or even more, and this without a complication of records. The author at one time had 5,000 tons of iron of one analysis thus piled All this metal, containing a certain percentage of silicon, was designated by one letter of the alphabet, and in mixture-making, by the use of iron from other smaller piles of different silicon content, everything worked without a hitch.

In the system developed by the author in connection with this method of piling, he received a report of every daily heat, the weighmaster being under the charge of the laboratory. The charges were delivered to the foundry foreman on the furnace platforms, and he received a copy of every mixture for his information. A record of every brand and silicon pile was kept, in net tons, as they came in. The daily melt was deducted, day by day. At the end of every month an order was placed for iron for delivery during the next three months, and the silicon was so specified that the relative proportion of the silicon piles was kept normal. Thus, suppose that at normal times the silicon should range as follows:

Silicon, per cent.	Per cent of the total iron.
0.75	5
1.00	30
1.25	50
1.50	15

If for any reason the high silicon pile were drawn upon heavier than the above ratio, at the end of the month this was corrected by the next iron order. It should be understood that the contracts were made in such a way that this specification for silicon could be given at any time without affecting the price. In case of a special bargain available, a very heavy tonnage was often taken, governed by the above ratio.

This method has been outlined for a special purpose. In these days of consolidations and the desirability to be free from exorbitant prices or imperfect deliveries, it is only a question of time when the very large interests in the foundry business will own their blast furnaces, or control the entire output of at least one stack. With the method of piling given, it is possible to have only a single brand in the yard and get perfect satisfaction. This is from actual experience. The author particularly commends this method of piling iron to the attention of malleable men in the interest of uniformity in excellence of product.

The coke irons we purchase today are known as *coke malleables,* formerly they were called *Bessemer malleables,* and found an outlet for those irons which would not pass as *Bessemer,* on account of higher phosphorus content. The *off Bessemer* irons, which had high sulphur, being palmed off on malleable works also, soon created such trouble that coke iron came into disrepute, and a revival of charcoal metal came about, as explained in the early chapters. Now, however, there is a regular production of pig iron from ores higher in phosphorus than the Bessemer limit, which are incidentally smelted with plenty of coke to make them honest, and these give first rate results.

Discussing next the sprues, gates, wasters, scrap hard castings, or whatever they may be called, these are essentially the regular malleable iron in the hard of the daily heats, and should be taken care of as fast as made. As every well-regulated malleable works should have the silicon content of every heat before the castings go into the anneal, the average silicon from all the daily heats, for the sprues, will be known at all times for mixture purposes. The calculation, therefore, becomes a fairly exact one, and changes in the mixture can be made, from time to time, as the silicon of these sprues goes up or down, presuming that the pig iron supply remains constant.

The quantity of these sprues varies with every works. In the case of very light castings, the proportion of the sprues in the daily heats may go as high as 60 per cent, whereas for very heavy work it may not exceed 25 per cent. It is absolutely necessary to use up the material as fast as made, so as not to pile it up in the yard, or have it in the way in the foundry. Once thus stored, it becomes an unknown quantity and may work havoc in subsequent mixtures.

A further consideration is the cleaning of the sprues. It is good practice to roll the sprues in a very large tumbling barrel, somewhere outside of the foundry, to remove the burnt sand adhering. This reduces the amount of slag made, but more important, thoroughly mixes the sprues from the various heats, they being brought to the sprue barrel from the different parts of the foundry floor in the nightly cleaning up. Rolling the sprues at night is advisable, on account of the dust made. The clean sprues are then weighed and distributed for the various morning heats on the charging platforms. If a heat happens to be higher or lower in silicon than expected, the sprues resulting will be so distributed that no damage will result. The foreman in charge of the weighing, by keeping in touch with the person making the mixtures, can keep him posted as to the supply of sprues to be cared for. In fact, the usual custom is to allow a trifle more sprues in the mixture than are actually made, and fill out the shortage with a low silicon pig iron. This keeps the floors clean.

The annealed scrap is a serious problem for the malleable shop. From the nature of the case, a piece of this material may remain apparently unmelted in a heat until the very last iron is being drawn off. The skin of a casting being almost as infusible as mild steel, the temperature of a bath of malleable is not high enough to melt it easily.

The interior of the casting may be fluid, but the shell holds it intact; hence the general practice of selling this annealed material as scrap, or making annealing pots of it by melting in the cupola.

The author took advantage of this peculiarity of the annealed casting to have its interior melted at the ordinary temperatures of the bath, while the skin might be intact, in caring for some 30,000 tons of scrap couplers, which were becoming a financial white elephant to one concern. By crushing these couplers under the hydraulic press, at a cost of about 50 cents a ton, the interior of the castings was exposed sufficiently to allow of a ready melting, and a regular progression of heats was made in which the malleable scrap was charged in increasing quantities until the bath actually contained 80 per cent malleable scrap couplers. The material had to be charged twice and melted down to get it all into the furnace on account of its bulk. The resulting castings did not have a nice appearance with these high percentages, but they were the strongest ever made.

With the advent of steel scrap in the mixtures, the melting point of the bath has been raised, and at the present time it is quite possible to charge good, clean annealed scrap in modest proportions and get results even without crushing. Formerly, a scrap coupler, when charged, would float about unmelted until the end of the heat, when the skin would burn off, with the consequent damage to the iron for castings.

The proportion of malleable scrap in a heat should not generally exceed 20 per cent, depending upon the proportion of sprues to be cared for. In the very large establishments it is customary to take back scrap malleable on account of new castings. In these works the above method of caring for scrap couplers means dollars. In the case cited, the difference between pig iron and the malleable scrap at that time, allowing for the cost of crushing was $10 a ton. Hence that pile of 30,000 tons, which was used up in two years, represented a handsome profit. More than this, the use of this material successfully enabled the concern to take any other scrap couplers in exchange for new ones at a high profit, and finally some four carloads a week of home and outside scrap were cared for in this plant.

An investigation of the behavior of annealed scrap in the furnace indicated a heavier loss of silicon than is the case in melting sprues, and hence the advisability of allowing a lower silicon content for this material in the calculations than there is actually present. Thus, the annealed castings, being in all probability normal malleable, the silicon ought to be about 0.65 per cent, more or less, generally more. In the calculations this scrap should be held down to about 0.40 per cent silicon, which will be found best for the purpose.

Very light malleable scrap is difficult to handle, as it is usually badly rusted, burns, and gives trouble generally. It should rather be used in the cupola for making annealing pots in connection with the proper pig iron for this purpose. A little incident of interest in this connection happened to the author. One of the officers of a concern had purchased a train load of gray iron scrap under misapprehension as to its use. The price dropped and a big loss was ahead. Incidentally there was an enormous pile of very light malleable scrap in the yard taken in exchange for good castings. The author added several charges of half gray iron scrap and half of this malleable scrap to the regular run of cupola for pots, and cast a special pig out of this mixture. This special pig was later fed into the regular malleable heats some 500 pounds at a time. The cost was not heavy for this melting. It saved the loss on the gray iron scrap, used up the small malleable, and made a profit each way, as the castings were sold at full price and were all right. It also illustrates the fact that when things are running right in a malleable foundry, some liberties can be taken with the mixtures.

Steel scrap in the malleable foundry is now very important, as the total carbon is reduced in this way, and stronger results obtained. Moreover, this addition has cut away every excuse for refining a heat, and the ideal conditions of a quick, hot melt without any refining action other than the unavoidable burning out of the silicon and manganese, should be aimed at. The scrap should be fairly light but not too thin. It should not be charged with the sprues as is frequently done, as it is sure to burn before being covered by molten metal. Steel scrap should be thrown into the bath after this is melted, and gotten under the slag cover as quickly as possible. Steel should not be allowed to burn, otherwise the malleable made will be inferior. The proportion of steel in a mixture will depend upon the amount of malleable scrap used. In any case, it should never exceed 10 per cent with no malleable scrap in the mixture.

Wrought iron scrap seems to be very active when put into malleable heats, as when very much is added the cracking of castings is noticed at once. In general, the efficiency of these scrap additions may be said to be as follows: 100 pounds of wrought iron scrap equals 500 pounds of steel scrap, equals 2,000 pounds of malleable scrap, so that substitutions in the mixture may be made accordingly, taking into account, however, the silicon content which is thus disturbed.

Borings, whether cast or steel, should, if used at all in a malleable heat, be charged under the slag when the bath is melted. When badly rusted the best place for borings is on the scale pile. When clean, they are best briquetted and charged just as pig iron. Probably steel and cast borings mixed will give the best results in malleable. Shot from the slag barrel should go into the furnace, the finest preferably under the slag, the coarser with the sprues.

Finally we have the ferro-alloys and cast iron scrap. The latter can be used in small quantities provided no burnt grate bars are included. The small addition of phosphorus introduced into the heat amounts to little, and mention is only made here of this so that a concern may know that it is possible to take care of its gray scrap without loss. It practically amounts to just so much pig iron saved in the heat. The quantity used, however, should not exceed 5 per cent.

Ferro-silicon is the only ferro-alloy which should be kept in stock at a malleable works for emergency use. Of ferro-titanium we can only say at this time that tests made indicate a future for its use in the malleable works on account of its purifying action on the bath of molten metal. It is best added just before topping.

There are two ways of using ferro-silicon for malleable purposes. As a high silicon pig in the bath in case it is running *high,* and in the ladle as a 50 per cent or 75 per cent alloy, in case it is desired to make very small castings from a low silicon heat suitable for heavy work. In the first case it is well to have a carload of pig iron running from 14 to 20 per cent silicon on hand. Some of this, broken up into small pieces, should be located where the weigh-master can bring it on demand from the foundry foreman or the melter. The amount used should be reported to the office or laboratory, and a record kept. There is a very great tendency to use this material in the heat just before tapping to save the iron, whereas the application of muscle in the first place on the part of the melter in rabbling well, will promote a quick heat and get good iron without the alloy. A long drawn-out heat is always a bad one, and hence the discouraging results when the tactics of the steel melter are introduced into the malleable foundry. The management, by keeping tab on the ferro-silicon pig thus used, will quickly know whether the melters are doing their full duty.

Where, through accident, a heat is lost by burning, the proper thing to do is to add sufficient silicon by means of this pig to get the heat up to the proper silicon content, and then pig the whole bath. This can then be fed gradually into subsequent heats without trouble.

Adding high grade ferro-silicon in the ladle is a comparatively recent innovation to which profitable attention might be given in works where the heavier class of castings is the rule. The discount being heavy for light work in these concerns, it will pay to catch the very last of a heat in a large ladle into which the ferro-silicon has been placed, or fed on the spout as the metal runs out. Probably better still, to stop the heat at the right time, add the rich ferro-silicon in the bath, rabble well, and then pour all this iron into light work as usual.

The materials going into a heat having now been discussed, the next matter to be taken up is the calculation of the mixtures.

Ordinarily, a malleable works has but one mixture running at a time. Where, however, attention is paid to the niceties of the art, and customers are given more nearly what they should have, especially with the open-hearth furnace, several mixtures may be run right along.

For instance, taking the most advanced practice, every time an open-hearth furnace has been rebuilt and heated up preparatory to making malleable, it is advisable to run a *pill heat* through it. This, pigged for subsequent use as sprues, merely serves to get the furnace into proper working shape and points out to the melter whether everything is working properly about his furnace. It forms a sort of insurance for good malleable next time.

Again, running over Sunday, the furnaces are apt to be a little colder than they should be, and hence a *Monday morning heat.* Then, of course, follows the *regular heat* of daily practice. When a good customer wants specially soft iron, a *special heat* is made which contains no steel scrap, and is higher in silicon than the ordinary mixture. The castings are by no means as strong, but they thread and machine nicely.

Next comes a *pot mixture,* run in either the air, open-hearth, or cupola furnace. In the case of the cupola, less silicon is burnt out, hence the mixture is arranged accordingly.

Sprue heats are sometimes made when things go wrong in the works and in this case, pig iron only, as a rule, forms the material melted.

It will be seen, therefore, that mixing can be made a fine art; and yet once the principles of the operation, as explained in the previous chapter so far as the materials used are concerned, are understood, the work is so simple that every foundryman can master the details in short order.

Commencing then with the regular mixture. Take first an easy mixture from the old days of charcoal iron, with no scrap other than the regular sprues. The work required consisted of couplers, the silicon demanded was 0.55 per cent in the mixture, to give from 0.30 to 0.40 per cent in the castings. Here is what was used:

Pig iron, brand.	Amount, pounds.	Silicon in brand, per cent.	Silicon in mixture, pounds.
Pioneer, No. 2	2,000	0.90	18.0
Elk Rapids, No. 2	1,000	1.00	10.0
Antrim, No. 2	1,000	0.76	7.6
Hinckle, No. 3	2,000	0.77	15.4
Antrim, No. 3	2,000	0.76	15.2
Pioneer, No. 3	1,000	0.61	6.1
Hinckle, No. 4	1,000	0.48	4.8
Sprues	9,000	0.30	27.0
	19,000		104.1

Or, every thousand pounds carried 5.5 pounds of silicon, or in other words, the mixture contained 0.55 per cent silicon. Now, in running about 10 heats a day in 10-ton furnaces of the open-hearth type, the resulting castings contained 0.35 per cent silicon and annealed first class. This mixture is given merely to show how low in silicon one can go and still get good work, provided the heats are quick, charcoal irons are used, and only domestic sprues enter the mixture. There are some works still so situated that they can use the above, or the equivalent, for their heavy castings.

Turning to more modern conditions and studying the method of mixture calculation at the same time, let us consider, for instance, the following points as fixed: The silicon required in the mixture is 0.80

per cent, so that when melted and cast the work may turn out about 0.50 per cent (for fairly heavy work), 21,500 pounds to be used to the charge for a 10-ton furnace running under pressure of work; 250 pounds of each steel and gray iron scrap to be in the mixture, as well as 3,000 pounds of malleable scrap; the percentage of sprues at the time being 8,000 pounds, thus keeping the sprue pile normal. These are conditions imposed upon the plant by the supplies on hand. It will be seen that in order to use that much iron in the furnace—its maximum at the time—with the steel to improve the metal, and the gray iron scrap to get rid of that amount on hand, and 3,000 pounds of malleable scrap which takes care of the supply of that material coming in at the time, only 10,000 pounds of the charge is pig iron, or a little less than one-half.

With 21,500 pounds of metal to contain 0.80 per cent silicon, the total silicon in the mixture must be 21,500 x 0.80, or 172.0 pounds. Taking first the fixed conditions of scrap, we have:

Metal, pounds.		Silicon, pounds.
8,000	sprues (containing by analysis 0.50 per cent silicon)	40.0
3,000	malleable scrap (estimated 0.40 per cent silicon)	12.0
250	steel scrap (estimated at no silicon)	....
250	gray iron scrap, heavy (estimated at 1.00 per cent silicon)	2.5
11,500	metal, containing silicon	54.5

This leaves 21,500 minus 11,500, or 10,000 pounds of pig iron with 172.0 minus 54.5, or 117.5 pounds of silicon to be provided to bring the mixture out right. Looking over our pig iron sheets we find that it is desirable to cut down the quantity of *D, B* and *N,* so we take say, 2,000 pounds of each, and have:

Metal, pounds.		Silicon, pounds.
2,000	"D" (Antrim pig iron, with 1.00 per cent silicon)	20.0
2,000	"B" (Spearman pig iron, with 1.25 per cent silicon)	25.0
2,000	"N" (Mabel pig iron, with 1.25 per cent silicon)	25.0
6,000	metal, containing silicon	70.0

Adding this to the above we have now 17,500 pounds of metal with 114.5 pounds of silicon provided for, leaving 21,500 minus 17,500, or 4,000 pounds of pig iron, with 172.0 minus 124.5, or 47.5 pounds of silicon still to be added.

We come now to making combinations with what we have left in the yard to get these 4,000 pounds of pig to contain as nearly as may be the 47.5 pounds of silicon. In the particular mixture in question, this proved to be the following:

Metal, pounds.		Silicon, pounds.
3,500	"G" (Briar Hill pig iron, with 1.25 per cent silicon)	43.8
500	"K" (Ella pig iron, with 0.75 per cent silicon)	3.7
4,000	metal, containing silicon	47.5

Thus, adding all the metal together, it happens we hit the exact amount, which is rather exceptional, usually a variation of a few pounds of silicon is unavoidable. Tabulating the several items we have the following:

Pig iron and scrap.	Metal, pounds.	Silicon in brand, per cent.	Silicon in mixture, pounds.
"D"	2,000	1.00	20.0
"B"	2,000	1.25	25.0
"N"	2,000	1.25	25.0
"K"	500	0.75	3.7
"G"	3,500	1.25	43.8
Sprues	8,000	0.50	40.0
Malleable scrap	3,000	0.40	12.0
Steel scrap	250	....	....
Gray iron scrap	250	1.00	2.5
	21,500		172.0

Dividing the 172 by 21,500, we get the silicon of the mixture 0.80 per cent.

This mixture gave castings with 0.50 per cent silicon, which annealed satisfactorily. It was used in all the morning heats for 10 furnaces. For the afternoon heats, as the furnaces were much hotter, occasionally the silicon had to be cut down a little and the silicon of the mixture made to run 0.75 per cent. On the other hand, for Monday morning, all the furnaces were charged with a mixture running 0.85 per cent silicon. Thus, with a silicon basis established in a works, it is easy to vary the mixture for the same furnaces, using the same tonnage, and provide for the peculiar heat conditions obtaining. This can be done with the air furnace as well as with the open-hearth.

To show that it is by no means necessary to have a number of brands in a mixture, though advisable to pile the metal according to analysis, many cars on one pile, the following mixture is appended, which gave very strong and good castings:

Pig iron, brand.	Metal, pounds.	Silicon in brand, per cent.	Silicon in mixture, pounds.
"O" (Mabel)	8,000	1.00	80.0
"E" (Mabel)	3,000	1.25	37.5
Malleable scrap	2,500	0.40	10.0
Steel scrap	500	....	....
Sprues	7,500	0.55	41.2
	21,500		168.7

Dividing 168.7 by the 21,500 pounds of metal we have the mixture containing 0.78 per cent of silicon, and only one brand of pig iron used.

The making of special heats is carried on just as the above example. It may be desirable to leave out the steel or reduce the malleable scrap or in some other way attain the desired result. When a new iron is to be tried, the method shown in the last example should be followed, that is, to retain the sprues, scrap, steel, etc., and substitute for the pig iron as much of the new iron as can be gotten in without upsetting the silicon balance. Cast the heat, and collect all the sprues for the next heat with the new iron. This will sufficiently impress the resulting castings, and by the strength of the test bars made, a very fair idea of the value of the new iron obtained.

In making annealing pots it is advisable to use only the best of materials, though occasionally much has to be put in which will not do very well in the regular mixture. Thus, the scrap pots are often cut up and melted in the cupola, and very thin annealed material, which may have been badly rusted, is sent through the cupola. The last is all right, but the first, or scrap pot, had better be sold to the blast furnace again, as it is badly oxidized, and always makes inferior pots which soon burn out. Here is a mixture for the cupola for making annealing pots:

	Pounds.		Pounds.	
"N" (Mabel pig iron, with 1.25 per cent silicon)	2,000	with	25.0	silicon
Malleable scrap (0.40 per cent silicon)	3,000	with	12.0	silicon
Charge	5,000	with	37.0	silicon

or 0.74 per cent silicon in the mixture.

As a general rule, where there are enough furnaces to take care of the current work, all extra iron is cast into annealing pots, and thus the cupola is used only occasionally. While this is convenient it is not altogether advisable, as in the first place the air furnace or open-hearth iron costs more, and cupola iron, though inferior in strength as malleable, when annealed, will withstand high temperatures better, being much closer in structure. It is, therefore, better to run the heats close to the floor requirements, and to start the cupola so many days a week as may be required for the supply of pots and stools.

There remains only the so-called *pill heat,* the pigs from which, if the furnace worked properly, consist of sprues. If the furnace showed signs of trouble, this would have to be corrected before going any further.

Here is a mixture for this purpose:

	Pounds.		Pounds.	
"T" (Briar Hill pig iron 0.75 per cent silicon)	10,000	with	75.0	silicon
"X" (Excelsior pig iron 1.00 per cent silicon)	6,000	with	60.0	silicon
	16,000	with	135.0	silicon

The silicon in the mixture is 0.84 per cent. It will be noted that the silicon is fairly high, and the amount of the charge smaller than the capacity of a 10-ton furnace, the only object being to get a newly built, or rebuilt furnace into proper working condition.

Once in a while, the bottom of a furnace gets high and in bad condition, and rather than tear it out and thus put the furnace out of commission for a while, a small heat of the worst iron available is charged and deliberately burned. The oxide of iron, thus formed, cuts the sand bottom, and the slag running off leaves it in the shape for building up again. Limestone is also used in this way, but requires great care as it is very active on a sand bottom.

In conclusion, it may be said that close attention to the scrap piles, the mixture requirements to make the proper classes of malleable, and the buying of irons to keep the minimum of metal piled up in the yard without being caught unprepared through slow deliveries, constitute the art of getting results without having to resort to the purchase of cheap irons which mean bad malleable every time. A good laboratory and still better, a good metallurgist, pay over and over again in a malleable shop, even with an output as small as 10 tons a day of finished castings.

It is understood, of course, that where a works require a silicon higher than the examples cited, the mixture is arranged accordingly. The mixtures quoted are from actual use, give fine results and have been selected in view of the tendency existing to use too much silicon for malleable castings today, partly through fear of getting it too *low,* and also through ignorance of the fact that the lower ranges give the strongest metal.

XI

Casting Malleable Iron

WE will now suppose the heat of iron is ready for pouring off. The slag has been duly skimmed off twice or three times, as required in the air furnace, or not at all in the large 20-ton heats of the open-hearth. Test plugs have shown the metal to be neither *high* nor *low* and the furnace is tapped in the usual way. In practically every foundry it is customary to have the molders line up, and take the metal in their hand ladles in regular rotation. Where the work is rather heavy, as for railroad castings, the shank is used, and up to 300 pounds carried at a time. Fig. 24 shows the ladles and shanks used.

Occasionally, two shanks, or one with an extra hand ladle is used, and again, for large, thin work, it may be necessary to have two or three hand ladles emptying metal into one mold at the same time. The metal, if right in temperature and not burned, is caught white hot, and flaring from minute particles of metal burning in the air. This dies down very quickly, and the metal is readily poured into the molds with a quick turn which practically throws it in.

The author, not satisfied with the danger and confusion which is liable to occur at the tapping spout, especially when a second heat has to be taken from an open-hearth furnace, with the breast in rather bad shape, undertook to tap into six-ton ladles from his three-spout furnaces shown in a previous chapter. The crane facilities permitted this, and the metal was distributed about the shop, nearly 800 feet, to the point wanted, and the ladle dropped into standards, or left suspended, while the men got the iron in their ladles and shanks the usual way. This cut out all work with the breasts, they were simply broken out, or the upper ones tapped so large that a few minutes sufficed to take off the heat in the furnace down to that level. The melter could attend to his heat while the first and second ladles were poured off,

Fig. 24—Ladles used in the malleable foundry

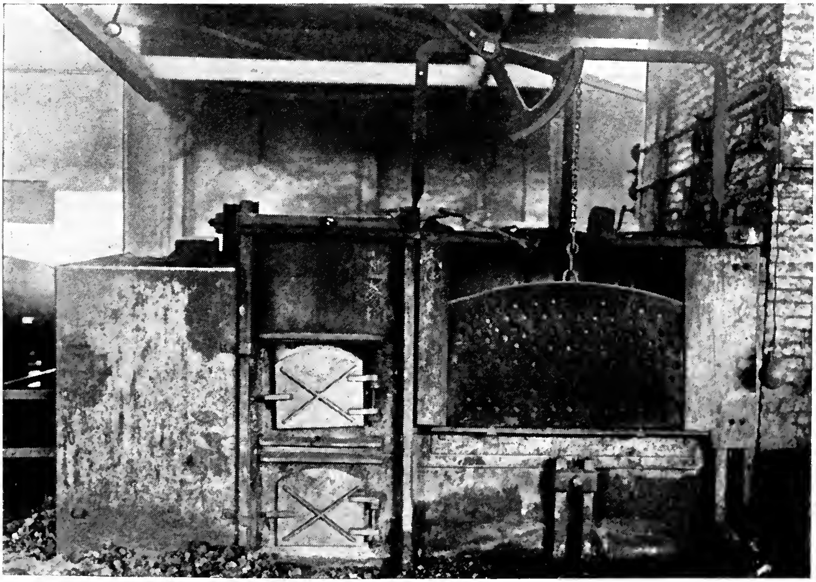


Fig. 25—Furnace used for reheating malleable iron castings

and the breaking out of the lowest breast, with consequent emptying out of the furnace altogether in one-half minute, allowed him to patch up bottom and get ready for the next heat.

In tapping each of the three spouts in turn, the following precaution was taken: Owing to the patching up of the bottom, and the consequent change in the content of the furnace for each spout level, while the big ladles held more than six tons each, it often happened that much more than six tons would come out, and hence a second ladle was placed on the floor in front of the suspended ladle at the tapping spout, so that any overflow of metal would be duly caught. This obviated all danger and the ladles were emptied sufficiently fast to have this surplus metal hot enough to pour in its turn.

As to the temperature of the metal thus poured, the following may be said: It became the custom in pouring off the first of the large ladles to leave some 500 pounds in the bottom, as the temperature got a little too low to pour light or medium work satisfactorily. This 500 pounds left in was taken to the furnace, and the second tap run into it. This second ladle was already so hot—the furnace being under gas all the time—that every drop of metal went into whatever work was on the floor. The final ladle, naturally the hottest, was of such a temperature that molds having three brake shoe keys in them, with vent holes at the end, when set slightly tilting and poured, spouted out three thin streams of metal through these vents.

Of late, there is being introduced in the larger malleable foundries the overhead trolley system. This will enable some 500 pounds to be taken to different parts of the shop and cast either direct or into hand ladles.

Perhaps the nicest system of handling metal known was used by the author in his works for a time, though not kept up after his leaving Pittsburg. This was the bottom-pour, with a peculiar spout arrangement. It came about through a suggestion of E. H. Mumford, the well known molding machine authority. He sketched out a device in which there was bolted just below the orifice of the bottom-pour ladle, a cupola spout, and this duly lined. When the rod was raised and the metal shot through the orifice, it struck this spout, and ran along it gently into mold or ladle, as desired. Thus a clean iron would be drawn off from the bottom of the ladle without any danger of cutting by reason of the head of metal above. There was no waste, and the ladle was not tilted at all. The author used this device in connection with his large ladles. These were brought by crane to one of several standards in the shop, left there, and the crane allowed to proceed with other work. The man in charge then simply pulled the lever and allowed as much iron as was wanted to flow into the hand ladles of the men passing by in turns. In fact, almost a steady stream was allowed to run. No waste and no heat radiated out on the men as when the large ladle was tilted. This more than balanced the additional cost of the stoppers and time to get them ready. The slag rising to the top of the ladle formed a crust on it, and effectually kept the metal hot. The ladle also could be covered if desired. At any rate, the men never got cleaner iron to pour off than at that time.

After the casting is completed, and the molds allowed to cool enough to get the work at least black, the molds are shaken-out, gates and defective castings separated from the good work, and the latter is sent to the hard tumbling room. Under no circumstances should the work be shaken-out red hot—with one exception as noted further on—as, otherwise, a casting may crack at some critical place, and thus be lost, or worse still, the crack may be so small that it passes inspection, goes through the anneal and is shipped, only to fail in service. Hence, attention should be given this point, and in the inspection, wherever possible, the castings should be struck to see if they ring true.

Where there is any likelihood of finding the castings cracked when shaking out, as for instance in the case of brake wheels and other work in which there are great casting strains, these are taken out as soon as they have set, and while still red hot. They are quickly placed in a so-called *reheating furnace* which is previously fired-up very hot. When fully charged with the day's work of this class, the reheating furnace is closed up and the heat allowed to die out over night. This, in a measure, anneals the castings, though not in a *malleable* sense, and the work may be now cleaned, inspected and go to the annealing room. Fig. 25 shows such a reheating furnace.

A further word in regard to the inspection of castings in the hard. As the molds are dumped, and later on the cleaning gang comes along—in large works at night—a rough separation of castings from the gates is undertaken. Cores are removed as much as possible, and in some cases with special core-rod pulling devices, for instance, in the making of couplers or other long, hollow work. Core rods, by the way, should be returned to the core room to wire straightening machines which operate better, cheaper and more effectively than the old hand straightening method. It even pays to put a pensioner watching the yard gates at work straightening the nails used.

The rought sorting will take out all the mis-runs, castings where cores may have been forgotten and other defective work which may be easily seen, even at night. All this goes with the sprues, in well regulated works, to the big slag barrel placed outside the buildings, and preferably run by a motor from the light circuit of the plant. The sprues should be rolled clean. There is a disadvantage in using sprues just as they come from the foundry. The metal is protected from the melting action of the flame in the furnace longer than it should be. Then more slag is made, which in turn makes the heat longer, more skimming must be done, and dirtier furnaces and dirtier iron are the consequence.

The good castings, as far as this may be seen, now go to the hard rolling room, or tumbling room as it is oftentimes called, to be cleaned there. This room is usually the bane of the works. When one has, say 60 of the rumblers usually employed in full blast and no dust exhaust, one can neither hear nor see, the electric lights simply glow as if in the dim distance, and no one stays there longer than necessary. This, however, is the very reason why attention should be given the department.

To roll a casting longer than just enough to remove the sand with the hard stars placed in the barrels and the contact of the castings with each other, is a waste of power and equipment. About 20 minutes seems to give good results under ordinary circumstances. However, at times the sand so strongly adheres to the castings, especially the heavy sections, that it practically forms an enamel on them. Rolling all day will only glaze the work instead of cleaning it, and hence attention should be given the sand to see that it is free from too many fluxing impurities, and particularly the iron as it comes from the furnace, which may be badly oxidized through over-heating, or holding too long, getting *high*.

The difficulty with sand burnt to the casting is usually seen when there is trouble with dull iron. A heat is sometimes kept in long after its proper time for tapping has passed, to get it hotter to pour well. This holding in the furnace allows the metal to slightly oxidize, the melting point is raised considerably, and while appearing extremely hot when tapped, the ladles skull and the castings are mis-run. Usually, in such cases, the sand trouble is noticed. The temperature of the metal was simply too high for the sand, and some of it fused to the casting. Considerable hand or air-chipping then becomes necessary for proper cleaning.

The hard rolling room crews must, therefore, be carefully watched to see that the charges of castings are removed when rolled sufficiently, and taken into the trimming room, where they are gotten ready for the anneal while being carefully inspected at the same time. The present practice of using exhaust tumbling barrels is doing much to make this department of the malleable works a habitable place and is, incidentally, cutting down the rolling cost. The stars placed in the barrels are made of the same metal as the regular castings, and the molding is generally a part of an apprentice's work.

From the nature of the metal in the hard, heavy castings cannot be rolled with very light and fragile sections without danger of breaking them. It is, oftentimes, necessary to separate large castings, in fact wedge them into the barrels with sticks of wood, so that they may not move, but allow the stars and other plain castings to tumble about them and thus do the cleaning. Light and fragile castings may not be rolled at all, but are pickled. This may be accomplished in two ways. With sulphuric or hydrofluoric acid, or by means of the sand blast. The advantages of the sulphuric acid pickling bath are its cheapness and ease of manipulation. Mixed about 1 to 30, or sometimes a little stronger, the light castings are preferably laid on a series of perforated, inclined wooden shelves, and the fluid poured over the top. It trickles down over the castings on all the shelves, and runs back into the vat again. The night watchman, in going his rounds, or preferably the night annealer, keeps this up during the night, and next morning the castings are washed down with the hose, and go to the annealing room. Another method is to simply let the castings remain in the pickling vat, which may be heated by a steam jet, taking them out when clean. The disadvantage of the sulphuric acid pickling bath, is that it dissolves iron and not the sand adhering to it, so that it really makes the sand scale off. Further, it emits a bad odor. Where pickling is done for galvanizing purposes, a second bath of hydrochloric acid is sometimes provided after the sulphuric acid pickle, which cleans the iron still better and gives the zinc a good hold on the surface of the metal.

Hydrofluoric acid has the advantage of dissolving sand and not the iron. If heated, the pickle can be 1 to 50, and fine results are obtained. Like the sand blast, it shows up the surface imperfections very strongly, and has the disadvantage of being poisonous to a degree. It must be handled with rubber gloves when full strength, but is all right when diluted in the pickle. The author at one time used two large wood tanks with a lead steam siphon, so arranged that the liquor of the pickle could be drawn from one tank into the other at will. Twenty-five tons of small castings were pickled daily, and the cost was no larger than for rolling. Inconvenience of location caused the experiment to be stopped at the time, but one interesting feature was noticed. After washing the castings thoroughly, they would rust very quickly. In the meantime, the liquor siphoned into the other tank was cleaning the next day's batch of small castings. Now these rusty castings, when duly annealed, would be dumped out of the pots without having the scale adhere to them, and most of them were shipped without being soft-rolled. They had a beautiful blue to black surface, and after chipping, grinding, or straightening, could be shipped with credit to the works.

The sand blast is just beginning to find its way into our foundries. In Europe, cleaning by this method is further advanced, notably in the stove shops. It is an excellent way of cleaning castings, and has come to stay. Rolling barrels can be arranged to have the sand forced into them while revolving, and if the castings can turn in all directions, they will be thoroughly cleaned.

When the castings come from the tumbling barrels, either by wheel-barrow or overhead trolley, they go to the trimming room tables where the sprues are chipped off with the hammer and are sorted and gathered according to the shop order on file there. This is one of the most important departments of the works. Not only can much subsequent grinding and chipping of the soft castings be done away with here by properly trimming off the comparatively easily broken hard metal, but the reputation of the works can be kept high or made poor by the vigilance of the trimmers and inspectors. Any *jacking-up* that may have to be done by the president of a concern when he finds complaints about the appearance of the work coming in, is done here, for the works management is apt to shut an eye to poor looking work, so long as the castings are sound. Furthermore, as all the castings are counted and weighed here, the discount is determined, subject to an addition before the finished castings leave the warehouse. From here the reports go to the shop office, and what goes into the anneal is known day by day in preparation of the shipments on orders.

Another good feature which should not be omitted in this department, is the gathering of the rejected castings into piles for the inspection of the molders during the noon hour. A man doing piecework has the right to see the castings for which he receives no remuneration. Moreover, this gives an opportunity for the foreman to go over some of the molding problems with the men, as it is not a desirable thing to melt iron for scrap, nor to lose any more floor space for paying work than is necessary.

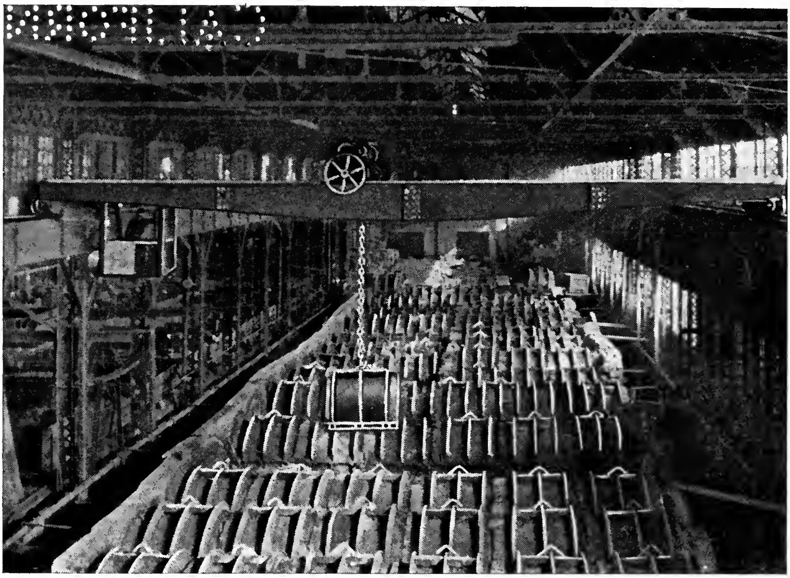


Fig. 26—Annealing furnace located in a concrete pit below the foundry floor level. From the crane is suspended a section of one of the furnace tops

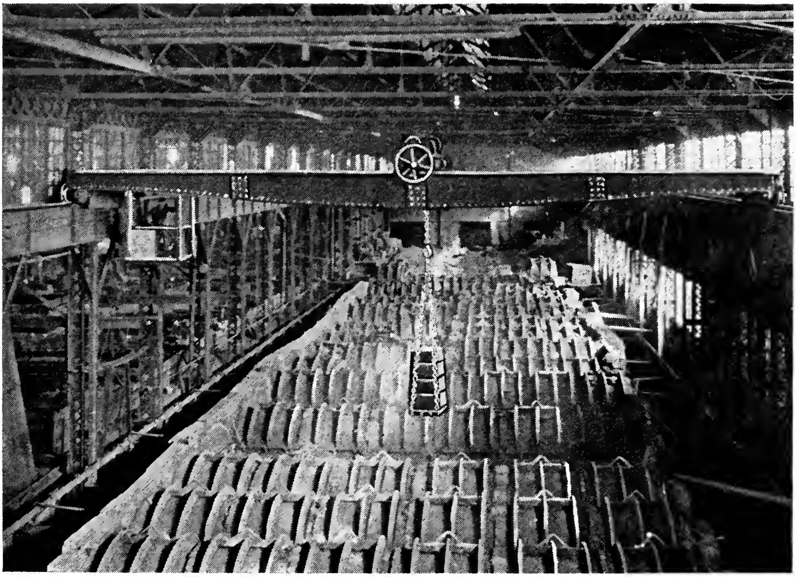


Fig. 27—Four charging pots suspended from an overhead traveling crane

Fig. 28—Pneumatic charging machine which serves the annealing furnaces, charging and discharging the pots

Fig. 29—Method of handling annealing pots with an overhead crane

Fig. 30—Interior view of a large, malleable annealing room

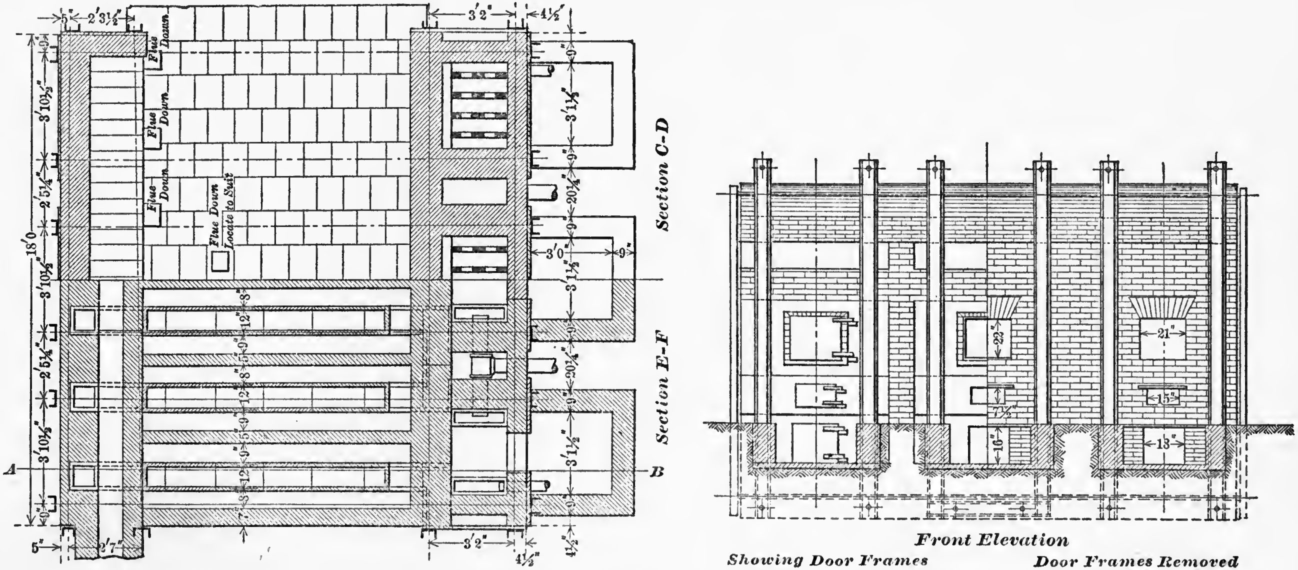
XII

Annealing Malleable Castings

FROM the trimming room, after inspection, the castings go to the annealing room. This department has its floor space divided into two portions, the packing floor, and the ovens. In the most advanced installations, where the ovens are dropped into the ground, and are practically soaking pits, a traveling crane doing the charging and discharging, the packing floor is at one end of the room, and the ovens at the other. In the older works, the ovens are usually in two rows, one on each side of the building, and the clear space between is used for the packing of the pots and manipulating the charging trucks, or the ovens are on one side only and the other is used for the packing.

The floor of the annealing room, where the packing and trucking are done, is covered with one-inch iron plates. These are cast as required, for the constant pounding on them and the effect of the heat tends to warp them badly, as well as breaking many. A floor of this kind withstands exceptionally hard usage. The annealing boxes or pots also called *saggers,* are heavy containers, either square, round, or more generally, oblong. When first cast, they are about one inch thick, with proper draft for the pattern. As they are used over and over again, if not broken the first time, being white iron they become thinner through the scaling-off of oxidized metal, and finally becoming too thin, they are scrapped. These pots are piled three and four high, and placed on a stool of iron, so that when luted up with mud, and similarly covered with this material—which is simply burnt sand from the rolling room mixed with water, and perhaps a dash of fire clay—or an iron plate, where particular care is to be taken, they make a more or less air tight receptacle for the castings packed in scale.

The scale used for the packing is more usually the cinder squeezed out of the muck balls where wrought iron is made. It is very rich iron



Front Elevation

Showing Door Frames

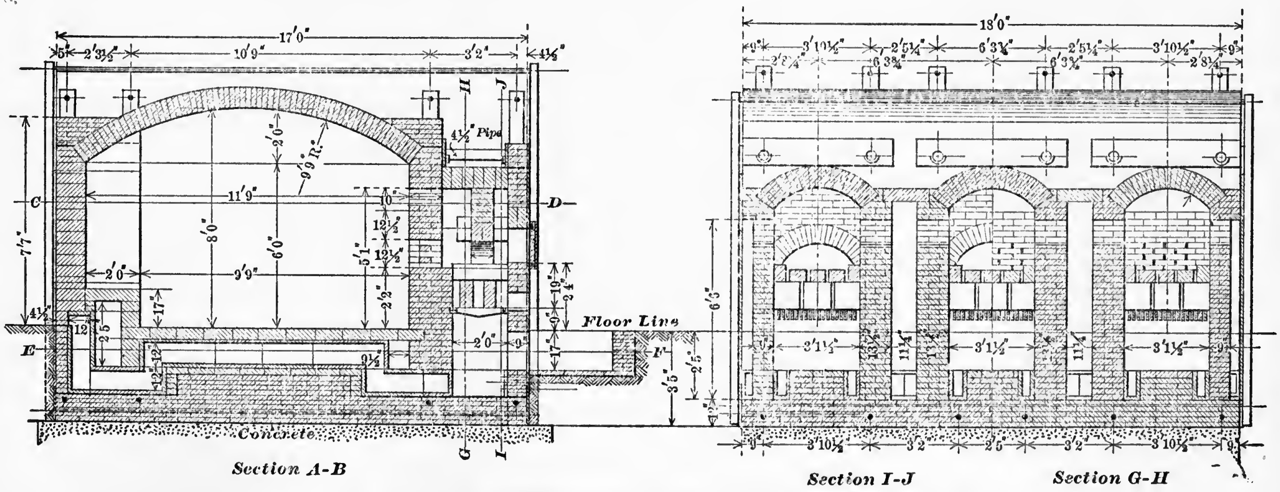
Door Frames Removed

Fig. 31—Plan and front elevation of a modern annealing furnace

slag, a silicate, with a lot of iron shot and small lumps in it. As this material is used over and over again, it becomes mixed with the flakes from the pots (which is the best material for annealing purposes when properly crushed), and gradually the scale pile becomes a more or less rich oxide of iron. This was formerly sprinkled daily with a solution of sal-ammoniac to *rust* it, and thus a nice little pile of money was thrown away yearly. Cast or steel borings are also put into the scale, but if at all salable, this process is a waste. The flakes from the pots, in all the older works, will be found to have made excellent roads around the premises, whereas the author, after purchasing the first batch of scale in the market, never bought any thereafter, the crushed flakes of the pots replenishing the supply, and necessitating an occasional screening to reject the fine powder which, through mixture with remaining sand on the castings, burns on in the anneal.

As the castings come into the annealing room, the operator places a pot on one of the stools, shovels in some scale, and lays the castings into this in regular order with scale to surround them, hammering the pot all the while to shake down the scale and tightly pack the castings. This is done to prevent warping as much as possible. The heavier classes of work are distributed in such a way that instead of bearing down on the smaller castings with their weight under the intense heat of the anneal, they rather support the whole structure. Many times, with flat work, it is not necessary to put scale between a batch of castings. Long, flat castings are placed upright, to remove the tendency to bend, and oftentimes, with brake rods, it is necessary to build up the boxes very high. The essential principles to observe are that no opportunity is given the mass to settle down and thus warp all the castings within the box, unless this settling is brought about by excessive heat ruinous to the castings, and to allow no chance for air currents to pass through the pots either through imperfect luting or settlement due to loose and careless packing. In the latter case, the work will be badly scaled away. Sharp corners will be rounded off to the disgust of the customer, or whole patches of the surface may lift off, and a very undesirable state of affairs will exist.

This scale is, however, not the only material for packing purposes. Hematite ore is much used, especially where cupola iron is the rule, and higher temperatures for annealing must be resorted to. More recently a very fine material has come in, and consists of magnetite from the



Section A-B

Section I-J

Section G-H

Fig. 32—Sectional views of annealing furnace shown in Fig. 31

Adirondack regions. This breaks in grains, and when sized to about a split pea, is just what is wanted for annealing work.

Intrinsically, however, sand and *brick bats* would answer for packing purposes, the real change in the castings being the conversion of the combined to an annealing carbon called *temper* carbon by the late Prof. Ledebur, of Germany. This change is brought about when conditions are correct as required by the malleable process for the black-heart castings made in this country, and practically any kind of packing may be used to protect the castings from the burning of free gases and excessive heat.

A number of tests on malleable castings annealed in the regular way and in fire clay, showed that when a packing is used that will not allow the carbon in the skin to migrate out and burn away—as it can in scale and ore—then the tensile strength of that casting is reduced by several thousand pounds per square inch. Hence, it would not seem advisable to change from the ordinary method of work. When the skin was machined off and the interior of these rather heavy test pieces subjected to the tensile test, the results practically agreed, and were not very much lower than the bars with the skin left on. This is stated here merely to offset the claim occasionally made that the interior of a malleable casting might as well be thrown away as the skin is the only strong part of it. Evidently the authors of such statements must have had in mind test bars, the centers of which consisted of a succession of heavy shrinkages. Normally made malleable castings should not show this to so serious an extent.

The pots duly packed and luted up, then covered with a coating of mud or an iron plate also luted tight, are now placed in the annealing ovens, in regular rows, with about four inches between them for the proper circulation of the gases carrying the heat. The ovens are luted-up and the firing commenced. This charging was formerly done entirely by hand-operated trucks, the forks of the truck passing under the stool, and raising it by a lever arrangement. Then a gang of men got behind and the pot was rushed into the oven in its proper place.

A radical change in the oven construction was devised by the author in building the works of the Pennsylvania Malleable Co., McKees Rocks, Pa. It was perhaps a rather bold departure. Thirty ovens of very large size were dropped into an immense concrete box, on account of occasional danger from high water. No braces of any account were provided, the tops were removable in sections, the construction was of the simplest kind, no tiles whatever being used, and an overhead crane was employed to do the work. The result was that the annealing cost was practically cut in half, and today the connecting wall of every second set of ovens has been taken out giving a single oven some 40 feet long, 11 feet wide and 10 feet high, fired at both ends, and working with a variation of but 50 degrees Fahr. throughout the entire interior. Fig. 26 shows these ovens in their pit, and one of the top sections suspended from the crane. In Fig. 27 are shown four pots being conveyed by the overhead crane.

But the old style of ovens have also experienced improved methods of charging, the old type of trucks finally being provided with power. This charging machine is illustrated in Fig. 28. The pots shown were, however, merely put on for the photograph, as they are not luted up or covered. Fig. 29 shows the method of transporting the pots within reach of the charging machine, the ovens being without the sphere of action of the crane. Fig. 30 gives an excellent view of the interior of an annealing room. There is shown first the iron floor plates, then the heaps of scale in the center, two completed pots on their stools, and the annealing boxes bowed out in the middle through the action of heat and interior pressure of the charge; finally the oven fronts with the doors on hinges, some of them open.

The construction of the ovens is in the main simple. Figs. 31 and 32 show a very good oven arranged for firing with coal. Ovens when built above ground must be tied together well, as they would otherwise soon go to pieces by reason of the expansion and contraction from successive firing. As a rule, they are used until they nearly collapse, and then a few more heats are taken from them on general principles. This is not very good for the castings as the variations in temperature must naturally become greater.

In the construction of an oven, the basic principle is the introduction of the heat from one convenient point, the spreading of that heat in a uniform manner, the holding out of as much free air—or in other words unconsumed oxygen—as possible to save the pots, and the quick heating and very slow cooling of the oven itself. It is, therefore, necessary to have the combustion space for the fuel no larger than absolutely necessary, the draft regulation perfect, the bottom of the oven underlaid by a series of flues which allow the gases to circulate before going up to the stack and thus get all the waste heat for use that it is possible to obtain without complicating the construction too much. It is not necessary to put flues in the sides or the top, as has been done, for the instability of the structure, unless heavily braced, makes this undesirable.

With a series of 12 ordinary ovens above ground and four of these sets each connected with a large stack, the waste heat was found to be so little that a concern that wished to put in hot water heaters for the boilers did not care to attempt the work. In fact it would probably have destroyed the draft.

A 4-inch lining of first grade fire brick for the sides, and a 9-inch lining for the top, with common red brick for the outside is sufficient for the annealing ovens. Where the removable tops are used, one thickness of arch brick on end alone is necessary, but the tops get pretty hot during the run. With so simple a construction, annealing ovens are not expensive, and it pays to have enough of them, so that the melting capacity of a works may not have to be curtailed while repairs are being made.

While Fig. 30 shows the doors of the annealing ovens hinged, this is seldom done, as the great weight of the construction tends to rack the oven. The doors, made in two sections for each oven, are usually handled by the truck similar to the pots. As the floor of the regular style oven is always laid with tiles, the cost for repairs on account of the damage done by the wheels of the trucks, is quite an item.

The firebox of the ovens is always built internal, in order to prevent undue loss from radiation. A long flame is desired, the ends of which come over the top of the fire box, and are deflected forward by the roof. With a good construction, when the oven is up to heat, only a foot of flame should appear over the top, and the dampers should be almost shut. The ideal fuel is natural gas, and with this it is simply necessary to arrange for three pipes into the fire box, loose brick closing up the entrance just sufficiently to furnish the necessary air for proper combustion. A very important item in this connection is the pressure of the gas, and consequent air supply necessary.

An elaborate series of tests made by the author to determine the difference of gas used at the ordinary fluctuating pressures of the city supply (between four ounces and 1½ pounds) and the same gas governed mechanically and issuing at two ounces, gave some interesting results which have a bearing on other methods of firing. The gas in the case of variable pressures was let into the oven fire boxes through three ¾-inch pipes, while the governed gas had three 2-inch pipes to issue from. The consequence was that with the larger pipes and slower flow of gas, this mixed with the air better and gave a good flame which rolled into the oven lazily, whereas the high pressure gas drew in a lot of unnecessary air, which tended to oxidize the pots unduly.

Among the results obtained with a large series of boxes carefully marked and watched, the following is of special interest. Three sets of pots, with boxes three-high each, were placed into an oven, with the gas not governed, the first in the presumably hottest place, or close to the fire box. The second set was placed in the center of the oven where the average temperature probably prevailed. The last set was located in the front row, or coldest point of the oven. These places were retained throughout the trial, the boxes kept in their relative position from the bottom to the top of the pot, and the pots returning to their identical points. As the boxes of the pots burned out, they were replaced by others, but a record of the used boxes was obtained. The same thing was done with another three sets of pots, this time with the gas governed.

The hottest pots lasted respectively 11, 15 and 16 anneals for the boxes from top to bottom with the gas governed, and 6, 8 and 10 the other way. The pots placed at the center of the oven gave 11, 13 and 14, respectively, gas-governed, and 7, 10 and 11 the other way. Finally the coldest position in the oven gave 16, 18 and 20 anneals for the gas-governed pots, and 8, 10 and 11 for the pots with gas at variable pressure. Rather strangely the hottest pots in the gas-governed oven suffered less than those in the center, whereas the reverse would be expected. Evidently this was due to the position of the pot which, while very hot, was protected more from the direct circulation of the gases in that corner of the oven.

The average life of the three sets of pots in the comparative tests was 15 anneals for the gas-governed series, and only nine for those in which the air currents were not kept at a minimum. The average weight of the boxes forming the pots was 316 pounds, and when wasted away too much for further use had dropped down to an average of 87.5 pounds. This shows what a large amount of money is lost by direct burning up in the annealing end of the malleable foundry, and why some of this should be saved by utilizing the flakes, after the luting has been picked out as clean as possible, for replenishing the supply of scale.

The tests referred to were made with gas-firing, conceded to be the ideal method for cheapness and excellence in results. When it comes to coal-firing, one hears reports of all kinds. Some works claim that their pots last for 30 heats, others confess to only ten. In no case, however, was there found, on inquiry, that tests were conducted with the care requisite for absolutely reliable results. The works giving high records were probably misleading themselves by watching those of the pots that lasted longest instead of getting the average.

The introduction of the steel pot had helped greatly, as it is possible with cast steel to withstand high temperatures longer than with cast iron. The carbon of the steel, however, must be as low as possible, so that the danger point is not reached in the ordinary annealing temperature.

A further point to be noted is the annealing temperature. When this is very high, as for cupola iron, the pots necessarily suffer more. The part of the process hardest on the pots is when the top bricks of the doors are removed. This allows cold air to rush in, and if not done carefully, a shower of sparks of the finest kind sweeps out of the oven indicating heavy oxidation of the pots going on within.

As natural gas is not always available, the next best fuel is producer gas made from soft coal. This is preferable to the use of the coal direct, on account of this very wasting away of the annealing boxes when the supply of air cannot be regulated nicely, as in the case of an open coal fire. Nevertheless, the author would not recommend the installation of a producer gas plant specially for annealing purposes, unless open-hearth melting furnaces are used in the first place. It is more satisfactory and about 10 per cent more economical to work with gas, but it takes more skill, and a small plant could hardly afford the expense of the installation, while the large plants will eventually all come to the open-hearth when castings are more generally bought under specifications.

The application of producer gas to the annealing oven is not a simple matter as it is necessary to get a proper adjustment of air and gas for economical results. The result of much experimenting has shown that it is best to keep the fire box inside of the oven as for natural gas, and to add a gas box just outside which allows the gas to enter into the interior fire box, or practically the combustion chamber, and at the same time have the oven draft bring in the necessary air. The dampers for air and gas have two ports, should be easily adjusted and not jam if heated red hot at times. The air for each of the two gas ports should enter above them, so that the upward tendency of the gas makes it break through the air current, and thus mix well. The arrangement must be, furthermore, so constructed that as little reflection backward of the heat of the burning gas acts on the fresh gas coming in, for if this gets too highly heated, soot is at once deposited and the ports are stopped up.

In using coal for firing the annealing ovens, care should be taken to get high quality fuel. It should be a good gas coal, low in ash and fairly so in sulphur.

The fires should be kept clean and be attended to regularly. The supply of coal should be convenient, thus offering no excuse for neglect in night firing. As the quantity of coal is not large for each oven, firing is done by hand sufficiently cheap to preclude the installation of machinery in most cases. However, as labor is seldom a reliable quantity, and as especially at night, there is great danger of either over-firing at times, or neglect of work in general, the installation of mechanical stokers has always seemed very desirable. It has remained for Germany to make the first successful installation on a large scale in this respect. In the plant in question a very poor grade of fuel is used from necessity. Some twenty annealing ovens are supplied regularly by a complete conveying system, and the ash is also taken out automatically. It is interesting to note that the ash drops into a water-sealed ash pit, thus cutting off all draft other than that provided by proper dampers. Probably this extreme precaution is the reason for the perfect success attained. It is to be hoped that the mechanical stoker will be applied to annealing ovens in this country in increasing numbers. The more a plant can become independent of manual labor the better, provided brains are made available to use the mechanical contrivances to the proper and fullest advantage.

Oil is also used as fuel. The author has successfully used this for annealing purposes, with ordinary and superheated steam, compressed air, low pressure air, and direct without any carrying medium. The best results were obtained by having the oil under 40-pound pressure throughout the works, and governed so that as the pressure went down the pump would start automatically. The oil was directed into the fire box of the oven through a very fine hole in the end of a ⅛-inch pipe, provided with a strainer to prevent clogging. This small oil pipe was inside of a 2-inch pipe, which was provided with a heavy cast iron nose on the end to retard burning off. The point thus made could be easily replaced without difficulty when necessary. Within the fire box a large tile was set on end to receive the spray of oil carried by the air from a blower, at about three ounces pressure. Below the tile, as well as the burner proper, and to cover the old ash pit, a floor was laid of fire brick on 2-inch pipes through which the air passed before entering the burner, thus, in a small measure, preheating it. Through this floor at the rear, openings were left, also behind the tile nose, to receive the oil and spread it, through which openings air passed upward, thus assisting in the combustion. The result was an intense heat, with a long flame, and very little gas carbon was deposited.

In general, oil is not to be recommended for annealing purposes, as the action is intensely local, the portion of the crown right above the fire box going to pieces in a very short time. However, good results are obtained so far as the castings are concerned, and where oil is cheap and coal expensive, it should be used by all means.

Pulverized coal has also been used with success. The fuel is ground very fine and blown in directly just as oil would be used. As the future, however, rather favors the gas producer, which will cost no more for installation, and is far safer to operate than grinding coal to the fineness required and storing it, it is a question whether, except in isolated cases, the direct coal-firing method in dust form will become an important factor in this country. Those who have perfected its use do not say much about it, except that it works satisfactorily.

Annealing the properly made hard castings is really a science, and many are the difficulties experienced where the proper means of control are not at hand. It may safely be said, however, that ten to one of the troubles encountered in annealing malleables come from improperly made hard castings, oxidized to a sufficient extent to resist heat treatment, and yet not showing this condition to the naked eye.

Let us suppose, however, that the castings were made right and have the proper composition. Then there are two ways in which the heat treatment, or annealing, as it is commonly called, may be carried out. First, a very high and short heating, and second a low and long one. The latter is the one used in this country for the production of the ordinary *black-heart* malleable, while the former is the *ignis fatuus* of the short-anneal inventor. With the higher temperatures, however, and longer time than even the regular American annealing process, we get the European *white-heart* malleable casting, and this is oftentimes produced here, as well as when defective material is reannealed several times to make it pass muster in bending, twisting, etc., and to some extent also in the annealing of cupola work containing high sulphur.

Black-heart malleable castings have a characteristic fracture. The core is a velvety black when the total carbon is at a maximum, and a lighter shade and of irregular structure when much steel is used in the mixture. A thin band of white forms the circumference, probably not over 1/16 inch in good work. Between the two lies a band of black of still lighter shade, corresponding to the crystalline structure of the original hard work, these particular crystals all being at right angles to the surface.

In the case of the European malleable, the fracture is steely with rather coarse structure. The material, however, bends excellently, and is very good, though slightly weaker than the *black-heart.* One seldom sees it this way in heavy sections, in fact when thick, it is inferior and not properly decarbonized.

A large number of annealing experiments were made in which a series of test bars were packed in scale the usual way, but enclosed in special, small, heavy boxes with iron covers, or in capped, iron pipes. Then these boxes or pipes were placed on top of selected pots with arrangements made to get them out of the oven as desired. These tests have given some clue to what goes on during the heat treatment. Normally, the process of annealing is to bring the oven up to heat as quickly as possible without exceeding the proper temperature; then to hold this maximum temperature for at least 60 hours; finally to let it drop as slowly as possible or convenient until black heat, when the pots may be drawn, allowed to cool still further, and finally dumped. In carrying out some of the above mentioned tests, enough boxes were filled with bars—all from the same part of the same first class heat of metal—and placed as far into the annealing oven as could be conveniently reached with a bar through an enlarged peep-hole in the door. Being on top of the pots, they got the full heat of the oven and naturally annealed quicker than the work in the pots themselves. One of these boxes was taken out every six hours, or four per day of 24 hours. After cooling, the bars were broken, and the fracture studied.

It was very interesting to note how the color of the fracture became darker, shade by shade, but still held the crystalline formation intact. Then, minute spots of black appeared which, when lifted out with a fine needle under the microscope, proved to be lamp black that evidently had been separated out between the larger plates of crystalline iron. The crystalline structure then began to disappear and the carbon spots spread uniformly all over the fractured surface, but not from the edges inward, as might be expected. As the heat the bars received was greater than the pots, in a measure, the annealing to *black-heart* was completed some time ahead, and hence, several bars could be taken out which had received too much heat. These showed decided *over-anneal,* that is, the normal thin white edge spread inwardly, with a distinct crystalline, but entirely different appearance than the original hard metal, and not parallel to the edges, but closing in around the central, black core. The tests always ended with this, but others made with a specially high heat, had this white, crystalline fracture which completely obliterated the black core, and the metal broke off very short. Had the process continued, without having the heat exceed a danger zone, European *white-heart* castings would have been produced.

That there is such a danger zone was distinctly and in a very expensive way demonstrated one night, when the annealer preferred the congenial atmosphere of a Pittsburg *speak-easy* to his work. The pressure of the natural gas rose suddenly and for several hours the temperature of a bank of 20 ovens went up to an unknown point. Next morning, a sadder lot of pots could not be imagined. They were wilted, tops sunken, and when finally removed and sledged apart, gave a collection of castings bristling with an enameling of scale and fractures, the crystal facets of burnt iron—dead white—being up to ¼ inch across. This, of course, is seldom seen in a malleable foundry, but shows that a high temperature and a short anneal may lead to disaster until more of the fine points are known. For this reason, all ventures based on quick annealing methods have so far uniformly failed, unless a return was made to the established process. This does not mean that we will not learn more about this subject, but until we do, it is wiser to let well enough alone.

We may, therefore, confine ourselves to the two standard processes. In the case of the *black-heart* the temperature of the pots in the oven—*not of the oven, but the pots in the oven*—should be kept at such a temperature that when this is taken at the coldest spot on the coldest pot, in the coldest part of the oven (which is the lower part of pots in the front row, the oven being fired from the rear) it will be about 1,350 degrees Fahr. It may be allowed to come up to 1,400 degrees for a short time if the oven is in fine condition, and as low as 1,250 degrees if the oven is rather old and the range of temperature within larger; but 1,350 degrees is the best all around heat. This, of course, refers to furnace iron, either air or open-hearth. Cupola iron temperatures should be from 150 to 250 degrees higher.

In case natural gas is used, and the supply is inadequate, some risk must naturally be taken in the matter of temperatures, and the author has found that when 1,250 degrees Fahr. has been reached in the pots, as previously described, and this temperature maintained for a period of 12 hours continuously, the readings could fall to 1,100 and even 1,050 degrees for a brief period at a time, and good annealing results obtained. The front, or coldest row of pots would, however, have to be watched closely, so that unannealed work might not pass through. This was simply returned again, either without disturbing the pots when it was positively known, or repacked with the new castings made. It was thus possible, in spite of difficulties arising from a short supply of gas, to get out important work for quick shipment, as the interior of the ovens was always hotter than the front.

While it is advisable to give 60 hours after full temperature has been reached, this is by no means obligatory. An ordinary heat, instead of taking six days for the cycle, can be completed in four, even with such heavy work as couplers, but the results are not of the best for safety. This helps to explain, however, why it is possible to get annealing effects with lower temperatures. Indeed, investigations made by the Smithsonian Institute on meteorites have shown that it was possible to trace the change from combined to *temper* carbon as low as 800 degrees Fahr., provided sufficient time was allowed for it to take place. All ovens will not come up to the required heat at the same time, depending upon their construction and location with reference to the stack. Thus, the smaller type with strong draft, will be up to full heat in 24 to 36 hours, while the old-fashioned double oven, if large, oftentimes takes 48 to 60 hours. If no leeway were permitted in the matter of holding up to the maximum temperature, it would not be possible to operate the annealing room with clock-like precision.

The pots should never be dumped while red hot. The metal always suffers. All the advantage gained by holding the temperature long and cooling very slowly is thus lost, and one might as well have made it a four-day affair. The immediate result can best be explained by noting the effect of hot-straightening a piece of malleable. If a casting has to be straightened before shipment because of warping in the anneal, this should be done cold. If made red hot and hammered, the *black-heart* will disappear, and the fracture becomes a brittle and finely crystalline white. This is especially serious if only one end of the casting has been thus treated. It will break at that point every time. For very thin casting, this, of course, does not hold, as they are usually so decarbonized, even in the *black-heart* process, that they would still bend and remain fairly soft, even if they should become white again. Some very interesting effects are obtained by hardening and tempering malleable castings, and this again forms the basis of much spurious *cast steel.*

The trouble is, however, that sometimes a malleable casting is so sensitive that it becomes very brittle, if not actually white, when dumped red hot from the anneal. It becomes air-quenched. It is a well known fact that ovens drawn so that the dumping of the pots takes place on Monday morning, when they are perfectly cold, always yield the softest castings; hence, strict attention should be paid to this part of annealing room practice. When the ovens are ready to have the firing cease, they are opened very slightly shortly after, so that the heat can escape. This helps to reduce the time for this operation. If, however, this is not done judiciously, that is, if strong air currents are allowed to be set up in the interior, one can plainly notice the wasting of the pots, the draft carrying myriads of tiny sparks of burnt iron outward.

For making the *white-heart* malleable castings, the annealing temperature is not only higher than for *black-heart,* but longer continued. It would practically correspond to our cupola iron temperatures, and instead of 60 hours maximum in anneal after being up to heat, it would be more nearly 100 or even 120 hours, with the same slow cooling.

Just why there should be a difference in the temperature required for castings of the same composition when made in the cupola or in the air furnace, is one of the unsolved problems. It may be chemical in that the degree of oxidation has its effect on the opening up of the structure under the influence of heat. It may, on the other hand, be a matter of molecular physics, and depend on the constitution and structure of the castings as made, either in the contact of fuel with iron, or not. Possibly it may be a combination of both, the chemical and the physical. Yet the problem still remains to be solved.

As to the occurrences in annealing, as previously stated, the *desideratum* is the conversion of the combined to an annealing carbon, called *temper carbon,* whatever may become of this afterwards. In the *black-heart* but little of this *temper carbon* is removed, and it is the opinion of the author that only that portion precipitated, as it were, out of the mass of iron, and lying in the band of crystalline material next to the skin which afterwards becomes gray or lighter than the center core, is removed, and that it migrates out rather than combines with oxygen from the outside. It further migrates out faster near the skin than near the center core. The author has invariably found that whenever oxygen did get into a casting in the anneal, through over-heating, and consequent undue opening up of the structure, or else through inability to resist penetration of oxygen by reason of too low an amount of silicon, it always gave the appearance of burnt iron. In fact it became the first part of the *white-heart* process. Unquestionably oxygen does play a part, taking out carbon by entering in the form of CO_2, this taking up an extra C and passing out.

It is quite manifest that the latter process is going to be most effective in thin castings, and published tests of European iron seldom show thicker metal than ½ inch round, which means ¼ inch to put under the influence of the process, which again in turn means that if the very center were unaffected, it would not affect the results. On the other hand, the *black-heart* process, which depends entirely upon the conversion of the combined carbon, can deal with castings several inches in thickness, provided these are cast in chills to get the metal white before annealing. The carbon removed from the skin, while acceptable, is not essential, and hence American practice, now already caring for fully 90 per cent of the world's production of malleable castings, will continue to dominate and when Europe begins to deal with higher prices for skilled labor, and does less machining on its castings, so that malleable castings are used as cast and not first turned off or otherwise finished, the *white-heart* method will be supplanted still further.

Mention should be made of the method of annealing without the use of pots at all. The rather small ovens required for this purpose, are still further sub-divided inside by brick walls, containing flues for the circulation of the gases. Into these spaces the hard castings are packed with the regular supply of scale, and instead of a collection of pots containing the work and packing material, the walls and subdivisions form the envelope from which the heat is made to penetrate through the contents. This method certainly saves pots, but has its disadvantages. It is difficult to carry out on a large scale, the lower portions of the work are apt to be under-annealed, and the upper burned. The thickness of the layer of scale and castings cannot be too heavy, as the heat from above and from the dividing walls must be able to get through as easily as would be the case in pots standing alone. On the whole, therefore, the process has found favor only in the smaller establishments, where the lighter classes of work are sought. Here, especially with long and complicated pieces, time can be taken to lay them out nicely in the oven, unhampered by the confined space of the pot. Warping is thus better avoided and satisfaction assured. Heavy castings bring difficulties and hence annealing of this class of work, without pots, is usually abandoned in the end.

XIII

Characteristics of Malleable Fractures

IN GRAY iron practice judging by fracture is so misleading as regards the value of the metal for melting purposes, that chemical analysis has practically superseded this method. Even for scrap, the fracture indications are not entirely conclusive, as artificial cooling of the metal by chills, unduly damp sand, or the reverse condition of the metal resulting from very heavy sections, make these unreliable. With *malleable* this is not the case, as the annealing process, if carried out properly, leaves the castings in their final form with a composition between pretty close limits. If not of proper composition, or not properly annealed, the fracture at once indicates this. It is, therefore, quite proper to judge a malleable casting by its fracture to determine whether it may be allowed to go out into service or not.

The characteristics of malleable fractures are not mastered in a day, and these have changed very much from the old charcoal iron castings with only pig and sprues, to the work made today, in which steel, annealed scrap, and even gray iron enter as an admixture. A classification of these fractures and a description of the illustrations in Figs. 33 and 34 will aid in drawing conclusions that will help in overcoming troubles. Unfortunately, it is very difficult to photograph a fracture so that it will show what is intended to be brought out. The surfaces are very irregular, and the light values, owing to shadows, are almost impossible to catch properly. However, the manufacturer of malleable castings, for whom, after all, this description is intended, will know just what is meant by going over his collection of *cripples* which, unfortunately, every one makes occasionally. The description of these fractures is, of course, intended to apply in the manufacture of the so-called *black-heart,* or American variety of malleable castings.

Fractures will either be black, white, or a combination of the two. Taking the white fractures first, these will be found to consist of metal that has either not been annealed at all, or is very much in the first stages of carbon change; or the castings have been what may be called *over-annealed,* which means that they were annealed to a black fracture and this has been changed to white again by exposure to higher than the proper temperature. This, as stated in previous chapters, means that if the anneal at this unduly high temperature could have been interrupted, the castings might have been satisfactory, as short anneals at several hundred degrees above the normal give the same results—almost—as the usual long anneal at the proper heat.

White fractures, arising from the castings not being annealed, may be again divided into those which are crystalline, of irregular, broken surfaces, in fact the counterpart of the hard casting, and those which have their crystalline structure destroyed. The former will be rarely seen in a malleable works, as long continuance in the ovens will leave a change sufficient to wipe out nearly all of the distinct crystalline structure of the hard casting, while yet being white or at least very much like a piece of oxidized silver, though not smooth. Such a piece, ¾ inch square (the photographs were all enlarged somewhat), is shown at *A,* Fig. 33. It will be noted that the crystalline structure characteristic of chilled white iron has disappeared. The piece is silvery, but no longer white, and a few, very small points of *temper carbon* have made their appearance. To illustrate the difficulty of obtaining a good photograph, it should be pointed out that the indistinct portion at the right is almost ¼ inch lower than the general level of the high points.

In *B,* Fig. 33, the carbon change will be seen to have gone further. The fracture is already a light gray. The surface is still very irregular, and along the bottom line will be seen a series of depressions, showing a tearing out of parts of the structure of the piece, which fractured first along the top and finally broke over. Both pieces are as weak as white cast iron, the latter, however, being much stronger than the first.

The annealing process advanced to a point where the next day would show the beginning of the *black-heart.* This is illustrated at

C, Fig. 33. It still belongs to the *white* class of fractures, though deep gray, and the fractured surface is already nearly flat.

An interesting fracture is shown at *D,* Fig. 33. With the exception of the rim around three sides, the fracture is similar to *C,* and its position in the scale of anneal is identical with this. However, the rim shown on the top and two sides, and a little over 1/16 inch wide on the sample—or just the band of crystalline structure in the original hard state, where these crystals are at right angles to the surface—is distinctly of a character of quenched tool steel. Here, evidently, in some way, the iron drawn too hot from the oven, was exposed to sudden cooling influences, sufficient, however, only to affect this regular band of original crystalline structure. The total carbon was evidently lowered considerably below the center, and hence the quenching effect is quite marked. That it is not very hard, however, is shown by the lower rim, which shows crushing and shearing effects, as the test lug of the coupler was bent over in breaking it off.

Attention should be called to the fact that these four pieces representing good malleable stock, if returned to the annealing oven, and given another run, preferably in the cooler sections of the oven, would have come out all right.

White fractures due to the improper constitution of the iron, so that the annealing process would not act upon it, will next be considered. In this class are irons that contain silicon below the lower limit of safety, with the other elements as they should be. This, as can be readily seen, will mean a progression of good malleable down to bad—which will be shown later—and iron which has the proper ordinary constituents, but has become oxidized in the melting furnace. Taking the latter case, the effect of undue oxidation of the bath is shown in its first stages by the *mushy* fracture appearance of the test piece taken before tapping. There is no longer the fine, silky, crystalline structure radiating from the center. It is true that this is also partly destroyed when the total carbon runs down, as the melting point, being up, the piece sets quicker, comparatively speaking. However, even this *mushy* iron will anneal. The next stage is indicated when the rim of the *tester* has pin holes, showing plainly that the metal has absorbed gases which develop in setting. This is usually coincident with a dropping in the silicon below the danger line, for with the proper composition of the charge, if the furnace is working

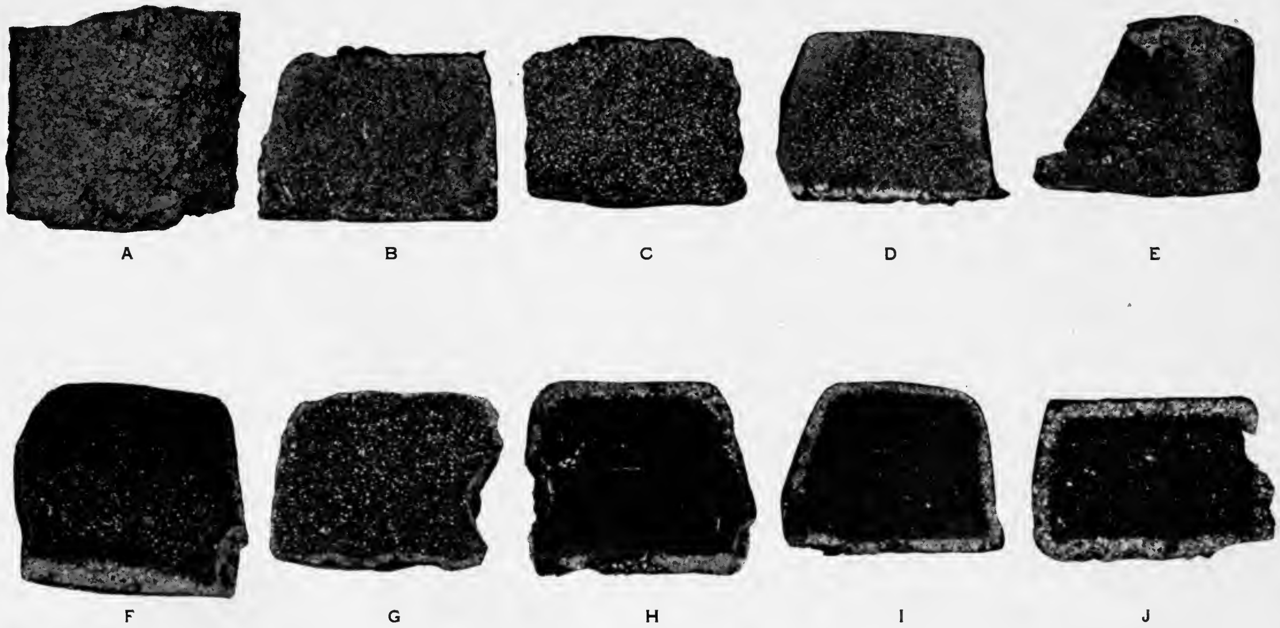


Fig. 33—Miscellaneous fractures of malleable iron showing poor and good material

all right, there should be no oxidation to speak of by the time the bath is ready to tap. When the heat is kept in the furnace too long, these pin holes appear and the castings begin to develop annealing difficulties.

The final stage is reached when the castings will not anneal at all. Usually, the absorbed gases are so marked that the castings are actually honeycombed. This is clearly shown at *E,* Fig. 33. In this sample, in spite of an absolutely unfit structure, the original white of what is left of the fracture, has been converted to a very light gray by the annealing heat. The reason for this is that the piece is still within the proper limits of chemical composition, so far as the silicon is concerned. This is also shown somewhat by the brightness of the blow-hole surfaces, where they were not exposed to the the air. In very low silicon pieces the honeycombing is usually so bad that nearly all the holes are connected and become oxidized or black on the surface. If, therefore, this metal had not been contaminted by dissolved oxides of some kind—likely by burnt metal in the charge or from the furnace bottom—it would have annealed satisfactorily. If of improper composition, the change to gray by the annealing heat would not have taken place.

We now come to the series of fractures, beginning with good malleable and shading to poor material by reason of a lowering of the silicon, but not undue oxidation in the melting. Here the array of crystals, perpendicular to the surface, becomes deeper as the silicon goes down, and the effect of the anneal is to burn these crystals to some extent—together with removing the carbon between them—if that is the proper explanation. In other words, the castings get a wider and wider rim of white, and become correspondingly weaker, while the iron begins to get *high.*

The fracture appearance of excellent malleable castings is shown at *F, G, H* and *I,* Fig. 33, the last two, perhaps, with the rim a little too wide. It is characteristic of such pieces, that just as the lower limit of silicon is reached—these happen to have 0.31 per cent silicon—the interior fracture surface, if the total carbon is high enough, has a fine, velvety appearance and no indications of interior shrinkage.

Nevertheless, these pieces are not as strong as the first two, with the silicon about 0.40 per cent, and in which the light spots are the reflections of crystals of minute size torn asunder in the breaking.

The lower rim in *F* shows how badly the piece was sheared in turning over as it finally broke loose from the coupler to which it was attached as a test lug.

In Fig. 33, *J,* and *K, L, M* and *N,* Fig. 34, show the downward progression of the silicon with the accompanying increase in the width of the rim, the last two even showing pin holes on the edges. Only the fracture, *J,* shows a solid interior of fine black, *K* and *L* having the odd characteristic of the white rim, then a fine black space between the rim and center. The center in these two specimens is quite strong, as it shows up badly when torn apart; *M* and *N* have very bad centers, the structure evidently becoming so open that the metal within was oxidized by penetrating oxygen from the annealing gases.

We now come to the second class of white fractures, those produced by *over-annealing.* Here the metal was originally annealed to *black-heart* malleable, but either the annealing temperature was too high, or the structure was too open, so that at what would otherwise have been the proper temperature, the oxidation of the metal was effected by a direct burning in the anneal. The probability is that both causes came to play in this series. The structure was too open evidently because the metal was slightly oxidized in the melting to start with, the heats having been held too long. At the time these were made, a steel melter had charge of the furnaces with the result that heats which should have been completed—between charging and tapping—in 2½ hours, often ran up to five hours, the open-hearth furnace being used. Instead of being charged correctly and rabbled well, the heats were allowed to simmer along after the manner of steel, and ferro-silicon was used to *dope* them back to the proper silicon before tapping.

Necessarily, the normal temperature of annealing would be very trying to this kind of metal, which, even if perfectly annealed, is considerably weaker than metal made properly. The fractures invariably indicate the creeping inward of the white exterior portions, but not with sharply defined limits strictly parallel to the outer edges. The white portion of this class of fractures is highly crystalline, but, unfortunately, like that of a badly burned steel.

The progression, with practically a constant composition, but increasing annealing temperatures, as taken from cooler and hotter por-

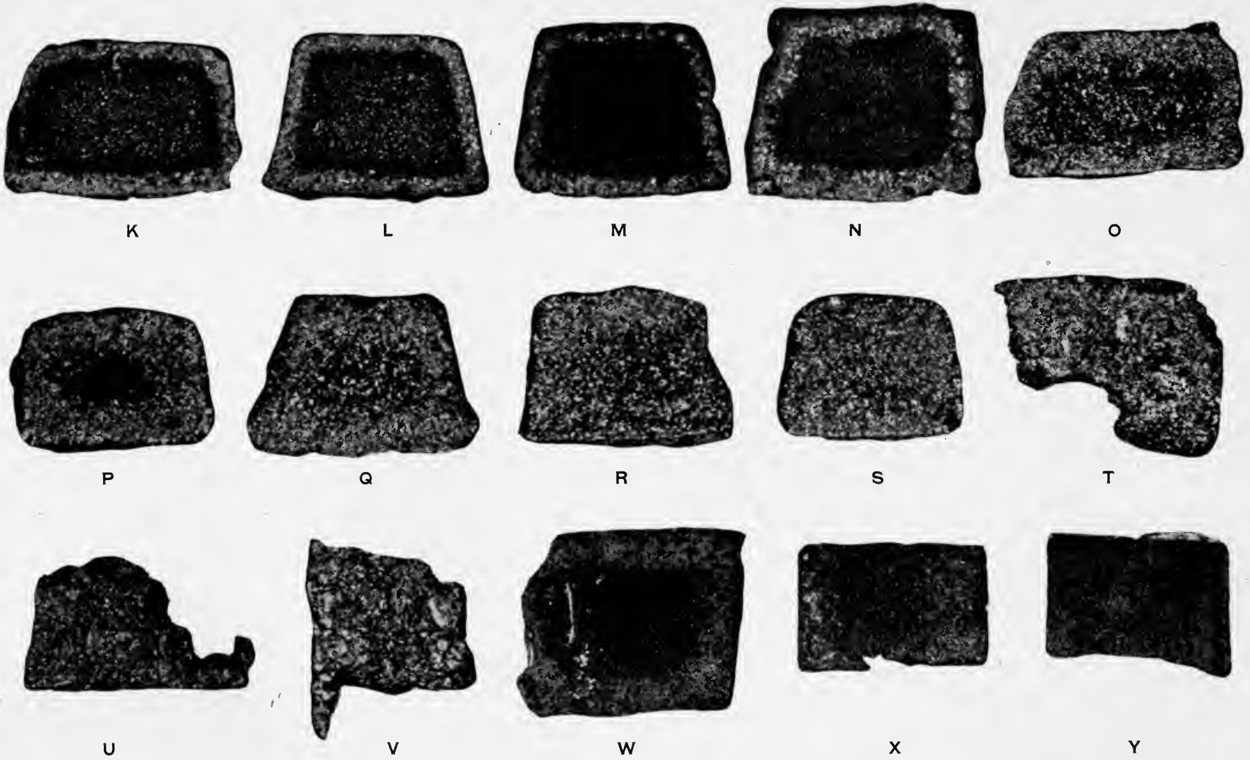


Fig. 34—Malleable fractures showing good and bad iron

tions of the pots and ovens, can be nicely seen at *O, P, Q, R* and *S,* Fig. 34.

At *T, U* and *V,* Fig. 34, we have the extreme cases of metal burnt in the annealing process. The photographs do not show the characteristic crystallization in which the facets of some of the crystals are over ⅛ inch across. The light spots in *V* give the best indications, for they are the mirror reflections of crystals of this kind, being oblique to the camera. It may be of interest to note that these particular pieces came from some 20 annealing ovens, the contents of which were ruined in a single night when the watchman took a notion to sample a neighboring *speak-easy.* The natural gas used for firing fluctuated considerably in pressure at that time of the year, and the consumption of large volumes of this rich fuel, for who knows how many hours, left a most disreputable collection of wilted *saggers,* melted *scale* inclusions and burnt castings unfit to use.

The last set of fractures which are met with in the malleable shop, and are dreaded most of all, are the so-called *low* fractures, and result from graphite separation in the hard castings. In other words, the hard castings were gray iron instead of white. The open structure, thus exposed to a high temperature for a long period, absolutely *rots* the metal—if such an expression can be used. It is weaker than the worst kind of gray iron castings coming from the anneal, often breaking by merely falling on the floor.

The oxidation extends through the metal, but strangely not leaving it white, but dark gray. Evidently the graphite protects the iron crystals somewhat, not allowing them to be acted upon like steel under the same conditions of temperature. That the metal portions must have been bright under the cover of graphite and that the structure has varying degrees of permeability to gases, is shown by the fact that castings of this kind, broken when still hot from the anneal, exhibit beautiful color effects—the colors seen in tempering steel—and these colors in distinct bands. The iron, therefore, is given the name of *calico* iron for a good reason.

This desperately bad material, which results simply from letting the silicon go too high in work of ordinary thickness, or from forgetting to apply chills for exceptionally heavy sections, is illustrated at *W, X* and *Y,* Fig. 34. The broad rim of gray around the black center in *W* is the characteristic. In *X* and *Y,* only the sides show the bands, the pieces having been cut through and the ends removed; *Y* happens to have a black center, and a red space between the black center and blue rims. The photographs, unfortunately, cannot reproduce these color effects.

As between this *low* iron and the *high* variety, the malleable man always prefers the latter, though he hopes and works toward avoiding both.

In judging by fracture, a careful inspector always takes into consideration the degree of softness, the bending, and the punishment the piece will stand before breaking, and also how it breaks, whether short or only after repeated pounding. Weak iron may still have a very fine fracture, and hence, in special work, recourse must be had to the information given by physical tests on specially prepared bars. For this purpose the set of specifications adopted by the American Society for Testing Materials is recommended. For ordinary commercial work, however, the proper fracture indication, coupled with the behavior of the metal itself under the blows of the hammer, breaking off the test lugs, is amply sufficient.

XIV

Use of Pyrometer in Annealing Room

IN MODERN practice it is essential that in any operation advantage be taken of every safeguard that may be available. Hence in every annealing room there should be a good pyrometer to keep track of the oven temperatures. The eye is not reliable enough for this purpose, and is the cause of much trouble in the old-fashioned plants. Probably the only guide the eye has is to note the cracks in the brickwork which, when appearing as white lines on a red background, indicate to the experienced operator that his temperature is about right. As the men detailed for this purpose are apt to get old in service, the eye loses its sensitiveness, and the result is either the under-annealing or over-annealing of the work. There are quite a number of pyrometers on the market but some types become unreliable when long in use. The Siemens pyrometer depends upon a given weight of water at normal temperature to which the zero of the scale is set, and into which a ball of copper, heated to the temperature of the annealing pots, as previously explained, is dropped. The resulting temperature, obtained under suitable precautions, sends the mercury thermometer of the instrument up to a point readily read off on the scale, and gives the temperature of the copper ball. The weight of the water is in fixed proportion to the weight of the ball, and hence this can change to a small extent without affecting results. As the balls scale off perceptibly, new ones of proper weight are substituted, and unless carelessly handled, this instrument remains serviceable for a long time and is absolutely reliable. The objection, however, is that it takes some time to get the readings. The copper ball must be held against the pot by an iron rod into the end of which it is inserted. It must remain in the oven about 15 minutes to properly acquire the temperature. Unless the test is conducted quickly and accurately, heat is apt to be lost, and the readings naturally will be low. The advantage is that the instrument is comparatively cheap, unless by carelessness, thermometers are broken.

The Le Chatelier pyrometer, on the other hand, depends upon the generation of a feeble current of electricity when metals or alloys of different kinds are joined together, and the junction is heated. This current is directly proportional to the degree of heat, and hence when measured by a suitable galvanometer, becomes very accurate and sensitive. While the Siemens pyrometer gets the true temperature within 25 degrees Fahr., the Le Chatelier comes within 10. The objection is the rather large first cost of a proper instrument, for unless the very best of this class is taken, troubles eventually crop up by reason of parasitic currents which develop in the platinum and platinum-rhodium alloy wires used.

As stated, quite a variety of pyrometers are manufactured for use in the annealing room. The two above mentioned are considered the most reliable, as the result of long experience with each. It does not necessarily follow that others are not equally as useful, and time will eliminate the weak applicants for favor.

The main thing in using a pyrometer, is to get the temperature of the pots and not that of the furnace proper, as otherwise the results are certain to be high and unreliable.

Of the two pyrometers above mentioned, and made by a number of manufacturers, only the best makes are to be recommended, as the others are liable to get out of order long before they should, the finer points of quality having been sacrificed for the sake of cheapness.

After the annealing has been completed, the pots are allowed to cool and then withdrawn from the ovens. They are next dumped on the iron floor of the packing space, and the castings picked out of the scale. This is shown clearly in Fig. 35. Naturally, some of the scale will adhere to the castings, and hence, in some works, a preliminary tumbling is given them to free them from this material and at the same time to save it. Usually, however, the castings go directly to the soft rolling room, where they either are placed in a number of the regular style rolling barrels, or into a long one set on an incline, the uncleaned casting going in on one end, and coming out cleaned at the other.

The very best material to add with the castings in these soft-

Fig. 35—Malleable fittings and other small malleable castings as they appear just after being dumped from the annealing pots

rolling barrels is the broken pieces of annealed castings, such as test lugs, and defective annealed work not liable to be mistaken for good. This rubs off the scale, and by reason of the contained graphite (*temper-carbon* is really amorphous graphite and acts similarly when used as a polishing medium) imparts to the castings a beautiful, glossy black finish.

The castings are now ready to go to the finishing departments. Depending upon the care originally exercised in the various preceding processes, there will be more or less work to be done before the castings can be shipped. Thus, with careless molding, castings will be over-weight, not true to pattern and the like. Careless trimming leaves much expensive work to be done in the grinding room to clean off fins, gates, and other excrescences, spoiling the appearance of the work. Bad packing leaves the castings warped, if not with wasted edges and corners; and so previous sins are all brought home to the detriment of low shop costs when the castings come from the soft-rolling room.

We, therefore, find in every establishment to a greater or smaller extent a chipping room where the rougher work is done in the vise by hammer and chisel; a grinding room where the lighter corrections are applied and finally a straightening department where this work is attended to, as well as where special jobs are gone over, such as getting pipe rings to true shape, forcing arbors through holes to make them pass the inspector's requirements as per specifications, etc. Here also are bent any castings, to their required shape, which are found advisable to cast straight originally.

The author again wishes to emphasize the importance of keeping these departments down to the smallest compass by previous excellence of workmanship. Every man used for chipping, grinding and the like, counts as unproductive labor. Every emery wheel—and some concerns have bills running over a thousand dollars a month for this item alone—is adding to the train of gold leaving the works to the waste pile. Such little items as seeing that the periphery speed of emery wheels is always at the maximum cutting rate, by having several changes of speed, and changing about wheels between stands running at different speeds, will help cheapen the cost greatly. The great place, however, to save is in the hard-trimming room, where gates and fins are knocked off while the metal is in the easiest state to do this. To see a row of grinding wheels in a plant of small tonnage is an evidence of carelessness on the part of the management. The same holds true where a line of chippers remove metal too expensive to handle by the wheels.

The castings now go to the shipping department or warehouse, as the case may be, under ordinary conditions. Oftentimes, however, it is necessary to galvanize or tin the work, and then the castings, after passing all the departments and being pronounced perfect, are subjected to these processes.

In the case of galvanizing, where we have to deal with baths that are too high in temperature, it very often happens that the work comes out too hard to thread afterward. The *temper-carbon* has gone back again, and a hard casting has resulted. While this may be avoided by changing the composition in various ways, or in other words applying metallurgical tricks, it is not a good policy. If the work were properly made in the first place, the composition correct, the metal not injured by oxidation, and the zinc bath not too high in temperature, the castings will remain soft enough to machine. It is advisable to introduce a second pickle between the first and the galvanizing. Thus, if either sulphuric or hydrofluoric acid is used for the first bath, a second with hydrochloric acid prepares the iron much better for the hot galvanizing than if the first pickle only were used.

Probably in no place will the introduction of the Sherardizing process be of so much value as for galvanizing malleable castings. This rolling of the work with zinc dust at temperatures below the melting point of that metal, will give the malleable casting a better chance than is the case at present. Furthermore, the zinc penetrates deeply into the body of the casting, and as such work is never used for important purposes, but rather only where protection from rust in addition to tightness against leaks is required, the probable loss of some of the strength by such penetration of the zinc will not matter materially.

For special classes of work the soft-rolling is carried out so carefully, by using leather scraps, old shoes and the like, that this not only cleans, but polishes the castings so nicely that they can subsequently be tinned, nickeled, and even silver and gold-plated, making the finest kind of art work, in which strength is combined with ease and cheapness in the making. Here the art blacksmith is done away with, and one piece is like another.

XV

Cost of Malleable Castings

THE malleable castings foundry being subjected to even fiercer competition than the ordinary gray iron foundry, the question of costs is all the more important. The work being practically all in quantity orders, it is expected by the consumer that costs are carefully kept and prices can be made on an equitable basis. Some manufacturers have, therefore, adopted systems which will allow the tracing of a particular casting through the shop, and they make a special price for each separate pattern bid upon. This has, so far, been considered unnecessarily complicated by the majority of producers who still make a pound price for the whole of the work bid upon, or perhaps divide this into classes with high or low molding cost, and high and low discounts expected. The very large works, especially those making railroad castings, are now taking orders on the thousand or over tonnage basis at a certain price per pound, patterns made by the foundry and freight paid to destination.

In discussing cost systems, the peculiar conditions existing in every locality naturally make it advisable to give only a general outline of the subject, and each one interested can carry it out in as much detail as he may desire. The basis of each system is probably best given in the carefully prepared report of the American Foundrymen's Association's Cost Committee. This, while made to cover the cost of gray iron castings, can be adapted to the production of malleable castings when the following points are taken into consideration: The total annual expenditure in a malleable shop is necessarily the total cost of the castings made. By dividing this with the net weight of good castings produced, the average cost per pound is obtained.

The first general sub-divisions of the total expenditures are into *Foundry Costs Proper* and *Commercial Costs.*

The *Commercial Costs* relate to the sales principally and include, for instance, the salaries in the sales department, commissions, traveling expenses, advertising, and such items which go to make up expense in the shop in connection with the closing of an order. In this division is also included a fair proportion of the *Administrative Expense,* but that portion only devoted to sales.

The *Foundry Costs* proper are sub-divided into four groups: (1) Metal; (2) Surcharges on metal distributed to classes on the basis of weight; (3) Applied labor charged to product and (4) Surcharges on applied labor, distributed on a percentage basis.

Looking over the probable items in each class will best explain what is meant. The *Metal* item includes the pig iron, scrap purchased, defective castings from the shop, the refuse metal from the cupola, air furnace or open-hearth, that comes from the cinder mill, etc., and the gates and sprues cleaned. The intention is to get the cost of the metal actually consumed, and the actual good castings produced, thus giving a very close check on this division of costs.

The next sub-division is composed of such items as cost of metal delivered at the yard. This includes labor for handling from cars, piling, etc., cost of labor and materials to cupola or furnace; costs to cover molten iron in the ladle, including cupola supplies, labor in charging, fuel, limestone, ferro-alloys, etc.; ladle expenses, preparing cupola and similar items. The next sub-division includes the cost of the molding supplies, sand, gravel, facings, chaplets, lumber for renewing flasks and the labor for this work. The last sub-division includes miscellaneous items, such as cleaning-up shop, recovering scrap, cartage, demurrage, power for yard and service about cupolas and furnaces estimated at a fixed rate per horsepower hour.

Next comes the sub-division of *Applied Labor.* We have here the pay of molders and their helpers, the apprentices, coremakers, cleaners and chippers. The coremakers, cleaners and chippers are only included in this sub-division if it is possible to charge them to individual jobs. If not, this expense is carried into the next sub-division distributed on a percentage basis as nearly as can be done.

Under surcharges on applied labor, we have the salaries of the superintendent, clerks, chemist and laboratory force, foremen, foundry office supplies, the proportion of the general administration expenses not charged to the sales department, and the power, light and heat, charged at a fixed rate per horsepower hour. In this sub-division are also included the wages of the carpenters, patternmakers and blacksmiths if this cost cannot be charged to applied labor, as well as the cost of maintenance and renewal of equipment, miscellaneous work and sundry supplies.

When all of these items have been properly classified, then together with the commercial costs, they give the total cost from which can be obtained the average cost per pound of castings.

This, while interesting is, however, by no means the end. There are castings and castings, and it would be foolish to take this general average cost, add a fair profit to it, and make bids on work that may be presented on this cost basis. Doing this would mean a dead loss on difficult or light castings, and a price on the ordinary sections in excess of commercial limits, which would result in a rejection of the bids.

It is, therefore, necessary to classify the work done into reasonably distinct divisions. To each division should apply a standard cost based on the shop experience, and to each is added a common sense division of the commercial costs. This will give the total cost per pound for each class. The totals are obtained by multiplying the actual weight of castings made in each class by its total cost per pound, as estimated. These totals added together, should nearly balance with the actual total cost for the year. If they do not, the per pound shop and selling cost for each class of castings should be reviewed and the proper corrections made. Experience has shown that this can be arrived at very closely, and in this way a very accurate per pound cost for the various kinds of castings made in the shop can be obtained.

While each manufacturer knows his business best, and in times of stress it becomes necessary to sell castings at cost, in order to hold the organization, the wise man never sells below cost. Were the makers of malleable castings better informed on the subject of their own costs, they might be in better position to let work pass them when too low a figure is offered. As it is, they often accept this business believing that they will squeeze through at cost, whereas they are losing heavily on such jobs, other classes of work carrying them. In this way buyers are accustomed to low prices, and in this day this is the last item to advance.

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