Dr. Edward Kirk's

System of Foundry Practice

Cupola Practice

THIRD EDITION

938 NORTH TENTH STREET
PHILADELPHIA, PA.

Cupola Practice

The Cupola

CHAPTER I

The word "Cupola" covers such a variety of objects that another word should be used in conjunction with it to indicate the object referred to, such as cupola furnace or foundry cupola, but to men familiar with foundry practice the word cupola is sufficient.

The cupola, in the melting of iron, has many advantages over any other melting furnace for foundry work. It melts iron with less fuel and more cheaply than any other furnace, and can be run intermittently without any great damage due to expansion and contraction in heating and cooling. Large or small quantities of iron may be melted in the same cupola, and the longer it is kept in blast the smaller the per cent. of fuel required in melting. These advantages have made it the melting furnace almost exclusively used in gray iron foundry practice.

Theoretically, a ton of iron can be melted in a cupola with 172 pounds of coke, but in practice 250 pounds are required in long heats, and in short heats 300 pounds. This is due to the same amount of fuel being required for the bed for a short heat as for a long heat.

The reverberatory furnace, a limited number of which are used in grey iron foundries in melting for special castings, requires from ten to twenty hundredweight of fuel to melt a ton of iron.

The pot furnace, in which the metal is melted in crucibles, requires a ton of fuel to melt a ton of iron.

In the blast furnace twenty to twenty-five hundredweight of coke is required in the smelting of a ton of iron.

It will thus be seen that in the cupola furnace we have the minimum consumption of fuel in melting a ton of iron, and it is also the most convenient and rapid melting furnace for foundry work, which accounts for it having been almost universally adopted as the melting furnace in grey iron foundry practice.

The objectionable feature of the cupola in the melting of iron is that the iron is melted in direct contact with the melting fuel and takes up impurities from the fuel in melting, which deteriorates its quality. But this objection has been overcome to a very considerable extent by the improvement in the manufacture of coke, which has become the universal cupola fuel. Also, by a more thorough knowledge of the inside working of the cupola when in blast, and correct method of charging fuel and iron.

The principal injurious element that is absorbed from the fuel in cupola melting is sulphur. The injurious effects of this element upon iron may be completely eliminated by a mixture of iron, made by analysis, to destroy the effect of sulphur upon the iron, which makes the cupola, the ideal furnace in foundry practice when properly managed.

Improvement in Cupolas

In no branch of foundry practice has there been more inventive genius and money expended than upon the improvement of the cupola. The cupola first used in this country was the old-fashioned English cupola; this cupola, as originally designed, was constructed of cast-iron staves, bound together with iron hoops, to form a cylinder or casing of a desired size. This casing was set on end upon a stone foundation that extended two or three feet above the foundry floor, and lined with soapstone or other refractory material, as was also the cupola bottom. An opening was placed in the staves on opposite sides of the casing, eighteen to twenty-four inches above the bottom for two small tuyeres, and a larger opening was provided at the bottom, at the front of the cupola, for a tap hole and for removing the dump or refuse after melting, which was drawn out with a hook or rake. This was known as the draw front cupola.

These cupolas were generally of small diameter and only seven or eight feet in height. For the support of the stack, four cast-iron columns were placed upon the corners of the foundation and upon the top of these was placed a cast-iron plate, on a level with the top of the cupola, and upon this plate a square stack was constructed of red brick.

The objectionable feature of these cupolas was that they were slow melters, which was due to the cupola being low and much of the heat escaping up the stack, and the tuyeres being too small to admit a sufficient volume of blast and properly distribute it for rapid and even combustion of the fuel. Another trouble was the bridging and bunging up of the cupola in long heats to an extent that it could not be raked out at the front.

To overcome these troubles, the larger foundries, making an occasional heavy casting, put in three cupolas of twenty, thirty and forty inches diameter, and for a heavy or long heat put one or more of them in blast at the same time.

Numerous attempts were made to improve this cupola, one of which was to construct a cupola of a larger diameter at the bottom than at the top. It was hoped that the taper, given to the cupola in this way, would prevent bridging an hanging up of the stock, but this proved a failure. The first improvement that proved of real benefit, and was generally adopted, was the drop bottom; this permitted the contents of the cupola to drop out at once when hot and the slag liquid, and saved a great deal of hard, hot work in raking out, which frequently was a very difficult matter, as cold air rushed in as soon as the front was taken out, which chilled and toughened the slag.

With the introduction of the drop bottom an iron bottom plate became necessary upon which to hinge the bottom door and provide room for the cupola dump. This plate was supported upon brick walls on two or three sides, and, later on, upon brackets cast upon the columns supporting the stack. This was the first real improvement in cupola construction, and as rolled plate became more plentiful the casing was constructed of boiler plate in place of the cast staves. Many of these improved cupolas are still in use, and, as the tuyeres have been enlarged, the only objectionable feature in them is the height of the cupola, which is seldom over ten feet in large cupolas and those of smaller diameter, eight to ten feet.

These improvements in construction did not improve the melting, and it was the practice to put on the blast immediately after the noon hour and blow all afternoon in running off the heat.

Mackenzie Cupola

The next improvement of note was the Mackenzie cupola designed by Mr. Mackenzie, a foundryman of Newark, N. J.

He also designed the Mackenzie blower, which was the first positive or pressure blower designed for a cupola. The cupola and blower were sold together, for the fan blowers of that time could not be used with this cupola.

This cupola was constructed oval in shape and contracted above the charging door, and had a round stack. The cupola and stack casing, which were made of boiler plate, were constructed in one piece and was probably the first cupola in which the iron columns and brick stack was done away with.

The cupola was provided with an inside air chamber and a tuyere extending around the cupola, formed by an apron riveted to the casing at the top and extending out into the cupola at the bottom to form an overhanging bosh and support the lining. The bottom of this chamber was open and the blast was admitted to it through a large square opening at each end of the oval casing, and escaped into the stock from under the air chamber which ran around the cupola, thus forming a continuous tuyere.

Prior to the introduction of this cupola it was the practice to put on the blast immediately after the noon hour and melt all afternoon in running off the heat. This cupola was a fast melter, and Mr. Mackenzie gave it the name of the two-hour cupola, which meant that a heat could be melted in two hours. Cupolas were constructed of different sizes to suit the size of the heat.

This cupola was introduced about 1860 and soon became the leading cupola. Many of them, with their blowers, were placed in foundries all over the country, and some of them are still in use. But it had its objectionable features, one of which was a great tendency of the lining to build out at the lower end of the bosh, with a very hard combination of slag and iron, which was difficult to remove. When this building out was permitted to go on for a short time the cupola became a slow melter and bridged badly.

It was called a two-hour cupola, and when run for any great length of time, bridged badly, even when the lining was kept in proper shape. Slag could not be tapped from it. With the enlargement of foundry plants and requirements for longer heats a more modern cupola was sought for, and this one gradually went out of use.

Truesdale Cupola

The next cupola to attract attention was the Truesdale cupola, designed by Mr. Truesdale, of the Reasor Stove Works, Cincinnati, O.

This was a round, straight cupola, with an inside air chamber formed by cast-iron staves shaped to give a bosh at the bottom of the cupola and a taper back from the bosh to the straight lining. The tuyeres consisted of a series of round openings of from one inch to three inches in diameter. These were made of cast iron and fastened to the staves by cleats cast upon them. The three-inch openings were placed in a row three or four inches apart around the cupola at a proper height above the sand bottom, a second row of a smaller diameter was placed over each tuyere in the first row, but only one inch above it, and another of smaller diameter one inch above this, and so on, until six, eight or ten rows were put in, the lower one being three inches and the top one one inch in diameter. This tuyere was called the Truesdale reducing tuyere.

These tuyeres were placed so closely together that fire brick could not be placed between them, and a plastic cupola daubing was placed between them to serve as a cupola lining.

One of these cupolas of larger diameter was placed in the Reasor Stove Works foundry, Cincinnati, Ohio, at which Mr. Truesdale was employed, and did the fastest and most economical melting of any cupola designed up to that time, and a large number of them were placed in foundries in Cincinnati and vicinity about 1873-4.

This cupola had its objectionable features. The placing of the inside air chamber in cupolas of small diameter contracted the cupola to so great an extent as to promote bridging, and only short heats could be melted in them.

In cupolas of large diameter the smaller tuyeres in the top rows frequently collapsed or became filled with iron or slag and had to be removed or replaced with new ones. There was so much detail in keeping this cupola in good melting condition that it never came into general use and only had a local popularity for a short time.

Lawrence Cupola

This was another inside air chamber bosh cupola, with a reducing tuyere. This cupola was designed by Mr. Frank Lawrence, foreman of the American Stove and Hollow Ware Co.'s foundries, Philadelphia, Pa., and was placed upon the market by him.

The cupola was egg-shaped, contracted at the tuyeres and charging door, and larger in the center or body of the cupola.

The tuyeres were three or four inches square, with a reducing slot extending up ten or twelve inches from the square tuyere. The slot was one and a half inches wide at the bottom and half inch wide at the top. This tuyere was placed in the cupola eight to ten inches apart, around the cupola, and held in place by dovetailed cleats cast upon the cast-iron staves that formed the air chamber. The cupola was designed for either coal or coke melting, and was a rapid and economical melter.

But the staves forming the air chamber frequently broke, due to repeated heating and cooling, and had to be replaced. The reducing slot tuyere, over the square tuyere, collapsed or became clogged with iron or slag and had to be removed and replaced, and when they were not carefully attended to and kept open the cupola melted unevenly and there was so much detail about keeping it in order that very few of them were placed in foundries, and Mr. Lawrence, after spending a great deal of money and time in his efforts to have it adopted by the foundrymen of 1873-4, gave it up and retired from the cupola business. There is probably not one of these cupolas in use at the present time.

Pevey Cupola.

This cupola was designed by Mr. Pevey, foundry foreman of the Lowell Machine Shop, Lowell, Mass. It was a flat cupola, with square corners and a sheet blast or slot tuyere on each side. The casing and stack were constructed of boiler plate and the stack supported on iron columns.

The large cupolas were made forty inches wide and of a length to suit the size of a heat, some of them being eight feet long. The smaller ones were twenty or thirty inches wide, and those designed for light heats were practically square cupolas.

The object of Mr. Pevey in constructing a cupola of this shape was to force the blast to the center of the cupola and give an equal distribution of blast and thus produce even melting. This result was obtained and the cupola proved a fast and economical melter, but it had objectionable features. The principal one was its great tendency to bridge over the tuyeres and hang up, and also the tendency of the flat lining to collapse. This tendency was so great that it had to be lined with square blocks and every one of them bolted or fastened to the casing, which also gave way if not very heavy and strong.

Only a very limited number of these cupolas were placed in foundries, and probably the only one now in existence is one in the foundry of the Pevey Foundry Co., Lowell, Mass. On my last visit to this plant I was informed that this one had not been in blast for several years and was only kept in place through respect for its inventor, who was founder of the Pevey Foundry Co. plant.

Colliau Cupola

The Colliau cupola was a cupola of French design, introduced into this country about 1875 by Mr. Colliau, from whom it received its name.

It was a round cupola, with an outside air belt extending from just above the top tuyere down to the cupola bottom plate. The tuyeres were placed in three rows, and in cupolas of large diameter, in four rows, one row above another, but staggered so that one tuyere was not placed directly over the one in the row below it. The lower row was placed eighteen to twenty-four inches above the bottom, and the rows above it ten inches apart. The first row went straight in and the upper rows pointed downward at a sharp angle.

Mr. Colliau later on extended the air belt up to just under the charging door and enlarged it to a considerable extent. The blast was admitted to this belt at the top, on opposite sides of the cupola, and passed down to the tuyeres. This construction was designed to heat the blast by heat escaping through the cupola casement.

Mr. Colliau called this his hot blast cupola, one of which he placed in the Tacony Iron Works, Philadelphia, Pa. They had some difficulty in getting hot even iron from this cupola and I was called upon to locate the trouble. I melted a few heats in it, but failed to find any perceptible heating of the blast in any part of the heat, but by closing the top row and reducing the size of the second row of tuyeres I succeeded in getting them hot even iron.

His arrangement of tuyeres in this cupola and also in his regular cupola required a very high bed, and was very extravagant in the use of fuel, and the size and arrangement of tuyeres was very destructive to the cupola lining. In some cases a four-inch fire-brick lining was burned through in one short heat. Although the cupola was a very rapid melter and produced hot iron, it proved a complete failure, owing to the extravagant use of fuel and heavy expense in keeping up the lining. Many of them put in on approval were rejected after a short trial and had to be taken out.

This was said to have so worried Mr. Colliau's financial backer, a lawyer of Detroit, Mich., that he committed suicide. Mr. Colliau, after securing another financial backer, died a few years later, and his death was said to be due to worry over the failure of his cupola. Mr. Colliau, whom I met many times, was not a practical foundryman but a civil engineer, who designed and constructed his cupola on theoretical, scientific principles, which, when put into practice, did not give anticipated results.

After the death of Mr. Colliau the manufacture of this cupola was taken up by other cupola builders under various names, and the present standard cupola, with the outside belt air chamber extending down to the bottom plate, is patterned after the Colliau, with only a modification in the number, size and shape of the tuyeres.

The Holland Cupola

This cupola was first placed upon exhibition at a foundry at Elizabethport, N. J., about twenty-five years ago and attracted considerable attention. I never learned of it being placed in any other foundry at that time. Some years later it made its appearance again at Pittsburgh, Pa., and about ten years ago at Syracuse, Ind. This is not really a new cupola, but an attachment that may be made to any cupola. The following description of it is taken from their advertising matter:

Our plan is extremely simple and when investigated reveals a scientific discovery for the betterment of all iron workers. The appliance can be connected with any ordinary cupola now in service.

The results obtained from the use of the Holland are outlined in the following explanation: A hot blast, capable of attaining a very high temperature, is produced by locating a heating tank in the cupola stack immediately above the charging door and connected with the air compressor or fan. The cold air is discharged into the bottom of the tank, thus protecting the same from melting or blistering by the high temperature of the escaping gas from the cupola blast. Two pipes conduct the superheated air from the tank to the tuyeres and are larger in area than the cold blast pipe, thus causing free circulation from the tank.

In addition to claims made for a hot blast in a modern cupola, the following claims are made for use of oil injected into each tuyere with the blast from an oil tank placed high and connected with each tuyere by pipes:

The hydro-carbon gas obtained by mixing air and oil under pressure is focused to the center of the cupola, which is the point of combustion. In other words, the four flames meet at one combined point, producing at least 3000 heat units within this space, through which all the particles of iron being melted above must pass before reaching the bottom. The intense heat will remove all slag and sulphur absorbed by the iron on its way downward, thus obtaining combined carbon as soon as the globules pass through the intense heat, guaranteeing against the chilling of the iron and insuring a close fluid metal that can be worked freely.

They claim for the Holland cupola the following advantages:

1st—Any quality of coke or hard coal can be used.

2nd—75% of stove scrap, 25% No. 2 pig iron, will give a soft, close iron.

3rd—There is no trouble of the first or last iron being hard.

4th—No such thing as hard iron, but a continuous flow of nice working metal.

5th—The acme of perfection in the melting of high and low grade iron into desired quality of castings.

6th—We guarantee satisfaction in every respect, when directions are conformed to, in the operation of our cupola.

7th—Hot blast without the oil is a perfect safeguard against the chilling of the iron, but by combining the oil with the hot blast, a more superior iron is produced, only requiring four gallons of crude oil to one ton of iron. By the use of oil you can melt with gas house coke and cannot chill the iron by pouring it on iron plates. The cupola can be used with or without oil.

Baillot's Cupola.

Baillot's cupola, which is claimed to be a hot-blast cupola, is of French design and was placed upon exhibition at the American Foundrymen's Association's Convention, Toronto, Canada, in 1908, where many of our students may have seen it in operation.

At that time the heated air for the hot blast was drawn from the cupola, just below the charging door, through a pipe connected with the inlet of the fan blower, and returned to the cupola through the blower and tuyeres.

The hot blast obtained in this way was very hot, in fact so hot that it would have destroyed the blower in a very short time.

To prevent this occurring, cold air had to be admitted to the blower with the hot air, and when this was done to an extent that kept the blower cool, the hot-blast feature entirely disappeared, and when the volume of cold air was reduced to an extent that gave only a limited hot blast, the blower became so heated that it could only be run for a very short time.

Later on, the cupola was remodeled, and the air blown through an air chamber placed in the cupola lining, just below the charging door, before entering the tuyeres. This proved a failure in heating the blast, and a large bustle or air chamber was placed around the cupola on the outside, just below the charging door, for the purpose of heating the blast, and a reservoir ladle was placed in front of the cupola into which the iron flowed as fast as melted.

One of these latest improved cupolas was placed in a large foundry at Springfield, Ohio, and proved a complete failure, for the blast was not heated to any extent, no saving in fuel was effected, and when the iron was drawn from the reservoir it was not sufficiently hot and fluid to run their work.

After numerous changes in the method of charging, volume and pressure of blast, and also to some extent in construction, this cupola was pronounced a complete failure. The reservoir was removed and the cupola lowered and converted into an ordinary plain cupola.

I regard all hot-blast cupolas as freak cupolas, for the hot-blast problem for cupolas was thoroughly tried out in this country, and also in England, more than fifty years ago, and it was clearly demonstrated that it was not practicable to provide a hot blast for a cupola.

As for putting oil into the tuyeres with the blast, I tried this myself, in a variety of ways, forty years ago, and I consider it only a waste of oil. Or to inject oil into a cupola in any other way, for increasing the melting, reducing fuel, or improving the quality of iron, is a waste.

English Cupolas.

While American foundrymen have been making every effort to improve their cupola designs and construction, foreign foundrymen have not been idle along this line and have produced a number of new designs that are a great improvement on their old, slow-melting cupolas.

Among the most prominent and successful English designers were Messrs. Ireland, Voisine and Woodward. These men, each acting upon his own initiative, produced a number of cupolas of new designs, a number of features of which are now embodied in the modern cupolas abroad and in this country.

Ireland's Cupolas

Ireland's cupolas, for which he took out a number of patents in England, about the year 1856, and which were largely used about that time, are still the leading cupola designs in England, were constructed of a variety of shapes and sizes, but probably his best design was a round, straight cupola, up to the bottom of the charging door, tapered from this point to the top of the stack, the top diameter of which was two-thirds the diameter of the cupola, and a stationary bottom and draw front were used. The lining was constructed at the tuyeres to form an overhanging bosh, so as to throw the blast to the center of the stock and provide room for holding molten iron in the cupola after melting, which was the practice at that time. Blast was supplied through a double row of tuyeres, placed one above the other around the cupola, and a slag opening was placed in the cupola at a lower level than the tuyeres.

Another design of Ireland's was his bottom or center blast tuyere. This cupola was similar in construction to the one above described, except at the bottom, where it was boshed from the bottom plate up to the lower edge of the melting zone. The blast entered the cupola through a tuyere placed in the center of the bottom, and no side tuyeres were used.

This cupola does not appear to have proven a success, for it did not come into general use either in England or this country, and the late Thomas D. West, when he thought he had made the discovery of an entirely new tuyere some twenty years ago, had never heard of a bottom tuyere having been used before his discovery.

Voisine's Cupola

Voisine's cupola was a round, straight cupola, with a short taper from just above the charging door to a stack of smaller diameter. The lining was slightly boshed at the tuyeres, with an overhanging bosh, and beginning at the lower edge of the melting zone it was enlarged or bellied out into the shape linings usually burn when in use for some time, and tapered back to the same diameter at the charging door as below the tuyeres. To obtain this shape lining, specially made fire brick had to be used. This cupola had an air belt riveted to the casing and a double row of tuyeres leading from it into the cupola. The lower row went straight in, and the upper row of a smaller size pointed down at a sharp angle. Mr. Voisine claimed that this arrangement of tuyeres burned the escaping gas, creating a second zone of combustion with these gases alone, and the second row of tuyeres reduced to some extent the evil effect of the formation of carbonic-oxide in the cupola.

This theory appears to have proven satisfactory in England, and was taken up by French foundrymen and introduced into this country from France, by Mr. Colliau, but his peculiar shaping of the lining does not appear to have been adopted in either England or France.

The theory of burning the gas created by the first row of tuyeres by placing a second row in a cupola has never been clearly proven, and the increased heat and more rapid melting claimed for the double row of tuyeres is probably due to a greater depth of fuel in a cupola being supplied with oxygen for rapid combustion, as no fuel is saved by a second row. A third and fourth row have effected no saving in fuel, nor has blast admitted to the cupola through small openings almost up to the charging door saved fuel, which would seem to indicate that there was no gas created above the tuyeres that can be made combustible by the addition of oxygen.

The Truesdale and Lawrence tuyeres gave the same results in fast melting as the double row of tuyeres, by distributing the blast to a greater depth of bed, but owing to the difficulties in keeping these tuyeres in good working order the double row of tuyeres is to be preferred.

Woodward Steam Jet Cupola

The Woodward Cupola as originally designed was what is known as a steam jet cupola. This means that no blast is supplied to the cupola and the melting is done by natural draft, increased by a jet of steam thrown into a contracted stack, to cause a vacuum and increase draft, and the tuyeres are all left open.

The Woodward Cupola was a straight, round cupola, with an overhanging bosh, double row of tuyeres and stationary bottom. The stack was very much contracted just above the charging door, and a steam jet of sufficient volume to form a vacuum and cause a suction of air into the tuyeres, so as to promote rapid combustion of the fuel for melting, was placed in the stack. The cupola was designed in two styles, one with a stack on top of the cupola and tight-fitting charging door, to exclude the air from entering the cupola at this point, and the other with a side stack constructed alongside of the cupola with a cross flue from the side of the cupola into the side of the stack in which the steam jet was placed. The top of the cupola was provided with a hopper, for charging the stock, and was fitted with a door upon which the stock was placed before dumping into the cupola and closed up tight after dumping. The tuyeres were fitted with doors or dampers that in case iron or slag chilled over one of them, others could be closed and an increased amount of air admitted to the clogged one to melt away the obstructions.

This cupola was a great improvement over the old, slow-melting natural-draft cupolas of those days, but was still a slow melter, and the system was limited to cupolas of small capacity.

Reservoir Cupolas

Prior to the designing of these cupolas there was in use in England what was known as the Reservoir Cupola. The casing of these cupolas was constructed of a larger diameter at the bottom than at the tuyeres or above them and lined to give a larger space for holding molten iron until wanted for pouring, or for accumulating molten iron for a heavy casting from a slow melting cupola. This system has now been abandoned as it has been found that iron can be kept in a molten state longer and hotter after melting, out of a cupola than in it. It is now the practice to draw the iron from the cupola as fast as melted, into a reservoir or tank, and tap it from this receptacle when wanted for pouring.

This system is said to be in use in small foundries in England, where the practice is to melt all day and pour whenever a mold is ready for pouring and there is sufficient molten iron to pour it.

The reservoir or tank system has been repeatedly tried in this country, but in every instance that has come to my notice has been given up as a failure. The great objection to it is that it does not give hot fluid iron for light work or clean castings. It has also been tried as a receptacle or means of treating molten iron with chemicals, charcoal, alloys and fluxes to improve its qualities, but this, too, has proven a failure.

Stewart's Cupola

The Stewart Cupola installed in the foundry of the Stewart Iron Works, Glasgow, Scotland, some years ago, was one of the latest designs of foreign cupolas, and was said to be the most rapid melting cupola in Scotland.

This cupola was a straight, round cupola of seventy-two inches diameter. It was boshed from the bottom plate to six inches above the top row of tuyeres, and from this point sloped back to the regular lining, with a long taper. Blast was supplied from a belt air chamber, through a double row of tuyeres, the lower row going straight in and the upper row, of a smaller size, pointing downward. In addition to these tuyeres, a number of gas pipes were attached to the top of the air belt, and extended up to near the charging door, with one-inch branch pipes extending into the cupola every twelve inches, to supply blast for the burning of escaping gases. This arrangement of pipes embodied the same principle as that described in the Greiner Patent Tuyere arrangement in Chapter II. In my opinion, these pipes had no effect whatever upon the melting, for it would be impossible to keep them open in the melting zone, and the small amount of blast they admitted to so large a cupola, even when open and free, could not be of any special benefit in melting.

The rapid melting of this cupola was due to the cupola being boshed to an extent that admitted of the blast being forced to the center of the stock, and the cupola melting as well in the center as around the side.

Dr. Otto Gmelin's Water Jacket Cupola

Dr. Otto Gmelin, a noted chemist and metallurgist of Budapest, Hungary, designed and constructed a water jacket cupola, the object of which was to prevent the cupola lining becoming so heated as to be burned away rapidly.

His plan was to construct a double water-tight casing with space of sufficient capacity between the outer and inner casing to keep the lining material comparatively cool and prevent its rapid destruction by heat. Cold water was forced into the space at the bottom and it flowed out at the top through a waste pipe when it became heated.

This plan was claimed to have worked so satisfactorily that only a thin daubing of clay was required on the inner casing or cylinder. Iron, copper and other metals had been melted in it daily for two and a half years without requiring any repairs to the inner cylinder and effecting a great saving in lining material and also a saving of six to eight per cent of fuel in melting.

The above outline or description of this cupola appeared in a foreign engineering journal more than fifteen years ago, and are given here to show what has been done in the way of protecting cupola lining with water.

That these claims have not been borne out in practice is clearly shown by the fact that although this cupola was brought to the attention of foundrymen more than fifteen years ago, and was fully described and illustrated in my "Cupola Furnace" in the 1903 edition, not one of them have been installed in a foundry in this country.

This theory was a hobby of a number of foundrymen I met years ago and is nothing new in this country, as it has been tried out in every possible way and proven a failure. Probably the most extensive experiment made along this line were made by the late Thomas Glover about forty-five years ago at the foundry of Morris & Tasker, which at that time was one of the largest and leading foundries in Philadelphia, Pa.

Mr. Glover was foreman of this foundry at that time and was given every facility for making his theory a success. He had constructed a double water-tight casing of small diameter for his experimental work. His first test with this cupola resulted in the water all being forced out of the water belt by the heat, and his pressure was not sufficient to replace it, so the bottom had to be dropped. For his next heat he connected the cupola with the city water system, but this pressure was not sufficient to maintain the water supply when the stock became thoroughly heated, and the little cupola was pronounced a failure, due to the water space not being sufficiently large.

A cupola of larger diameter with a larger water space was then constructed and tested; this one proved a success so far as retaining the water in the casing, and keeping the linings cool to an extent that slag and cinder did not adhere to it, and a clean drop was attained. But the iron melted slow and was not hot, nor could it be melted sufficiently hot to run very thin castings, and there was no saving in fuel effected. After varying the pressure of blast, height of bed, weight of charge of fuel and iron and doing everything that could be done to make this cupola a success and failing to do so, it was pronounced a failure and taken down.

Another plan to protect the lining that has been repeatedly tried is to place a coil of gas pipe around the cupola at the melting zone and placing over this a double lining. A light firebrick lining has also been tried, but nothing was gained in either way, for while the lining was protected to some extent, and the saving effected, the loss due to slow melting and dull iron was greater than the saving. I do not believe it at all practical to construct a water-jacket cupola.

These various cupolas described represent the principal theories that have been tried out in cupola construction, with the results obtained, and are given for the benefit of our students who may contemplate designing a new cupola, that they may not be going over the same ground that has been tried out and proven a failure.

Theory of Cupola Construction.

In the early days of cupola construction, the theory of melting was to force the blast through tuyeres, placed on opposite sides of the cupola, to the center of the cupola, and have it meet in the center and diffuse through the stock. With this object in view, two round tuyeres were placed in a cupola of small diameter on opposite sides and four in cupolas of large diameter. The tuyeres were made of small diameter to concentrate the blast, and give it greater force to penetrate to the center of the cupola.

This theory would have been correct had there been no stock in the cupola, for the blast from the opposite tuyeres would have met in the center and been diffused and filled the cupola, but when the cupola was filled, with coal or coke in front of the tuyeres, this acted as a damper or blast gate, and the blast was thrown back again upon the blower, and a sufficient volume of blast did not enter the cupola to promote rapid combustion of the fuel and give fast melting.

Mr. Mackenzie discovered this defect and designed his cupola to give a volume of blast in place of pressure of blast. This gave a more even and rapid combustion of the fuel and faster melting. This theory was generally adopted by foundrymen and the tuyeres increased in the old cupolas in use at that time.

The success of the Mackenzie cupola stimulated improvement in the construction of cupolas, and many new designs in shape and arrangement of tuyeres were constructed, the principal ones of which were those just described.

In these cupolas the theory of volume of blast was kept in mind, and its equal distribution to all parts of the cupola and ample tuyere area provided, but other important matters, namely, bridging and bunging-up of the cupola in long heats, keeping the tuyeres open, saving of lining, and economy of fuel were overlooked, and from one or more of these defects every one of these cupolas proved a failure, and have gone out of use. We are now back to the old-fashioned round cupola of a hundred years ago, with only the improvements of a proper tuyere area and increased height of cupola. These improvements have more than doubled the melting capacity of cupolas and greatly reduced the per cent. of fuel consumed in melting, and have made the cupola the most convenient and economical furnace for foundry practice.

Cupolas are now constructed by a number of cupola manufacturers, located in different sections of the country, all of which are designed upon practical, scientific principles, with air belt and tuyeres of a proper area for the diameter of the cupola. These cupolas can be purchased, ready for erecting, or the lower section, with air belt and tuyeres only, may be ordered. This section with bottom plate, doors and supports may be ordered and the cupola and stack casing of an old cupola used as casing, or a casing may be constructed at home to suit conditions, but foundrymen will generally find it cheaper to buy their cupolas complete or in parts, than to design their own.

A Cheap Cupola.

In constructing a cupola, the belt air chamber riveted to the casing with its tuyere doors, manhole opening, etc., are not necessary to the success of the cupola. Nor is the heavy steel plate, accurately riveted casing actually necessary. When a cheap or temporary cupola is desired, all these things may be dispensed with and the home-made cupola constructed at very little cost.

An old plain round steam boiler that can be purchased for the price of scrap iron makes an excellent casing for a small cupola. No door on the opening is necessary and blast may be supplied by two branch pipes from the main blast pipe to the tuyeres, and when more than two tuyeres are used, a tin belt air chamber, separate from the cupola, with branches for each tuyere may be used.

The heavy steel plate commonly placed in casings is not required for strength, for there is no great pressure upon the casings when properly lined. These plates are used for endurance rather than strength required, and a small temporary cupola casing can be constructed of much lighter metal.

At one time I constructed two thirty-inch cupola casings of No. 8 sheet iron, which answered every purpose and lasted for years. But I would not advise the construction of so light a casing with the present highly corrosive steel plate, if the cupola is to last very long. The bottom plate, legs and door for each of these cupolas did not weigh over five hundred pounds, which made them a very cheaply constructed cupola.

At another plant I constructed a cupola with an old steam boiler casing that has now been in use for over forty years, and is still serving its purpose as well as when newly constructed.

The building of cupolas as an industry practically only began in this country with the introduction of the Colliau Cupola. Prior to that date foundrymen designed and constructed their own cupolas, and when an old steam boiler of a desired size could not be procured, casings were ordered from a boiler yard, and the necessary castings made in the foundry if in operation or ordered from another foundry.

This description of cheap cupolas is given for the benefit of men with limited capital who desire to start a foundry and for others who desire to construct a cheap, temporary, small cupola.

Cupola Tuyeres

CHAPTER II

Iron may be melted in a cupola by a strong draft induced by a high stack or by a steam jet placed in a contracted stack to cause a vacuum and increasing the volume of air flowing through the cupola thus produce more rapid combustion of the fuel. Either of these systems gives slow and unsatisfactory melting, and a forced blast has been applied to cupolas, which makes necessary openings in the side of the cupola for its admission. These openings are known as tuyeres.

Round Tuyeres.

The design of the cupola for the remelting of pig iron was originally taken from the blast furnace, and many of the blast furnace principles and theories applied to it. One of these was the small round tuyere of the blast furnace, and the driving of the blast into the center of the cupola. Blast furnaces were supplied with a force blast and high pressure, and the cupola may have been so supplied when originally designed, but later on cupolas were generally supplied with blast from fan blowers of imperfect design, with the result of very slow melting, bridging and bunging up of the cupola.

The tuyeres placed in cupolas upon this theory were all small round ones, two tuyeres of three to four inches in diameter were considered sufficient for a cupola of twenty-four inches in diameter, and four tuyeres of this diameter sufficient for a cupola of forty inches in diameter.

Tuyeres were placed opposite each other, that the blast might meet in the center and be diffused through the stock. This theory would have been practical had the blast been given sufficient penetrating force to drive it through the crevices between the pieces of fuel, but this not being the case, and the tuyeres not being of a size to admit a sufficient volume of blast to fill the cupola, the result was slow melting, due to imperfect combustion of the fuel in the center of the cupola, and the melting being principally done around the outside of the stock, resulting in bridging and bunging up of the cupola.

These troubles led to an investigation and study of the tuyere problem, and tuyeres of almost every conceivable shape and size were placed in cupolas, and they were arranged to point up, point down and point sideways to give the blast a swirling movement around the cupola, etc.

Since that time I have seen a number of tuyere epidemics, when almost every foundryman or foreman had a new tuyere, and it was almost impossible to get near a cupola for fear their tuyeres might be seen and the secret of their reported extraordinary melting learned.

It would be useless for me to describe all the various designs of tuyeres I have seen in use, for many of them were never placed in cupolas other than that of the foundry in which they were designed and were only used there for a short time, and I shall only describe a few of those that attained some local or general reputation.

Oval Tuyeres.

The oval tuyere was the first one to attract foundrymen's attention, and was quite extensively used all over the country. With the enlargement of the diameter of the round tuyere, it was found that a greater depth of fuel was required for a bed, and the oval tuyere was the natural solution of this problem.

This tuyere was a flat tuyere with rounded ends and was laid flat in the cupola lining. It proved to be a very good tuyere, and was adopted by all the leading stove foundries, who have always been more advanced in their cupola practice than machine and jobbing foundries. It did faster, more even and more economical melting, and this is still the case at the present time.

This tuyere is made from two to four inches in width and six to ten inches in length, to suit the diameter of cupola, and any number required placed in the cupola.

Slot Tuyere.

The saving in fuel effected by the oval tuyere led to the designing of the slot tuyere, with a view of still further reducing the depth of fuel required for the bed.

This tuyere was a continuous slot opening around the cupola, formed by two cast iron plates, separated by a bracket or pieces of iron laid between them to support the upper plate, upon which rested the cupola lining.

The slot was made from one to two inches wide, according to the diameter of cupola it was designed to supply with blast.

This tuyere gave very good results in short heats, but its tendency to promote bridging in long heats was so great that it soon went out of use, although extensively tried.

Horizontal and Vertical Slot Tuyere.

This was a tuyere that was designed to overcome the strong bridging tendency of the horizontal slot tuyere. It was a horizontal slot, extending about one-third of the way around the cupola on each side, leaving a blank space between the two tuyeres. From each of these tuyeres a slot extended up from eight to ten inches; these slots were placed twelve inches apart and were made of the same size as the horizontal slot, which varied from one to two inches according to diameter of cupola.

This tuyere was claimed to give very satisfactory results, but I never saw but one of them in use and it never came into general use.

Reverse T Tuyere.

This was a slot tuyere in the shape of a capital letter T when turned upside down, and was practically the horizontal and vertical slot tuyere in sections, to be placed separately in the lining, with a blank space between each tuyere.

This was an excellent tuyere, that distributed blast to a greater depth of bed and admitted the larger portion of it at the bottom of the tuyere. It was quite extensively used, and gave excellent results in melting when kept in its original condition, but the upright slot frequently collapsed, which destroyed its efficiency, and when the double row of tuyeres came into use, they gave the same results in supplying blast to a greater depth of bed and were more easily kept in good working order. The T shape tuyere was generally thrown out and replaced with a double row.

The Vertical Slot Tuyere.

This was a slot tuyere, two to three inches wide and eight to ten inches long, set on end. They were generally made square at each end, but sometimes were pointed at the top and bottom.

This tuyere was designed for cupolas of small diameter, to prevent bridging, and proved a very good tuyere for this purpose, but was never used to any great extent in large cupolas.

The great objection to all vertical slot tuyeres is their great tendency to collapse and the difficulty of keeping them in good melting order. For this reason they have generally gone out of use.

Mackenzie Tuyere.

The Mackenzie tuyere was a horizontal slot tuyere extending around the cupola. This tuyere was formed by an apron riveted to the cupola casing on the inside, to form an inside air belt and an overhanging bosh in the cupola. The blast entered the cupola from under the edge of the apron and the overhanging bosh all around the cupola, and there was practically no limit to the volume of blast that could be forced into the cupola, the design being to fill the cupola with blast, instead of driving it by the force of the blower to the center of the cupola.

This plan worked out very nicely, and completely revolutionized the old theory of driving the blast to the center of the stock, but the tendency to bridge was very great with a fan blower, and even with the Mackenzie Pressure Blower the tendency to bridge was so great that it could not be kept melting to its full capacity for a greater length of time than two hours.

This tuyere and cupola with all its defects was a great improvement over the small tuyeres and low cupolas of its time, and came into general use all over the country, and is still in use to a limited extent, but has generally been replaced by cupolas of more modern design and tuyere arrangement.

Doherty Tuyere.

The Doherty Tuyere was designed by Mr. Doherty, of the firm of Bement & Doherty, of Philadelphia, Pa. This tuyere was a common round tuyere placed in the lining at an angle, in place of going straight into the cupola, as tuyeres commonly do. The object of this was to give the blast a whirling motion, which it was claimed would distribute the blast more evenly to the stock and create a higher degree of heat for melting.

That the blast was given a whirling motion could be plainly felt by the hand placed in the cupola at the charging door, and seen by the whirl of the flame when it appeared at the door, and the tuyere had every appearance of producing a hotter fire.

This appearance brought the tuyere to the attention of the foundrymen of Philadelphia, and it was placed in the cupolas of most all the foundries of Philadelphia and vicinity. It was found that this motion of the blast was deceptive, and that no fuel was saved or better iron produced by its use, and it was taken out and the tuyeres formerly used put back in place.

This tuyere had but a short run, and was so completely thrown out that but few of the present generation of Philadelphia foundrymen ever saw or even heard of it.

Blakney Tuyere.

This tuyere was designed by Mr. Blakney, of Springfield, Ohio. This was a continuous belt tuyere constructed between two plates, with partitions between the plates placed at an angle a few inches apart, to give the blast a swirling motion, similar to that of the Doherty tuyere just described, and it had this effect upon the blast. It differed from the latter in construction, the Doherty tuyere, being a straight round tuyere placed at the same distance apart, as when they went straight in.

This idea of a tuyere was probably taken from the feed belt of turbine water wheels, which are designed to give the greatest possible power by having the water strike the paddles of the wheel in the direction in which it is revolving, and thus use the spouting velocity of the water.

This tuyere, although extensively advertised by the M. Steel Co., of Springfield, Ohio, never came into general use. Its use was probably limited to a few of the Springfield foundries for a short time, as it is now entirely out of use.

Truesdale Reducing Tuyere.

The Truesdale Reducing Tuyere was designed and patented by Mr. Truesdale, foundry foreman of the Reasor Stove Works, Cincinnati, Ohio, and was quite extensively used in Cincinnati and vicinity about 1874-5. I visited Cincinnati about that time and found an epidemic of tuyere inventing in full swing. Almost every foreman had invented a tuyere and either was or had been trying it out.

This tuyere consisted of a series of round openings, varying in diameter from one to four inches. The openings of the largest diameter formed the lower or first row of tuyeres, and over these were placed openings of smaller diameter until reduced to one inch. The four-inch openings or tuyeres were placed in cupolas of large diameter and those of smaller size were placed in cupolas of smaller diameter for the first row. This made the number of tuyeres placed in each row, in reducing from the larger tuyeres down to one inch in the top row, give a deeper tuyere space in cupolas of larger diameter than in those of smaller diameter.

Blast was supplied through the tuyeres from an inside belt air chamber formed of cast iron staves, upon which were cast cleats for holding the cast iron tuyeres in place. The lower or first row was placed only one or two inches apart, which placed the upper rows so close together that no fire brick could be placed between them and the lining was made of cupola lining material.

The placing of an inside belt air chamber in cupolas of small diameter caused a great deal of trouble from bridging and bunging up of the cupola, and in cupolas of larger diameter the smaller tuyeres frequently collapsed or became filled with iron or slag, making it necessary to remove and replace them. The tuyere, although a good one when in perfect order, soon went out of use.

Lawrence Reducing Tuyere.

This tuyere was designed by Mr. Frank Lawrence, foreman and general manager of the American Stove & Hollow Ware Plant, Philadelphia, Pa. It had a four-inch square opening, with rounded corners, and over it a slot one and one-half inches wide at the bottom and reducing to a point at a height of twelve inches. It was supplied with blast from an inside belt air chamber, formed of cast iron staves, upon which the tuyeres were fastened with cleats.

Mr. Lawrence also designed an egg-shape cupola in which these tuyeres were placed six to eight inches apart. This cupola and tuyere did excellent melting and was probably the fastest hard coal fuel melting cupola ever constructed.

But it had its objectionable features, one of which was the frequent collapsing of the reducing slot, and a failure of the melter to report it, to save himself work, as it required considerable time to cut away the lining and replace it. Another trouble was the breaking of the staves forming the air chamber. This, however, was finally overcome by placing a boiler plate in the cupola to replace the cast iron staves.

The collapsing of the slot could not be overcome, and after considerable time and money spent in his efforts to introduce his cupola and tuyere, Mr. Lawrence gave it up and retired from the business, and both his tuyere and cupola soon went out of use.

Colliau Cupola Tuyere.

This is a tuyere introduced in this country from France by Mr. Colliau in connection with his cupola which was known as the Colliau cupola. The tuyere was rather a combination of tuyeres than a new design of tuyeres. The lower or main tuyere was an oblong square-cornered tuyere laid flat in rows. The second row was of the same shape but of smaller size, and placed ten to twelve inches above the first or lower row; and above this was placed a third and sometimes a fourth row, each of smaller size. The upper rows were staggered, that is, placed between the ones in the row under it.

This combination of tuyeres was a complete failure at the start for any but cupolas of large diameter melting large heats. The numerous rows of tuyeres required so high a bed that the use of fuel was too extravagant for small heats, and many of the cupolas and their tuyeres were condemned and thrown out.

Later on Mr. Colliau made a greater success of his cupola by reducing the number of rows of tuyeres, using only two rows and also reducing the size of the second row. It was not until after the death of Mr. Colliau and the making of his cupola was taken up by other cupola manufacturers that it was really made a success. This was done by reducing the size of the upper or second row and placing the two rows closer together.

After the introduction of the double row of tuyeres, it was soon discovered that the upper row gave the same results as the reducing and slot tuyeres, and was far more stable and less liable to get out of order, and these tuyeres soon disappeared from cupolas.

Greiner Tuyeres.

The Greiner Tuyere was not really a tuyere for melting iron, but a device that was attached to cupolas for admitting air to consume gases escaping from the melting zone. It was called to the attention of foundrymen about twenty years ago, and the following description of it was given in the advertising matter:

"The novelty of this device consists in a judicious admission of blast into the upper zones of a cupola, whereby the combustible gases are consumed within the cupola and the heat utilized to pre-heat the descending charges, thereby effecting a saving in the fuel necessary to melt the iron when it reaches the melting zone. This device consists of a number of upright gas pipes attached to the top of the wind box around the cupola, with branch pipes of 1 inch diameter extending into the cupola through the lining and about 1 foot apart, from a short distance above the melting zone to near the charging door. It is claimed that these small pipes admit a sufficient amount of oxygen to the cupola to burn the carbonic oxide produced by the carbonic acid formed at the tuyeres absorbing carbon from the fuel in its ascent. A great saving in fuel is thus effected by consuming this gas and preparing the iron for melting before it reaches the melting zone."

This theory sounded so plausable that many foundrymen attached it to their cupola, but it was soon found that no fuel was saved by it, and the theory was thoroughly impracticable, as it was found that many of the one-inch pipes extending into the cupola could not be kept open throughout a heat, and all of them became more or less closed and the device was soon abandoned.

Bottom or Center Blast Tuyere.

The bottom or center blast tuyere is a tuyere placed in the center of the bottom of a cupola. This tuyere is formed by passing a pipe of a diameter capable of carrying the entire volume of blast required for the cupola, up through an opening in the cupola doors, to a height above the sand bottom similar to that of side tuyeres.

On top of this pipe is placed a rounded cap, extending out over the side of the pipe, an inch or more, to prevent iron or slag falling into the pipe. Under this cap is placed the tuyere, which consists of an opening all around the pipe, of a size to admit the proper volume of blast to the cupola. The opening or tuyere is formed by supporting the cap on rods or other supports attached to the pipe, at a proper distance above the end of the pipe.

This pipe and cap have to be protected from the heat of the cupola and molten iron, and this is done by making the pipe and cap of cast iron, upon which are cast prickers for holding daubing in place, and they are heavily coated with ordinary cupola daubing.

The first designer of this tuyere of which there is any record was Mr. Ireland, an English cupola inventor, who took out a number of patents for cupolas about the year 1856, in one of which was described and illustrated the center blast tuyere.

But although patented and known in England at this early date, it has never come in use in that country as a standard tuyere, and Mr. Ireland does not appear to have been favorably impressed with it, for later on he took out patents for cupolas of other designs and tuyere arrangements.

Something like thirty years ago I met a number of old foundrymen in the New England States who had used the bottom tuyere about 1840, and it appeared from what they said there had been a bottom tuyere epidemic among foundrymen about that time, and I have met in other sections of the country foundrymen who tried the bottom tuyere many years ago.

A bottom tuyere for cupolas was patented August 13, 1867, in this country by B. H. Hibler, and was quite thoroughly tried out about that time in this country, as had been done in England years before. It proved such an utter failure that it was so completely forgotten that the late Thomas D. West had never heard of it, and when he conceived the idea of a center blast tuyere for cupolas thought that he had made a new discovery.

Mr. West placed one of these tuyeres in the cupola of the Thomas D. West Foundry Co., Sharpsville, Pa., and after repeated test of the tuyere made an elaborate report on the highly beneficial results obtained by the use of it before the American Foundrymen's Association Convention, Chicago, October 18th, 1893.

Mr. West's standing as a leading foundryman was so high at that time that the tuyere problem was at once taken up by foundrymen, and the center blast tuyere placed in cupolas all over the country. Then began the usual troubles of a bottom tuyere, such as the tuyere getting filled with iron or slag, daubing falling off from the tuyere pipe and pipe being melted, leak through the sand bottom around the tuyere, etc.

That Mr. West's tuyere was not free from these troubles I learned on a visit to his plant at about the time when this tuyere excitement was at its height. Mr. West showed me around the plant, but failed to show me the center blast tuyere or say anything about it, and upon my inquiring said, "There it is lying over in the corner; it got filled with iron and I threw it out."

I then learned that his tests of the tuyere had not been free from the usual troubles met with in this form of tuyere, such as iron or slag in the tuyere, run outs around the tuyere, trouble in putting it in place and maintaining it in place, and removing it before dropping the doors, etc.

Many of these troubles appeared to be due to improper construction and arrangement of the tuyere, and after Mr. West had been refused a patent, due to Mr. Hibler having already been granted a patent for the same thing, and Mr. Hibler's patent having expired, the invention became public property.

The tuyere was then taken up by other inventors, and a number of patents taken out on the construction and arrangement of it, and companies formed to construct center blast cupolas.

The making of this cupola was also taken up by other cupola manufacturers and many of them were placed in foundries, all of which proved a complete failure, and were sooner or later taken out or changed into side tuyere cupolas, and probably more money was lost on the center blast tuyere than any tuyere ever invented.

The advantages claimed by the promoters of this tuyere were faster melting, decrease in per cent. of fuel required in melting, less destruction in cupola lining, and prevention of cupola bridging and bunging up. Not one of these claims was ever substantiated, or any better results obtained with the center blast tuyere than with the side tuyere, which it was designed to replace entirely.

Mr. West was probably the only foundryman who met with any satisfactory results in the use of this tuyere. This he did by placing it in a cupola of very large diameter and using the side tuyeres in connection with it.

This tuyere, which had a cap upon it of twenty-four inches in diameter, which represented the size of the tuyere, was constructed upon a blast pipe placed under the floor and extended up into the cupola and was permanent in this position; the bottom doors being cut out to fit up around it. A flange was cast upon the pipe just above the doors for the support of fire brick placed around the pipe for its protection in the cupola, and the sand bottom made up around it. This prevented any leak around the pipe, when the bottom was properly made up.

The height of the center tuyere outlet was the same as that of the side tuyere, and was designed to supply blast to the center of the stock. This it did, and the cupola melted much faster and hotter iron than with the side tuyeres alone.

This was the only instance that came to my notice in which this tuyere was a success, and its use was continued until the plant was remodeled and cupola melting dispensed with.

Zippler Tuyere.

This tuyere was designed by the late Michael Zippler, an expert melter of Pittsburgh, Pa., and about 1880 was placed in the cupola of a large stove foundry at which Mr. Zippler was employed in Pittsburgh.

The tuyere gave such excellent results in this plant under Mr. Zippler's care that it was placed in a number of other stove foundry cupolas, where it gave satisfactory results, but the shape of lining required for the tuyere was so difficult to maintain that it did not come into general use and was soon abandoned by those foundries that had placed it in their cupolas.

About the year 1900 Mr. Zippler improved the tuyere by placing cast iron blocks over and around it, for the support of the lining, and added a second row of tuyeres, for which design he obtained a patent, and he placed a large number of them in cupolas all over the country, and no doubt realized considerable money out of his invention.

This tuyere is really not a new tuyere, for the flat common tuyere opening is used in it, and the overhanging bosh of the lining was patented in 1856 by Mr. Ireland in England, who also used and patented the double row of tuyeres about that time.

The novelty of this tuyere, therefore, consists in the manner of supporting the overhanging bosh of the cupola to throw the blast to the center of the stock; this is done by placing a few courses of cast iron brick or blocks under and around the tuyere where the heat is not sufficiently great to melt them.

This tuyere and boshing arrangement has given excellent results in cupolas of large diameter, in which the blast has not been given sufficient force to penetrate to the center of the stock from the side tuyeres, and is reported to have effected a saving of fuel, giving hotter iron and faster melting in such cupolas. In cupolas of small diameter it has not proven so great a success, as it concentrates the blast too strongly upon the molten iron in its descent to the bottom of the cupola, and the boshing of the cupola create a tendency to bridging and hanging up the stock.

Watt Tuyere.

The Watt Tuyere is the latest tuyere to have attracted foundrymen's attention to any great extent. This tuyere was designed by Mr. Watt, founder of the Watt Mining Car Wheel Co., Barnesville, Ohio, for use in the cupola of their plant, and it gave such excellent results in melting and such clean dump that Mr. Watt was induced to obtain a patent upon the tuyere and formed the Watt Cupola Tuyere Co. to place it upon the market.

This was a continuous tuyere extending around the cupola, and was formed by a cast iron belt air chamber laid up in the cupola lining. The front of this belt was covered by a series of lattice work of cast iron plates, through the openings of which the blast escaped into the stock. This arrangement distributed the blast evenly to the stock, and gave very good results in the cupola of the Watt Mining Car Wheel Co.

Mr. Watt learned of my presence in Barnesville one evening, and the next morning would not permit the melter to touch the cupola until he had gotten me around to observe the clean dump and good condition of the cupola after melting a heat.

The cupola only had a very light, brittle fringe of slag over the tuyeres, and the lining was not burned out to any extent. The tuyeres certainly made a good showing.

The cupola was a forty-inch one, and on inquiry I learned that the average heat was a small one for this size cupola, and melted in an hour to an hour and a quarter.

The short heat in my estimation accounted for the fine appearance of the cupola, and correspondingly lowered in my estimation the value of the tuyere, and I suggested to Mr. Watt that it might not work so well in long heats, but Mr. Watt stated that it had been tried in long heats and gave as good results as in short heats. On trial in long heats it did not prove a success, and, together with the variation of the volume of blast applied to cupolas in different foundries, made the tuyere a complete failure. The company organized to promote it, after losing about all the money they had invested, gave it up as a failure, and the tuyere soon went out of use.

Triangular Tuyeres.

The triangular tuyere was designed by the writer many years ago for use in cupolas of small diameter, to prevent bridging and bunging up of the cupola, which was a far more common occurrence at that time than at the present, as this tendency has been greatly reduced by the use of limestone as a flux, to the extent that admits of tapping and drawing off of slag to prevent it filling up and clogging the cupola.

With this object in view, the triangle was generally made shorter at the base than on the sides, to give it a sharper point at the top. This had the effect of reducing the volume of blast at the top, where the tendency to bridge is the greatest in all tuyeres.

This tuyere had also been placed in large cupolas, with very satisfactory results. One of these instances was that of the Magee Furnace Co., a large stove plate plant located at Chelsea, now part of Boston, Mass.

In this cupola, which was five feet four inches diameter at the tuyeres, the tuyere was made nine inches wide at the bottom and sixteen inches long on the sides; it was not extended up to a sharp point, but rounded off two inches below the top. This was done to avoid the collapsing of the sharp point, due to a limited amount of cold air passing through it. This tuyere remained in use for more than twenty years, and was not abandoned until the plant was removed to Taunton, Mass., where a pair of modern cupolas were installed to replace the old-fashioned one, the shell of which had become worn out.

It has been used to form a reduction tuyere, having the same effect as the Truesdale and Lawrence reducing tuyeres. This was done by making the base narrow and the sides long, and placing numerous partitions in it to act as braces and prevent collapsing. It has also been used in place of the double row of tuyeres, and gave very satisfactory results and is probably the oldest tuyere in use at the present time.

Expanded Tuyere.

The expanded tuyere is a slot tuyere in which the slot is made longer at the outlet than at the inlet, which gives it the name of the expanded tuyeres.

The object in constructing a tuyere of this shape is to distribute an equal volume of blast to each tuyere from the air belt, and not admit of a larger volume of blast entering another tuyere when one or more tuyeres become slightly clogged.

The outlet of a tuyere is closed by fuel in front of it, and the only avenue open for the escape of the blast from the tuyere is through the crevices between the pieces of fuel, and the object in making the outlet of this tuyere larger than the inlet is to increase the number of crevices in front of the tuyere between the pieces of fuel, and in this way make the outlet equal to the inlet.

This is a slot tuyere laid flat in the lining, the width of the outlet of the slot is made of the same size as the inlet, but the length of the slot is increased until the outlet is two to three times greater than the inlet. The width or depth of the slot may be made of any size to suit the diameter of the cupola and varies from three to seven inches. The length of the slot may also be made of any length to suit the size of cupola, and any number desired placed in a cupola. In very large cupolas, the outlet slot is generally made three times the length of the inlet, and they are placed so close together as to form an almost continuous tuyere.

In cupolas of small diameter this tends towards bridging, and they are not expanded to so great an extent or are placed further apart by placing a lesser number of tuyeres in the cupola, and leaving a blank space between them. In case of trouble with bridging, when this tuyere is used, this may be overcome by closing the point of the tuyere with clay.

This tuyere is more extensively used at the present time than any other tuyere, and gives very satisactory results when properly arranged.

Size of Tuyeres.

When I first started out as an expert melter, about 1874, with the small tuyere theory of that time, I was somewhat surprised to find in a stove foundry at St. Louis, Mo., a large cupola with only two square tuyeres 12x14 inches doing excellent melting with anthracite coal fuel, which was the cupola fuel used there at that time. I had never melted with this coal, and thought that was the size of tuyere to be used with this coal. But later on I found that the tuyeres used for this fuel in the east, where this was the only cupola fuel used, did not differ from those of coke fuel cupolas.

Later on I found in a school furniture foundry in Buffalo, N. Y., a sixty-inch cupola melting with coke and only two tuyeres 12x14 inches. This cupola did excellent melting.

At the present time there is in use in a bedstead foundry at Shelton, Conn., a cupola of 12 inches in diameter blown with one tuyere eight inches in diameter. This is a cupola of English design, for slow melting and hot iron, and the volume of blast applied to it is only about equal to that of a high stack and natural draft.

These three examples of large tuyeres and good melting show that there is nothing in numerous small tuyeres for distributing the blast to all parts of the cupola, and that it is the volume of blast and not the force of blast that does the melting, and the shape of tuyere has but little to do with it so far as melting is concerned. The main object sought for in shape of tuyere is the prevention of bridging, and this tendency can be prevented to a larger extent by the shaping of the lining, as will be explained under that heading.

Tuyeres should always be placed opposite each other, so that the blast from each may meet in the center and be diffused through the stock. If this is not done, the blast will be thrown against the lining on the opposite side of the cupola and cause an excessive destruction of lining at this point.

The two large tuyeres above referred to as doing good melting were in large cupolas melting short heats, and it is doubtful if as good results would be obtained in these cupolas in long heats. I should not recommend such tuyeres, as I consider a more even distribution of blast gives better results, but in all cases a large tuyere that admits blast freely is to be preferred to small ones.

Tuyeres to Improve Quality of Iron.

At one time an impression prevailed that the quality of iron could be improved when melting in a cupola by the arrangement and shape of tuyeres, and tuyeres of every conceivable shape and size were placed in cupolas. They were arranged to point down, to throw the blast upon the molten iron in the crucible of the cupola. To point up, so as to have the force of the blast strike the molten iron in its descent, drop by drop, and when melting. To point straight in and at various angles, to fill the cupola with a body of air, through which the molten iron fell, drop by drop, in hopes that this would remove sulphur and other impurities from it, or prevent sulphur being taken up from the melting fuel.

All these attempts to improve the quality of iron or prevent its deterioration proved a complete failure, and it was found that the shape of tuyere or direction in which it pointed had no effect whatever upon the quality of an iron.

Improvements in Tuyeres.

It will be seen by the foregoing description of tuyeres that the tuyere problem has been pretty well covered, and these represent but a small proportion of the various sizes, shapes and arrangement of tuyeres that have been tried out, but only those that have given some apparently satisfactory results and attracted the attention of foundrymen have been described.

Of all these tuyeres, only three remain in use. These are the triangular, oval or square, and expanded tuyeres. The first of these is used principally in very small cupolas, to reduce the tendency to bridge, and the second in the larger small cupolas, and the third in large cupolas.

The oval and expanded tuyeres are laid flat, and should not be made so long and narrow as to form a slot tuyere, for this promotes bridging, and there is trouble with the slot collapsing. The slot should not be less than three inches wide, and of a length to give the desired area. For large cupolas the slot may be made of any width above three inches, necessary to give the required area, and expanded until the ends of the tuyere almost meet.

The tuyeres placed in cupolas by all the regular manufacturers of cupolas are of a proper area for the diameter of cupola, and their size should not be changed except in cases where the diameter of the cupola is reduced by extra thickness of lining, or there is a deficiency of blast, in which case they may be reduced by placing clay in them to reduce their area.

When there is trouble with building out over the tuyere, and bridging, and the expanded tuyere is used, this can sometimes be prevented or greatly reduced by closing off the points of the tuyeres, to give more blank space between them.

When trouble occurs in melting, one of the first things many foundrymen do is to blame the trouble upon the tuyeres, or upon the blast, and this is frequently done after the cupola has been melting satisfactorily with the same tuyeres and blast for years. This is a mistake, for if the tuyeres are the same, and the blower in good working condition, the trouble must be due to some other cause, and the place to look for it is in the burning of the bed, height of bed, weight of charges of coke and iron, manner of placing them in the cupola, and shape of lining. These are things that change without being noticed, and will generally be found to be the cause of trouble in melting, as will be explained later on.

There have been so many failures of scientific arrangement and shape of tuyeres, and the present shape and arrangement of tuyeres has given such satisfactory results, that it has come to be a common saying that only a foundryman who doesn't know how to run a cupola places a new-fangled tuyere in his cupola, and the tuyere inventor has a very slim chance of making a success of his tuyere outside of the foundry in which he does his experimental work.

Constructing a Cupola

CHAPTER III

Location.

In installing a cupola, the first thing to be considered is the point at which it should be located. There are two important matters to be considered in deciding this question. These are the getting of stock to the cupola and the getting of molten iron away from it.

It is easier to carry cold iron to a cupola than to carry molten iron away from it, and if the molten iron is to be carried by hand the cupola should be located at a point that will give the shortest possible carry for the iron. This is important in that it not only saves time and labor for a lot of men, but gives a hotter and more fluid iron for pouring.

If the molten iron is to be carried in large ladles, by a traveling crane direct to the mold, or by an overhead track system in large ladles to the molding floor, using hand ladles or small bull ladles for pouring, the cupola may be placed at a point most convenient for getting up the stock and removing the dump. The cupola may also be placed near the stock by arranging the molding floors to have the small work molded near the cupola, and crane ladle castings molded at a distance from it.

Foundation for a Cupola.

In putting in a cupola foundation, the weight of the cupola, stack, lining, etc., must be considered, and also the weight of stock when the cupola is fully charged for the heat. Put in a good, solid foundation sufficient to support the cupola and load when fully charged for a heat, for if the foundation settles unevenly, the bottom plate is liable to crack, and a cupola with a broken bottom plate is practically useless, as it is almost impossible to mend it in a satisfactory manner.

Satisfactory foundations may be constructed of concrete, stone or brick, and walls for the support of a square bottom plate may be constructed of the same material. But a round bottom plate with cast iron supports is very much to be preferred, as they give more freedom around the cupola, for removal of the dump, putting up the doors, etc.

When columns or other iron supports are used, they should be placed at a sufficient distance apart to admit of the bottom doors swinging between them, as this not only prevents the doors being broken by striking the supports, but also admits of a free circulation of air around them, which greatly reduces their tendency to be warped by the heat of the dump.

Cast iron supports are preferable to steel ones, as they are not corroded so rapidly by the heat and dampness in wetting down the dump as steel ones, and last a great deal longer.

Height of Bottom Plate.

The bottom plate is the bottom of the cupola, and the height at which it should be placed above the foundry floor varies with the size of the cupola and the method of handling the iron. Cupolas of small diameter are placed low, as the ladles are generally small ones, and a great height is not required for ladle room under the spout. Large cupolas may be placed at any height to suit the ladle to be filled.

Three feet is about the lowest point that admits of the dropping of the bottom doors, removal of the dump and necessary repairs being made to the lining, and when a cupola is set lower than this, for catching the iron in small ladles, a pit must be provided for dumping. When the cupola is placed in the foundry, this may be done by constructing a wall on three sides of the cupola up to a level with the foundry floor, and leaving the other side open for the removal of the dump. When a cupola is set outside of the foundry, with the spout extending in to it, a pit is not necessary, as the floor may be lowered on three sides, which gives more room for removal of the dump.

Height of Cupola Spout.

The cupola spout is laid on or made up upon the bottom plate and the height of the bottom plate determines the height the spout is placed above the floor, and the height it should be placed depends upon the character of the work to be cast, size of ladles required, and method of handling the molten metal.

In all cases the spout should be close to the top of the ladle in tapping, and of a length to throw the stream to the center of the ladle, for it is difficult to catch in a small ladle a high stream, the location of which varies with a large or small body of molten iron in a cupola, which throws the stream out with greater or less force. The stream, when permitted to strike the side of the ladle for any length of time, may cut the ladle lining, and is also liable to jump over the side of the ladle when a small obstruction is removed from the tap hole by the stream or falls short of it when a small obstruction gets into the tap hole. To avoid these troubles, place the mouth of the ladle up near the end of the spout, in a position where the stream will fall near the center of the ladle.

For all hand ladle work a good height for a spout is eighteen to twenty inches. This admits of a cone open at both ends being placed for setting the ladle on when filling, and makes it much easier to pick up when full than from the floor. Gives room for catching over, and by removing the cone, room is made for a small bull ladle in case it is required. By digging out the floor a little, a larger ladle may be placed under the spout when only occasionally required.

For shank carrying ladles and small crane ladles, thirty to thirty-six inches is a good height. This height admits of trestle being placed for resting the shank upon, which makes it more easily lifted than from the floor. This height of spout admits of a ten or twenty hundred crane ladle being placed under it, and in case a larger ladle is occasionally required, a small pit may be dug in the floor in which to set the ladle to admit of it being placed under the spout. This height of spout is the one most commonly used in small jobbing foundries. The height and length of spout should always be designed to best suit the size of the majority of the ladles used, and provision made for an occasional casting requiring a larger ladle.

When the greater part of the work to be cast requires large crane ladles, the cupola bottom plate and spout may be placed at any height required for the size of ladles, and the iron for shank pouring carried to the floors by the crane, in ten to twenty hundred ladles, and poured into the shank pouring ladles.

When an extra long spout is required, for filling a large ladle, or direct casting into the mold for an anvil block or other heavy castings molded in the floor, this may be provided for by making the spout in sections, daubing and drying them separately, and fastening them together and to the regular spout by cleats, hooks or other devices, and looting the joints with new molding sand.

The regular cupola spout should always be securely fastened to the cupola bottom or casing, to prevent its being moved if accidentally struck by a ladle; for the disturbing of a spout during the heat cracks the lining and may disturb the front or sand bottom to an extent that makes it necessary to drop the bottom.

A spout should be made narrow and deep, to prevent overflows, as this concentrates the stream and keeps the spout clean. A wide flat-bottom spout permits the iron to flow all over the bottom, and frequently gives two or more streams at the end of a spout, which are difficult to catch in small ladles. A spout for a small temporary or experimental cupola may be made by laying two short pieces of pig on the bottom plate and building up the spout between them. This was the way in which spouts were constructed for small cupolas fifty years ago, and is still the practice in many of the old small foundries in country districts. But the cast spout now generally used is to be preferred.

Cross Spout.

A cross spout is a spout placed cross ways at the end of the regular cupola spout, and attached to it by a swivel in the center that admits of it being turned to cause the iron to flow out at either end.

This spout is used for filling large track ladles when running in a continuous stream from the cupola, and also for large crane ladles when the cupola is a large one and fast melter and cannot be stopped in for a sufficient length of time to admit of the full ladle being removed and the empty one put in place.

The ladles are placed on either side of the spout, and when one is filled the spout is turned to throw the stream into the other, and while the full one is being poured the other one is filling. This saves time in changing ladles, which, in case of large ladles, can only be done with the crane and requires considerable time.

Considerable trouble has been experienced from cutting out of the lining in the cross spout in long heats at the point where the iron falls from the cupola spout into the cross spout. This trouble may be overcome when a sufficiently refractory lining material cannot be found to last through a heat by forming a small basin in the cross spout and lining it with fire brick. This precaution is seldom necessary except in all-day heats. A proper mixture of fire clay and fire or sharp sand makes a very refractory spout lining when thoroughly dried.

Double V Shape Spout.

This is a spout designed to fill two ladles at the same time from one tap hole. The stream from the tap hole is divided at the point of the V and throws a stream into each leg of the V. This was a freak spout that I have seen in use in stove foundries, but was never generally adopted by them, as it was only satisfactory for a very fast melting cupola and a large stream and filled ladles entirely too slow when the cupola was not doing its best. Following the failure of this spout, many of the stove foundries placed two spouts in their cupolas, side by side, and tapped one or both of them at the same time, as conditions required, to take care of the molten iron.

One or More Spouts.

One spout is sufficient for a cupola if the method of handling the molten iron admits of its being taken away as fast as it is melted. If this cannot be done, then two or more spouts are necessary.

The filling and taking away of a 40 lb. hand ladle in ten seconds is rapid work, and the filling and getting away with this ladle in six seconds is about the limit in which it can be done with any degree of safety. In case the stream gets away from the men for only a few seconds, it is necessary to stop in and remove the hot iron from the floor, and when tapped again the stream comes faster than before, and the molten iron must be handled more rapidly, which is very dangerous work.

A 40 lb. ladle every ten seconds is 240 lbs. a minute, or 14,000 lbs. per hour. A 40 lb. ladle every six seconds is 400 lbs. per minute, or 12 tons per hour, this requires ten men to catch every minute and allowing five minutes for carrying the iron to the floor, pouring it and getting back to the cupola, which is very quick work, fifty men are required to take care of the iron from the cupola as melted. This may be done, if the carriage is short, and the work is such that the iron can be rapidly poured, but if the work is light, and numerous flasks are to be poured from the same ladle, or the carry is long, the work cannot be carefully poured in so short a time. Even with a greater number of molders, it is not as satisfactory or as safe as six ladles per minute, which is fast work in handling iron in hand ladles and also in small bull ladles. A cupola melting more than seven tons per hour, for hand ladle work, should therefore be provided with two tap holes.

It was the practice in large stove foundries of Albany and Troy, N. Y., years ago, to place two spouts in their large cupolas side by side, this was done to take care of any excess of molten iron in the cupola, by using the two spouts at the same time, and also to keep the tap hole at a proper size for the stream. This was done by stopping in and using the other spout, while the bed became hard and a tap hole of a desired size was then cut through it. The other tap hole when not required in taking care of the iron was closed.

Two or more spouts are not only placed in cupolas to take care of the molten iron, but also for convenience in handling the iron and shortening the carrying. In this case, the spouts are generally placed on opposite sides of the cupola, to avoid carrying the iron around the cupola, through doors, etc., and gives greater freedom around the spout for handling of ladles. This arrangement is frequently made in slow melting cupolas, in which case only one spout is used at a time, the tap hole of the other being closed.

A spout may be placed at any point desired and at as many points as desired, as it is only a matter of sloping the sand bottom so that each spout drains the cupola.

The spout problem is a matter that has not received proper attention in many foundries that have been enlarged since their original construction, and not only greater safety to the men may be insured, but also time and labor saved by a consideration of this problem.

Bottom Doors.

Bottom doors may be made as a single door, double doors, or in four parts, but are generally made as a single door for cupolas of small diameter and as double doors for a cupola of large diameter.

A cast iron door is the most rigid, and not so liable to warp or spring and crack up the sand bottom when charging is being done, as the lighter steel doors, and is the door generally used for cupolas of small diameter, but is rather heavy and difficult to put up when very large.

For large cupolas steel doors are generally used on account of their light weight. They should be well braced by ribs and flanges, and must be well supported by props at every point, as they are likely to spring when put up.

Belt Air Chamber.

In the early days of cupola construction it was the practice to run branch pipes from the main blast pipe to near each tuyere, and make connection with the tuyere by means of a short leather hose and a rounded tin elbow. The leather hose was securely tied over the end of the pipe and elbow with a strong leather thong or belt lace. This made a flexible adjustment for the elbow in the tuyere. The elbow and leather hose were removed from the pipe before dropping the bottom to prevent them being destroyed by the heat of the dump.

An improvement on this method was a cast iron pipe to each tuyere, bolted to the casing, and a peep hole in the elbow closed with a wooden plug.

Next came the round cast iron belt air chamber, placed high above the tuyeres, with branches to each tuyere. The next improvement was a round tin belt air chamber with cast iron tuyere boxes, having a door and peep hole for each tuyere, with which the belt air chamber was connected by a branch pipe.

Following this came the inside air chamber formed by an apron riveted to the shell to support the lining; and the outside air chamber riveted to the shell on a level with the tuyeres. With the introduction of the Colliau cupola came the belt air chamber extending from above the tuyeres down to the bottom plate.

Of all these plans, the belt air chamber riveted to the casing has proven the most satisfactory, as it distributes the blast evenly to the tuyeres and is less liable to get out of order and leak air than any of the others, and has been universally adopted by all cupola manufacturers. But any one of the other plans, when properly arranged, gives good results, and may be adopted when constructing a cheap or temporary cupola for experimental work.

There are two forms of belt air chambers in use. These are the square chamber around the tuyeres only and the long chamber extending from just above the tuyeres down to the bottom plate.

The square chamber of the Newton type has the advantage of being up out of the way, and gives more freedom at the tap hole and around the bottom of the cupola and may be extended up to any required height for air space. An improvement on this form of belt chamber would be a sloping of it at the bottom upward as the deep air belt is sloped downward at the top. This would make it still more out of the way.

The deep air belt of the Colliau type is not only in the way, but is liable to be filled with iron or slag up to the tuyeres without giving any indication that such a thing is occurring until the casing becomes red hot, and it is too late to prevent the overflow, or remove the iron or slag in a molten state. As a rule, no provision is made in cupolas of this construction for giving an alarm in case of overflow, or permitting the overflow to escape from the air belt when in a molten state. An inspection of air belts of this construction in use at the present time would no doubt show, that fully one-half of them are filled with iron or slag up to the tuyeres, which can only be removed by removing the entire air belt.

When this deep air belt was introduced, it was done upon the theory that a large air belt acted as an air reservoir, and distributed the blast to the tuyeres more evenly than the small chambers. This theory is no doubt correct, but I have never been able to see why this enlarged chamber should be placed under the tuyeres, where it takes up valuable room needed for the manipulation of the cupola, in place of being placed above the tuyeres, where it is out of the way and in a space that cannot be utilized for any other purpose.

The placing of this belt above the tuyeres, with the bottom of it just under the tuyeres, in place of the top of it just over the tuyeres, would admit of an opening being placed under each tuyere and the opening covered with a thin piece of sheet lead to allow any overflow iron falling into the chamber escaping from it. A slight oval depression with a good slope outward in the lower side of the flat tuyere, would act as a spout and drop the molten iron upon the lead which would instantly melt and give an alarm by running out. The door now placed in front of each tuyere would allow for the removal of any slag or iron that might become chilled in the air chamber, and also of any iron that might become chilled in the tuyeres. The removal of such iron may be rendered much easier by giving the tuyere a good coating of clay wash, which can readily be done with a brush when making up the cupola.

The same precaution may be taken to prevent the filling up of a belt air chamber extending down to the bottom plate, by placing a hole in the bottom plate under each tuyere, to be covered with a piece of sheet lead. This is a precaution generally taken by experienced foundrymen in ordering this design of cupola, and it has proven of great value in many cases. But such openings are seldom put in unless so specified in ordering the cupola.

The placing of the air belt high also admits of an additional tap hole being put in at any time it is found necessary to do so, which cannot be done with a deep air belt, without a great deal of expense and loss of time.

Height of Tuyeres.

The height that tuyeres should be placed above the sand bottom depends upon the system of handling the molten iron. When a continuous stream is permitted to flow from the cupola, they may be placed low, but when iron is to be held in the cupola, until a sufficient quantity is melted to fill a large ladle, tuyeres must be placed at a height that will admit of this, and in small foundries where the pouring force is limited, the tuyeres should be placed at a height that will admit of delays in pouring.

Tuyeres have been placed in cupolas in stove plate foundries one inch above the sand bottom on the back of the cupola, and they have been placed five feet above the sand bottom in steel work cupolas and satisfactory melting done in each case.

The function of the fuel below the tuyeres is to support the stock above the tuyeres, and it is not consumed after the blast is put on, even in the longest of heats, but is charged through in lighting up, and broken up in the dump and rendered useless as a cupola fuel. Unnecessarily high tuyeres are therefore waste fuel, and tuyeres should be placed at the lowest point that the method of tapping and handling the iron will permit.

Another advantage of the low tuyeres is that they give a hotter and more fluid iron. In the steel works referred to above, the iron melted was only a bright red as it flowed from the cupola and on mentioning this to the foreman, I learned that they never in any part of the heat were able to melt what would be termed a hot iron in a foundry, but this iron answered their purpose for steel making; while in the stove foundry with the low tuyeres, the iron was sufficiently hot to run stove plate.

Six to eight inches is a good height above the sand bottom in cupolas where the iron can be handled as fast as melted. This height admits of slag being drawn from a slag hole, and the hole permitted to remain open through the heat after the first tapping.

Tuyeres should always be placed at an equal distance apart, and made of an equal size that the blast may be evenly distributed to the stock, if this is not done, the cupola will not melt evenly, and trouble will occur before the end of a heat, if a long one.

In investigating a hoodoo cupola a short time ago, I found it to be an old cupola in which no slag hole had been placed when originally designed. In order to get the slag hole in a desired location, one tuyere had been removed, the slag hole placed a little to one side of it, and a tuyere of a smaller area, placed on the other side, this arrangement gave uneven distribution of blast. The cupola melted very well at the start of a heat, but at the end of an hour in blast began to melt slowly, and at the end of another hour, would scarcely melt at all. An investigation of this cupola after the bottom was dropped and became cold, showed that the stock had hung up, on the side where the blast was deficient, and had thrown the blast against the lining on the other side, which was badly cut out.

A tuyere should never be placed directly over an iron or slag tap hole, as the cold blast from a tuyere so placed, has a chilling effect upon molten iron, and to a greater extent upon the slag, the tap hole for which is placed higher and nearer the tuyeres.

One tuyere should always be placed a little lower than the others to act as an overflow, or a depression one inch deep may be made in one tuyere to act as a spout, to carry overflow iron out of the cupola and act as an alarm tuyere.

Height of Cupola.

The height of a cupola is the distance between the cupola bottom plate, and the bottom of the charging opening, commonly designated as the charging door. All cupola construction above this point is cupola stack. This fact was recognized by foundrymen in the days of brick cupola stacks, which were constructed square upon an iron plate, supported on iron columns, on a level or a little below the top of the cupola.

In the early days of cupola construction, cupolas were made low. This was probably done to facilitate getting up stock for melting. Many of these cupolas were so low, in proportion to their diameter, that fully one-half of the heat developed by the fuel escaped up the stack without being utilized in any way. In my first work on foundry practice, published in 1877, I called the attention of foundrymen to this fact, and suggested as a remedy, an increased height of cupola, that more stock might be placed in a cupola, and the heat escaping from the melting zone utilized for heating the iron and preparing it for melting, before settling into the melting zone. This theory was at once taken up by foundrymen and proved to be correct, and all new constructions are greatly increased in height.

In this work I placed the table for the height of cupolas, according to diameter, ranging from six feet for a twelve-inch cupola, to fifteen feet for a sixty-inch cupola. The suggestion of a fifteen-foot cupola was ridiculed by many foundrymen and pronounced impractical, for the reasons that throwing in stock from so great a height would knock the bottom out of the cupola, or break up the sand bottom, or heavy iron thrown upon the fuel would break it up in such small pieces that it would be worthless for melting, etc. But since that time, cupolas have been constructed of double this height (thirty feet), and none of these bad effects have resulted from throwing in fuel and iron, from so great a height, and many eighteen to twenty-foot cupolas are now in daily use.

The height a cupola should be is indicated by the heat at the charging door when the cupola is filled with stock to this point and melting at its full capacity. A cupola of a proper height shows but very little heat and no flame at the door, and the hand can readily be held in the cupola without danger of burning.

Should this not be the case, and there is an excess of heat and flame the cupola is too low, and heat is escaping up the stack, without being utilized in any way for melting.

When a cupola is too high, this is indicated by the extent to which the stock settled before flame appears at the top of the stock, but it is better to have the cupola a little too high, than a little too low. In fact, the only objectionable feature to an excessively high cupola, is the getting up of stock, and a little increase in destruction of lining above the necessary height.

The objectionable feature of a very low cupola in addition to the loss of heat, is excessive heat at the charging door, which in hot weather sometimes prevents the men from keeping the cupola properly filled, and results in a bad heat. The following table shows approximately the proper height for cupolas of different diameters:

Diameter, Inches	12	18	20	24	30	35	40	45	50	60	72
Height, Feet ...	6	8	9	10	11	12	13	14	15	18	20

In cupolas of very small diameters the iron in charges is liable to become jammed and when expanded by the heat becomes lodged against the lining, hangs up the stock and melting stops. When this occurs it can only be dislodged by a bar worked down from the charging door, through the stock, and for this reason, cupolas of small diameter should be low. I have frequently seen this lodgement occur in cupolas up to twenty inches in diameter. Above this diameter it seldom occurs when scrap is properly broken and charged, but this may occur in cupolas up to thirty inches in diameter, if large scrap is charged.

Cupola Stack.

The stack of the cupola takes no part in the melting of iron in a cupola and a cupola melts equally as well without any stack at all and entirely open at the top, as with a high stack. But a stack is of value in giving draft for lighting up in low cupolas, and to carry the fumes of combustion away from the men in charging, and prevent sparks being thrown upon the scaffold at the latter end of a heat, when stock gets low in a cupola.

The height and diameter the stack should be, therefore depends upon conditions and surroundings. A narrow stack gives a stronger draft than a broad stack of the same height, but throws out sparks freely, due to the contraction of the blast, and also makes a greater heat at the charging door.

A stack of the same diameter as the cupola casing, with a lighter lining permits the blast to expand and lessens its lifting force, and permits the heavier sparks and pieces of coke falling back into the cupola when it is of a good height.

To eliminate the objectionable cupola fumes from their other plants, and also from their neighbors, the Brown & Sharpe Mfg. Co., Providence, R. I., constructed a cupola stack 50 feet high; this carried the fumes so high that they were not noticed, and any sparks thrown out at the top of the stack, become so cooled in their descent that they were not dangerous.

The draft of this cupola was so strong, that in their first heat, they found molten iron flowing from the spout before the blast was put on. To prevent this occurring every heat, it was found necessary to put in the front and close the tuyeres.

At the foundry of the Philadelphia Sash Weight Works, Philadelphia, Pa., where the metal melted was principally steel scrap, consisting of tin cans and other refuse, containing dirt, paper, pieces of wood, and other rubbish, a great deal of complaint was made by neighbors of fumes and sparks from the cupola, and the fire department of this city notified them that this must be stopped. To overcome the trouble, a cupola stack, fifty feet in height was constructed, and rows of openings placed in it from just above the foundry roof to near the top of stack. These were put in for the purpose of admitting cold air to cool off the heated air from the cupola and deaden the sparks. On top of this stack was placed a large drum, covered with wire netting of small mesh, through which no sparks of any size could escape, and in addition to this, a one-inch pipe was arranged for spraying water into the stack when the cupola was in blast.

This arrangement effectually prevented the escape of sparks from the top of the stack, and the cold air admitted through the openings in the stack cooled the heated air from the cupola to an extent, that the wire netting placed around the top of stack was not at all injured by the heat.

This arrangement thoroughly prevented the escape of sparks from the top of the stack, but when a high wind was blowing, it blew into the openings on one side of the stack and blew the sparks out of the opening on the opposite sides, and no advantage was derived from this construction, and a new design is now being prepared which I may be able to describe before this work is completed.

Stack Hoods.

A cupola stack hood is a device placed over the top of a cupola stack for the purpose of arresting sparks from the cupola and throwing them back into the cupola or down upon the foundry roof.

These hoods have been constructed of various designs, one that was popular some years ago, was an arch open at both ends formed of boiler plate and lined with fire brick, which was placed across the top of the stack, with the ends extending out over the sides a foot or more. This arrested the sparks and threw them back into the cupola or out at the ends of the hood, with so little force that they fell close to the cupola. Some few of these hoods may still be seen on cupolas, but they have practically gone out of use.

The most popular hood at the present time is a round boiler plate hood, of the diameter of the cupola stack, or a little larger, supported on iron supports two or three feet above the top of the stack. These hoods arrest the sparks in their upward course and throw them back into the cupola or down upon the foundry roof, when the wind is not high, but with a high wind, the sparks may be carried to as great a distance as without the hood. These hoods are corroded rapidly by the heat and gases from the cupola, and are seldom replaced, which would seem to indicate their uselessness.

The placing of these hoods on cupolas seem to be a hobby of some of the cupola manufacturers as they are seldom seen on any but new constructions at new plants, and the older foundrymen seldom have them placed even on new cupolas.

Stack Door.

A stack door is a door placed upon the top of the cupola stack, when the cupola is placed within the foundry to serve as a damper for retaining heat in the foundry during the winter months.

This door is constructed of boiler plate, and hinged to lay flat on top of the stack. Levers are attached to it for the purpose of raising and lowering it, and operated by a chain or heavy wire extending down to the bottom of the cupola.

During lighting up and when the cupola is in blast, this door is stood up on end, and when the bottom is dropped and a few buckets of water have been thrown upon the dump, the door is let down to shut off the draft from the cupola, and the heat of the cupola and dump keep the foundry warm during the night, and prevents freezing of the molding sand in cold climates. It also serves to retain heat from stoves or open fires in a foundry, during the day, as a cupola placed near the center of the foundry is a perfect funnel for the escape of heat when the bottom doors are down. For this reason the bottom doors of cupolas, not in daily use, should be put up, and the front and tuyeres closed in cold weather.

Number of Charging Openings.

One charging opening or door is sufficient for a cupola of small diameter, but more than one should be provided for a cupola of large diameter to admit of rapid charging and an equal distribution of the fuel and iron.

In a cupola of sixty or seventy-two inches diameter with a single charging door, fuel and iron has to be thrown clear across the cupola. It takes considerable muscular power to throw heavy iron so great a distance, and the iron does not always reach or land in the desired place or position, and an even distribution of the fuel is also difficult and the result is uneven settling of the stock, and uneven melting. For this reason, two or more charging openings should be placed in all cupolas of large diameter. Two or more charging doors are also of an advantage in the handling of stock, as iron and coke may be placed all around the cupola making the carry shorter, and charging more rapid, which is a great advantage in cupolas melting fifteen to twenty tons per hour, and charging has to be rapidly done to keep the cupola filled and keep down the heat from the men engaged in charging.

When a cupola is high and the scaffold fireproof, charging doors and stack may be dispensed with, and the cupola charged direct from the top. At the Homestead Steel Works, Homestead, Pa., four cupolas ten feet in diameter and thirty feet in height were installed. On the top of the casing of these cupolas short cast iron columns were placed for the support of the stack, which was constructed of boiler plate, and unlined. This left the cupola open all way around for charging, and a short stack carried off the heat and gases of melting equally as well as with one or more charging doors.

Charging Doors.

The charging door of a cupola takes no part in the melting of the cupola and is only of value for closing the opening to give draft to the cupola for lighting up, and to prevent flame and sparks being thrown out upon the scaffold when stock gets low in the cupola, toward the end of a heat.

Charging doors are made of various material and construction. They are generally hinged doors, constructed of fire brick and made to close into the cupola flush or almost flush with the lining of the cupola, and may be single or double doors depending upon the size of the opening to be closed. There are two ways of holding the brick in place, one is to construct a boiler plate door with a deep flange to hold the brick in place, another is to construct a steel or cast iron frame for holding the brick. The objectionable feature of both these designs is that the flange or frame burns away or warps to an extent that they do not hold the brick or cannot be closed.

Another style of door is the steel frame of a size to overlap the casing, this prevents it being burned or warped by the heat, and the frame filled in with wire netting. This form of door answers the purpose equally as well as the fire brick door, lasts well, and is light and easy to handle.

Doors may be hung on hinges, hung in grooves to slide up and down with a balance weight, or placed on rails to be pushed around the cupola out of the way during the charging. For either of these forms of doors, I prefer the wire door, as it is light and easy to handle, and I prefer the hinge door to the sliding door or the balance weight door, as these doors are frequently thrown out of order by the warping and twisting of the cupola casing.

Cupola Scaffold.

The cupola scaffold is a far more important factor in the successful management of a cupola than many foundrymen appear to realize, judging from the size of scaffold provided for many cupolas.

The successful melting of iron in a cupola depends to a very large extent upon fuel and iron being placed in the cupola in proper proportions and the production of an iron of a desired quality from a mixture cannot be obtained from a mixture, if the mixture is not in proper proportion to produce an iron of that quality, and an accurate mixture cannot be made or correct charging done without weighing, and if there is no room for scales upon the scaffold, in a proper place for weighing stock, as it is placed in the cupola, all is guess work, and the results are uncertain both in melting and in the quality of the iron.

In many of the modern foundries, where the cupola is placed in the foundry, the cupola scaffold is made to extend the length or breadth of the foundry, and the space under it used for a core room, bench work floors or other light castings. These scaffolds in many cases take the place of a stock yard, and provide room for a carload or two of coke, which can be placed upon the scaffold as fast as it is unloaded by means of a bucket elevator. Pig and scrap may be taken up in the same way, and many tons placed upon the scaffold, as may also limestone, wood, etc., thus placing everything under cover and convenient for use. This plan saves a great deal of labor, and also the annoyance of having cupola men lay off in bad weather as they are very liable to do.

This plan of scaffold was described and recommended in my cupola work of 1899, and has been adopted in many new constructions. Many of the older plants have not been designed to admit of this plan of construction, and a different plan must be adopted.

In the early days, cupolas were generally placed outside of the foundry, with the cupola spout extending into the foundry, and the scaffold consisted of two platforms, one placed lower than the other. The iron for charging was placed by hand upon the first platform, and lifted from this to the second, from which it was thrown into the cupola; small scrap was lifted up in boxes, or thrown upon the charging platform by hand. This plan answered the purpose very well for the small low cupolas then in use, and is still the practice in many of the old small foundries, and may be adopted for small testing cupolas, or short heats in temporary cupolas, when work is scarce and a few castings are wanted in a hurry.

When a cupola has more than one charging door, it should be placed in or near the center of the charging floor, so as to give room all around it for charging, and when there is but one charging door the cupola should be placed to one side, near the center. This provides room for coke on one side and pig and scrap on the other, with the scales in front of the door. A cupola should never be placed in a corner, for this hampers the charging men in their work.

When iron is weighed in the yard, and placed on trucks or cars in charges, of pig and scrap, and coke is taken up in baskets or barrels, room should be provided for more than one charge on the scaffold at a time and also room for a quick return of empties to the yard for loading.

The distance the floor should be placed below the lower edge of the charging door, depends upon the method of charging. For hand charging a good height is twenty-four inches; this is a good height for the handling of pig, and also for throwing it into a desired place in the cupola. For barrow or truck charging, and also for tin plate charging, the floor is generally placed on the level with the door.

The charging door of a cupola of large diameter should never be placed low in the cupola. I saw in Franklin, Pa., a few years ago, a seventy-two inch cupola, in which the door was placed so low to suit an old scaffold, that when looked into from the door, it looked more like a large washtub than a cupola, and when in blast, a very large per cent of the heat escaped up the stack without being utilized, and the heat at the door was so great that it was difficult to keep the stock up to the door.

When a charging door is placed high above the charging floor, and a charging platform is constructed in front of the door, as is sometimes done, more time and labor is required in charging, it is therefore more economical in the long run, to have the cupola of a proper height and arrange the scaffold floor to suit it, than to have to lower the cupola to suit the scaffold.

Fireproof Scaffold.

In the days of wooden foundry buildings and wooden scaffolds, supported upon wooden posts, the fireproofing of the scaffold was considered a very important matter, and many plans were devised for rendering it and all woodwork about the cupola fireproof.

The most common practice was to cover all the woodwork with sheet iron. This was very effective when new and properly put up, against flame and flying sparks of slag and iron when the bottom was dropped, but when it became rusted and full of holes, was more of a firetrap than a protection against fire, as it concealed any hot slag or iron that may have fallen behind it, and many founders preferred to have the wood exposed and wet it down after each heat. The protecting of woodwork in this way at the present time with our present quality of thin steel plate, the life of which, even when galvanized, is only from two to three years, would be perfect folly, for when woodwork about a cupola is once thoroughly protected, it is seldom given any further attention until a fire occurs.

One of the oddest way of rendering the scaffold and cupola room fireproof, is that in a foundery located on Fort Street, Detroit, Mich., which I visited some forty years ago. The walls for this room and supports of the scaffold were constructed of brick, up to six feet above the scaffold floor, from this point, it was gradually contracted, to form the cupola stack. The scaffold floor was made of iron plate, supported upon iron joists, the cupola was placed upon one side extended up above the floor about two feet, and was entirely open at the top for charging. The scaffold was provided with an iron door which was tightly closed, to give draft to the cupola for lighting up; the spout of the cupola extended into the foundry and alongside of it a small door for observing the tuyeres, and a large one at the back of the room for removing the dump, both of which were provided with iron doors.

This construction rendered the cupola room scaffold and cupola fireproof, as sparks from the cupola fell back upon the scaffold, and seldom went out at the top of the stack, and there was nothing to burn upon the scaffold, and the dump was entirely surrounded with brick walls, and no wood or woodwork in the room to burn.

The objectionable feature of this cupola, which was still in use at the time of my last visit to Detroit, about two years ago, was the heat upon the scaffold in charging, and when stock got low in the cupola, the heat and sparks prevented it being charged at all when in blast.

The best way to make a scaffold fireproof is to have the supporting walls of brick or concrete, and if other supports are used, make them of cast iron or steel. When the steel supports are used, they should be protected at the bottom by a cast iron sleeve filled with concrete to prevent them being rusted off, at the bottom by dampness of the cupola room. When the wooden supports are used, leave the wood exposed and wet them down after cooling down the dump.

Lining Material.

After erecting a cupola, the next thing to be done is to line it. For this purpose there are a variety of refractory materials that may be used, such as soapstone and micaschist, that are classed as native lining materials from being used in their natural state; fire brick and blocks and common red brick, that are classed as manufacturers' lining material; gainster and mixtures of fire clay and fire or sharp sand, that are classed as plastic lining material.

The first of these, soapstone, was the only lining material obtainable in this country in the early days of foundry practice, and made a very satisfactory lining and it is still the lining material used by small foundries in isolated districts, where fire brick is difficult to obtain. In these localities, flat soapstones obtained from the bottom of small streams are frequently used.

The Homestead Steel Works, Homestead, Pa., some years ago, constructed four very large cupolas for melting iron, to be converted into steel by the Bessemer Process. These cupolas were designed to be operated upon the blast furnace principle, and be kept in blast night and day as long as the lining would last. All of the various lining materials obtainable at that time, were tested in these cupolas, to learn which one would enable them to keep the cupola in constant blast for the greatest length of time. In these tests, a soapstone obtained from a soapstone quarry in Virginia, proved the most durable, and was used as long as this system was practiced. But they found it more practical to run a cupola for a week and drop the bottom than to keep it in blast until the lining burned through.

Micaschist is a comparatively new cupola lining material that was tested at the foundry of Cramp's Shipyard, Philadelphia, Pa., a few years ago, and proved very durable, and is now being used to a considerable extent for a cupola lining.

The objectionable feature of both soapstone and micaschist is the expense and the time required in laying up a lining, as each stone or piece has to be cut to fit the cupola casing, and the space it is to fill. A week or more may be required to line the cupola, which puts a foundry with only one cupola out of business for this length of time.

These materials, when ground and molded into cupola lining shapes, are said not to possess the refractory property to so great an extent as when in their native state, but I have not learned of any special cases in which this has been tested.

Common red fire brick may be used for the cupola lining. These bricks when set on end make a cheap lining, that can be rapidly put in, but they only possess refractory properties to a limited extent and are not at all suitable in large cupolas for long heats, and have only been used successfully in small cupolas in which short heats are melted; two or three time a week, and even in these, they only serve as a backing for a good cupola daubing, possessing refractory properties. When used in this way they have been made to serve the purpose for a year, but when not protected in this way, the frequent relining required makes them a very expensive lining.

Fire brick as now manufactured makes the most economical and most satisfactory lining of any of the cupola linings.

This brick may be obtained of any desired size or thickness, and the circular variety can be obtained for any diameter of cupola. The circular brick to be laid flat, makes the most compact lining, and is to be preferred to the straight or wedge-shape brick to be set on end.

Gainster is a soft material, similar in appearance to a mixture of sharp sand and small gravel. Another soft lining material is composed of fire clay and sharp or fire sand in proper proportions. These two lining materials are classed as plastic linings, and are only placed in cupolas of very small diameter. The method of putting in a lining of this kind is to make a form or plug of such size in diameter as will allow of a lining of the desired thickness being put between the form or plug and the casing, place the plug in the center of the cupola, and after wetting the lining material to a cohesive state, ram it in solid around the plug, and pull the plug up as the lining is put in.

This is a very common way of lining small cupolas in foreign countries, but in this country it is only practiced in a few of the bedstead foundries using very small cupolas.

Number of Cupolas Required.

In the leading foundries of years ago, it was the common practice to place two or three cupolas of different diameters in a foundry and put the one best suited to the size of heat in blast, and when an extra heavy piece was to be cast, to place two or more cupolas in blast.

But the tendency of late years has all been towards a single cupola, tapping of slag and long heats, and a cupola is generally installed to suit the average heat, and in case of an extra heavy heat, is kept in blast for a greater length of time. In dull times and light heats an extra thickness of lining is put in to reduce its diameter. In the very large foundries, one large cupola is generally installed to do the melting, although two or three of about the same capacity are generally installed in order that one may always be ready for use, when relining and repairs are necessary. This is very good practice, where conditions are suited to it, and very poor practice when they are not.

It has long been the practice for molders to stop molding when the blast goes on, and in hand-ladle foundries, to divide the men into sections and have the sections take iron turn about. The first section gets through and out of the foundry first, and this is done to give each section a fair chance. In machine and jobbing foundries, the molders are given ladles turn about, so that all get through pouring and shaking out about the same time. This cuts the molding time short an hour or more in long heats, and reduces the output of castings to that extent.

To obviate this loss in molding time, many foundries have adopted the pouring gang system, which admits of the molder molding the full eight or nine hours of their day's work, but this system is not practical in all lines of castings, which is more especially the case with light hand-ladle work, in which case the number of men required to do the pouring would be about equal to the number of molders, and for this class of casting a skilled pourer is required.

To prevent this loss of molding time, many founders are putting in extra cupolas to melt short heats, and placing them to give the shortest carry for the molten iron. By this system, they gain an hour's time in molding, which for fifty molders is equal to a day's work of six additional molders, while the extra expense for cupola help and fuel, is only one melter and a little extra coke for bed, which is far more than offset by the increased output of castings, even when the castings are all piece work.

The pouring gang system which is generally placed in charge of one or two molders, works out very satisfactory and is rapidly being adopted in foundries in which the line of castings are suitable for it.

Or it may be placed in charge of an assistant foreman, who trains laborers to do the pouring, and in case of important pieces, or loss of casting that might be attributed to improper pouring, or dull iron, gets points from the molder as to the thickness, shape, gating of the casting, etc., and pours it himself with iron suitable for such a casting.

Cupola Management

CHAPTER IV

Laying Up a Lining.

In laying up a cupola lining a very important matter that should be remembered is that the mortar placed between the pieces of lining material is not so refractory as the lining material and is burned away more rapidly, leaving crevices between the pieces of lining material into which the heat and flames penetrate and burn off its edges. The lining is burned out more rapidly than when the lining material is laid close together. When a lining has been in use for some time, and each piece can be seen sticking out as a rounded knob, an excess of mortar between the pieces is the cause of this condition.

In laying up a lining of fire brick, the only mortar required is a thin grout composed of fire clay and sharp sand in proportions that have been found to give the best results as a cupola daubing. This material is wet to a thin slush, and the bottom plate slushed with it, a brick is then pressed into the slush, and the end of the next brick, is dipped into a bucket of this slush, and pressed closely against the edge of the first brick, and so on around the cupola. The brick should be laid close against the heads of the rivets in the casing, which places the lining a half inch or a little more from the casing, between the rows of rivets, and allows space for expansion of the lining when heated.

After the first layer of brick has been put in, slush the top of them with a thin grout, and lute the joints between the bricks with a little stiff clay, at any point at which the grout may run out, and see that all the joints between the bricks and the space between the brick and casing are filled with grout and the top of the brick covered with it.

On top of the first row lay the second row in the grout, after dipping the end of the brick in the grout, and slush in the same way as the first row and put in each layer in the same way, being careful to break joints in each layer.

A lining laid up in this way lasts a great deal longer than one laid up with a thick mortar and open joints, and requires no drying. A heat may be melted in it the day after laying up without injury to the lining or metal melted.

One of the most objectionable features to the native lining material is the large joints between the layers and pieces of material which must be filled with a clay and sharp sand stiff mortar to hold up and not run out. This mortar burns out, exposing the edge of the lining material, which increases the rapidity of its destruction.

The common straight fire brick, set on ends, does not make a durable lining, for the reason that at the side next the casing they have to be set far apart to form the circle of the cupola diameter, and only in the inside diameter can they be placed close together, and as they are burned away the space between them becomes larger and their destruction is more rapid.

The wedge-shape straight brick, set on end, makes a very serviceable lining and at one time was a very popular lining, but they are more difficult to put in than the circular brick, and have practically gone out of use for cupola lining.

The circular brick makes the best lining, and may be more rapidly laid up than any other, and is the most popular lining used at the present time. The size of brick most commonly used, is those of three and four inches in thickness.

Thickness of Lining.

The thickness of lining required depends upon the size of cupola and length of time it is kept in blast.

For a cupola of small diameter, only kept in blast from one to two hours at a heat, a four-inch lining is sufficient. For cupolas of large diameter, kept in blast for many hours, an eight, ten or twelve-inch lining may be required and are generally put in for safety whether actually necessary or not.

At a large car wheel plant visited, where the cupola was kept in blast for from eight to nine hours each heat, a six-inch fire brick lining was put in and inside of this a four-inch lining was put in. This plan admitted of the four-inch lining being burned out in the melting zone, and being taken out and replaced in the melting zone without disturbing the main lining. This is a very good practice, as it prevents shelving of the lining, as frequently occurs in cupolas with thick linings, maintains the lining near a standard diameter and insures safety from burning through to the casing, and perhaps having to drop the bottom in the middle of a heat.

This is a precaution frequently taken by foundrymen for safety in the smaller cupolas by putting in a two-inch lining of straight fire brick, or common red brick, next to the casing, and inside of this placing the cupola lining of circular brick; this serves as a warning to melters who sometimes do not notice that the lining is thin, until the casing gets red hot.

Putting Up the Bottom Doors.

When a cupola has been lined it is ready for melting, and the first thing to be done in preparing for a heat, is to raise the bottom doors into place. This may be done by hand, or by one of the various devices designed for raising them into place more easily and quickly.

When raised into place, a single door should be supported by a good strong prop placed near the front of the door, and in case of double doors, the main prop should be placed in the center under the overlapping door and an additional light prop placed at each end of the joints of the doors, to prevent springing and cracking of the sand bottom when throwing in the stock. Old doors that have become thin and shaky, should be supported at any point where they are likely to spring. The prop may be made of wood or iron. In the days of the old professional melters, many of them were so superstitious or desired to throw so much mystery about the management of a cupola, that they would not use an iron prop and must have a new wooden prop every time the old one become the least bit scorched by the heat of the dump. The days of this nonsense have gone by and the iron prop is universally used.

It is the practice in many foundries to imbed an iron plate in the sand every heat, upon which to rest the main prop; this is poor practice as the plate frequently has to be raised or lowered, to get the prop of a proper length, and a better plan is to imbed an iron block in the floor of a sufficient depth to make it permanent. The prop is then always of the proper length, and a great deal of time and labor is saved in adjusting the prop.

A very good practice is to place a cast iron plate under the cupola to cover the entire surface between the cupola supports, this gives a good foundation for props, and a good floor from which to shovel the dump, and greatly facilitates the removal of the dump. This plate should always be covered with dry refuse sand before dumping, to protect the plate and prevent iron and slag flying on suddenly coming in contact with it.

Many foundrymen attach a ring to the bottom of the main prop, in which a hook may be placed for the purpose of drawing it from under the dump, and prevent it becoming heated and bent. This ring should be placed near the bottom end of the prop, as the prop is always drawn from the bottom and falls inwardly, thus placing the ring end of the prop at the outer edge of the dump.

Sand Bottom Material.

The sand bottom material must be of a material that neither cracks nor melts up into a semi-molten mass, for if cracked, the molten iron is liable to work its way down through to the iron doors, where a leak will occur, through the bottom, which is very difficult to stop, and if it melts and cakes up, it will not fall out when the bottom floors are dropped, and may hang up the cupola dump.

For these reasons, a new strong loomed clay should not be used, for this cracks in drying. Fire clay and sharp sand should not be used, for this cakes up into a tough adhesive mass when highly heated, and combines with the iron, which it absorbs, forming a tough adhesive mass when hot, therefore, new material should not be used for a sand bottom. The best material for a sand bottom is burning molding sand. This may be taken from the sand heap, but this is rather extravagant, as sand collected from the gangways, and other refuse sand answers the purpose very well, when riddled and wet up. Should this contain an excess of burned parting sand, it may be strengthened by the addition of a few shovels of new molding sand, but too great a quantity of this should not be added, as it tends to cake and crack up.

When a bottom tends to hang up and not drop freely when the door is dropped, this may be prevented by using part of the sand bottom from the previous heat. This material when passed through a No. 2 riddle contains a sufficient amount of cinder to prevent the bottom caking, and drops freely. This material, with a few shovels of gangway sand added, makes the very best bottom for small cupolas, in which the sand bottom is more liable to hang up than in large cupolas.

A little experimental work should always be done with sand bottom material when there is trouble with cutting through or hanging up, and a proper material found for such a bottom.

Putting in a Sand Bottom

The material for a sand bottom should be wet only to the extent of a molding sand when tempered for molding. If wetter than this, it packs too close, and molten iron will not lay quietly upon it, and it should not be rammed any harder than the sand in the drag of the mold, for hard ramming also causes molten iron to boil, and this boiling cuts up the sand and may cause a leak through the bottom. Wet sand and hard ramming are two of the most common causes of sand bottoms cutting through.

In putting in a sand bottom the first thing to be done is to close all holes or openings that may have been made in or around the doors, by runouts or wearing away due to heat and rusting.

This is done by placing a thin plate of scrap iron over large holes, and looting large cracks with clay. This is done to prevent the sand running out when it becomes dry, and forming a vacuum into which the molten iron may settle and work its way down to the door, and cut through it.

After the leak spots have been attended to, a little bottom sand is thrown in through the front opening, and carefully packed with the hand around the edges, this is the danger points for leaks, and this is done by careful melters to insure the sand being properly packed at this point and prevent a leak.

About one-half of the bottom sand is then thrown in, spread evenly, and tramped or butted down, the remainder of the sand is then thrown in, evenly tramped and butted down. The melter then goes around the edges and feels for soft spots, and banks the sand up a little around the edges to throw the iron off from the lining, and prevent it working its way down to the door and leaking through between it and the bottom plate.

I have found in long heats that banking up of the sand around the lining in this way is a very important matter. In a cupola in which twenty-five tons were melted at a heat a leak frequently occurred after about twenty tons were melted. This was entirely prevented by banking up the sand slightly around the edges.

The sand in a bottom should be rammed perfectly even, as molten iron does not lay on a hard-rammed sand, but boils and cuts up the sand.

The pitch that should be given to a sand bottom to cause the iron to flow to the tap hole is one-fourth of an inch to the foot, a higher pitch throws the iron out of the tap hole with greater force and makes it more difficult to catch the stream in small ladles, and also causes slag to flow out with the stream when there is very little slag in the cupola.

In case of two or more tap holes, the pitch is given toward the center of the cupola and a perfectly level trough constructed between the tap holes. This is done that the cupola may be drained from either tap hole and chilling of the iron prevented at either if not tapped for some time. This trough should be narrow, that the iron may be concentrated to throw it out of the tap hole, and not a large flat surface that will admit of iron becoming dull in case of slow melting.

It is very difficult for a melter to see what slope he is giving a sand bottom when inside of the cupola, and many of them do not give the bottom the same slope from day to day. To avoid this, the melter should be provided with a measuring gauge; this may be in a shape of a ruler, with notches for the height of each tuyere, above the sand bottom.

The sand for a bottom may be thrown in through the front opening or taken up and thrown in at the charging door, this is a matter of convenience or fancy of the melter. In cupolas of small diameter the sand bototm is put in from the front, and butted with a bench or other short rammer; in large cupolas the melter goes into the cupola and spreads and tramps the sand as his helper throws it in.

The thickness of sand bottom required, depends upon the diameter of the cupola, and length of the heat and varies from three to six inches. In cupolas of small diameter a three-inch bottom is sufficient, and in cupolas of larger diameter, a four to six-inch bottom is generally put in, and even a thicker bottom is frequently put in by some melters for greater safety.

When trouble occurs with a sand botom, such as cutting through and running out, the first thing to do is to look to the support of the bottom doors, and see that they are supported in a manner that does not admit of their springing and cracking, or shaking up, the sand bottom when charging is being done. The next thing to look to is the putting in of the sand bottom, and see that the foregoing instructions on the putting in of the sand bottom are strictly carried out. Should these remedies fail, then the bottom material must be looked after and some change made in it. But a change is not necessary, if the running out is only occasionally and the melter is at fault in putting in the bottom.

Stopping a Leak.

A leak of molten iron through a cupola bottom is a very difficult thing to stop, and as I have said before in my writings, the place to stop it, is in the putting in of the sand bottom, for such leaks are entirely due to carelessness in properly supporting the doors, and putting in the sand bottom, and if my instructions are properly followed, no such leak will occur.

Such leaks generally occur around the edge of the bottom doors and are due to carelessness in packing the sand around the lining, and to crevices between the bricks, into which the molten iron runs and works it way down to the doors. All such openings should be carefully closed with a stiff cupola daubing, and all dry sand and refuse removed from the bottom plate, before putting up the doors.

Many melters give little attention to this part of the lining, which is frequently permitted to remain in when relining, and becomes ragged and shaky, and runouts have been traced to the molten iron working its way down to the door through crevices in the lining. This part of the lining is as important as any other part and should be given as much attention as any other part. When it becomes ragged and shaky, it should be carefully daubed and all crevices securely closed.

When a leak occurs, the first thing commonly done, is to throw water upon it, to chill the iron in the leak and stop it. This is about the most foolish thing that can be done, for water cannot be thrown into a small leak, with a stream of molten iron running out, and the water can only be brought in contact with the iron that is already out, and the chilling of this cannot possibly stop the leak.

Another remedy commonly applied is the bod stick and bod. This is rarely effective, for the opening is so small that it is impossible to get the bod material into it, and the leak is frequently from such a location that the bod when applied on the outside is seldom effective.

The best way to stop such a leak is with a wide board or plank, placing on the end of this a good wad of stiff cupola daubing, and press this up into the leak, quickly, with a strong leverage and hold it there until the iron becomes chilled, and for safety keep it there during the remainder of the heat.

For the greatest safety in preventing a leak, always remember my first instructions—be careful in putting in the sand bottom and put it in properly.

Lining the Spout.

The bottom lining of the spout is generally put in at the same time as the sand bottom, and made to extent under the tap hole and front, and connected with the sand bottom.

The lining material used for short spouts and short heats, is generally new molding sand, which is sometimes given additional refractory properties, by wetting with fire clay, clay wash. The cheeks of the spout lining are made of the same material, and the bulk of it may be used over from day to day, by breaking and wetting up, and it is sometimes permitted to remain in the spout and patched up for a number of heats.

For long spouts and long heats, a mixture of fire clay and sharp sand is generally used, as this material lasts longer than molding sand.

This material is worked into a thick plastic mass, and worked into balls, which are placed in the spout and worked into shape by the hands. When the bottom of the spout lining is put in, it is made to extend up under the tap hole and spout, and connected with the sand bottom the same as the molding sand lining, and the material for the cheeks is worked into balls and pressed into shape with the hand and no ramming is necessary of this soggy material for either the bottom or cheeks of the spout.

In putting in a spout lining, the cheeks should be shaped to give a narrow groove at the bottom for the stream of iron, the concentration of the stream in this way makes it much easier to catch, than from a broad, flat-bottomed spout, and the stream keeps the spout clean. The bottom of the spout should be given a little more slope than the sand bottom. This may be done in short spouts in making up the spout lining, but long spouts must be given a slight incline.

Front.

The material used for putting in the front is generally the same as that used for the spout, that is, new molding sand or a mixture of fire clay and sharp sand.

The front is generally left open to give draft for lighting up, and when the lighting up is done with a torch, this has to be done, and the front is put in after the bed is burned up. The old way of putting in a front was to build up a wall of coke in front of the fire, and ram the front material against it. This leaves a ragged uneven front on the inside, and when the coke burns away, the loose sand falls down and frequently is carried out of the tap hole with the iron.

The modern practice is to cut a board the shape of the front opening with a notch in the bottom for the tap hole rod, and set this in the front of the fire, and ram the front sand against it. This board burns away and not only dries the front, but also leaves a smooth front on the inside. Before putting this board in place, all dust and ashes are removed from the spout, and the front opening brushed with water or clay wash all around, to make the front material adhere to the opening and insure a good joint. A rod of the desired diameter of the tap hole is then laid in the bottom of the spout, and the front sand rammed into the opening, until it is flush with the casing. The front is then cut away, downward and inward from the top and sides of the opening, to the bar forming the tap hole, until the tap hole is only one and a quarter or half inches long. The cheeks of the spout are then made up, when new, or the front connected with them if old. The tap hole rod is then withdrawn, and the spout brushed out.

The spout and front are then ready for drying. This is done by building a wood fire upon the spout, which skin dries them and that is all the drying that is necessary.

When a clay or sharp sand material is used for putting in a front, this is used as stiff as possible to prevent sagging down from the top of the front, and is worked into balls, and after the tap rod has been laid in, the front is built up by hand, only the lower half of it being put in, before the bed is burned up, and about ready for charging. The upper half is then put in. This is done to admit of the lower half drying out to an extent that it will support the upper half without sagging. But even then the upper half has to be watched and pressed up against the top of the opening before it becomes hard from the heat of the bed. This front is shaped up the same as the sand front, and is dried in the same way but more wood and time is required in drying it.

This front material is but little used at the present time, as it has been found that the sand front answers every purpose and is much easier and quicker put in, and in case the sand does not possess sufficient refractory properties, it is wet up with clay wash, of a strength that gives to the sand the required refractory properties.

The front is always made up fresh or nearly so, with the inside of the cupola lining, and cut out on the outer side to give the desired length of tap hole. This is done to give strength to the front, sufficient to resist the pressure of molten iron in the cupola. Were a front only one and a half inches in thickness, to be put in flush with the casing, it would be pushed out, by a very limited body of motion iron in a cupola.

In case of extra thickness of lining, the front is not put back flush with the inside of the lining, but is placed only far enough in to give it a firm hold on the front opening, which should not be less than four to six inches.

Tap Holes.

Some foundries have an endless amount of trouble with the tap hole and I have been called upon many times to locate and overcome these troubles, and have always found them to be due to either improper material, or lack of knowledge in putting in the front and tap hole.

The principal troubles complained of are enlargement of the tap hole and failure to maintain it of a proper size to suit the system of handling the iron; failure of a bod to hold; the stream of iron shooting upward and over the side of the spout in place of it following down the bottom of the spout; chilling of iron in the tap hole; etc.

The chilling of the iron in the tap hole is due to the tap hole being too long for a slow-melting cupola, and a long time between taps. This can be prevented by making the tap hole short, making the bod pointed, and pressing it well into the hole. The tap hole should not be more than one and a fourth inches long in any case.

The shooting of the stream upward or over the side of the spout is due to the sand or spout bottom being cut out under or in front of the tap hole and the pressure of molten iron forcing the stream upward. This condition is generally due to the bottom being cut by blowing out before the iron comes down, and another cause for it is the holding of the tap bar in such a position that it cuts away the top of the bod, and leaves the lower part in the bottom of the spout to form a hump at the outlet of the hole.

The remedy for the first of the causes is to extend the bottom spout lining into the cupola a safe distance beyond the tap hole, if this does not stop it, brush the surface with clay wash or wet the spout lining material with clay wash; as a last resort, a lining of sharp sand and fire clay may be put in at this point. This should only be a thin layer over the sand, for it is slow to dry out, and if the cupola is not permitted to blow out, may chill the iron in the tap hole before the first tap.

In tapping, the lower part of the bod should be cut away before opening the hole, and the bar should be laid flat in the bottom of the spout before withdrawing. This removes any possibility of a hump being formed in the bottom of the spout by the bod, and makes the hole in line with the spout.

The failure to maintain a tap hole of a desired size is due to the material used in making the tap hole not being suitable to the purpose; also to carelessness of handling the tapping bar. Some of the molding sand used for putting in the front does not possess the requisite refractory properties for a tap hole, and are burned or crumbled away by the stream. This can be prevented by using a better grade of sand, or wetting the sand with a strong clay wash, or placing a mixture of fire clay and sharp sand around the bar to form the tape hole and making the sand front up around it. When the hole has become too large, it may be reduced by pressing a fire clay and sharp sand bod well into the hole, and cutting a hole of the desired size through it before it becomes too hard. This stops further enlargements and maintains a hole of the desired size.

When a hole closes up and is difficult to keep open, this is due to the tap hole material melting and clinging to the sides of the hole. This is a condition that sometimes occurs with a fire clay and sharp sand front or tap hole. The remedy for this is a more thorough mixing of the clay and sand when it only occasionally occurs, and an increase or decrease of the sand in the mixture until the proper proportions of clay and sand are found, if it occurs daily.

Permanent Size of Tap Hole.

In the running of a continuous stream from a cupola, a permanent size of tap hole during the heat that will admit of the iron flowing from the cupola as fast as melted is desired.

This may be made in a number of ways. One of the oldest ways of doing it is to make a mixture of fire clay and sharp sand, and mold this into a half round or square block in a core box, and placing in the flat side of it, a tap hole of the desired size. This is then dried in the core oven, or upon the heating stove, and when dry is set upon a fire brick, placed in the spout under the tap hole, and the front made up around it. This gives the tap hole of a permanent size.

Another way is to drill a hole in a piece of fire brick and place it in the desired tap hole position in the bottom of the spout lining, and make up the front around it. A split brick is sufficiently thick for this purpose.

A fire brick with a tap hole in it is now regularly made by fire brick manufacturers, and can be had made to order. This brick is square at one end, and rounded at the other end, to fit the circle at the top of the front, with a depression around the tap hole for insertion of the bod, and to give a proper length of tap hole. These bricks are generally made to order with a hole of the required size and in the proper place to suit the thickness of sand bottom. This brick is put in place by the melter's helper when he is putting in the sand bottom, and the bottom is made up to the hole, by the melter when putting it in, and the helper makes up the spout lining at the same time. A sand front is put in against the brick, and cut away, the same as when a board is used, to prevent the sand from being rammed into the coke.

There was a permanent spout, front and tap hole, patented by Mr. Moore, something over fifteen years ago. This spout and front was made of a black lead and clay mixture similar to that used in the making of black lead crucibles. The spout lining was designed to be laid in the iron spout and the front, with the tap hole in it, to be placed in the front opening.

This spout lining and front were made to order to fit any sized spout or front opening, and a thimble was provided for placing in the tap hole when it became too large to reduce its size. The front and spout lining were claimed to last from three or four years, and save a great deal of labor and material in making up the front for each heat, but for some reason it never came into general use, and I have not seen one of them in use for many years, and they have probably gone the way of many more valuable but impracticable inventions.

Size of Tap Hole.

Tap holes are made of a size to suit the size of cupola, and the method of handling the molten metal, and vary in diameter from a half of an inch to one and a quarter inches.

Five-eighths of an inch is the size commonly placed in small cupolas, and in large cupolas for all hand ladle work. This size opening throws out a good stream, when there is a body of molten iron behind it, that fills the hand ladle very rapidly, and generally as fast as the molten metal can be handled.

The one and a fourth inch hole is only placed in large cupolas in which iron is accumulated while pouring, and it is desired to fill a large ladle rapidly. Such a large stream should not be caught in hand ladles, and would be impractical in small bull ladles.

A tap hole may be made of any diameter between these two diameters, but must be of a size that will admit of the iron being drawn from the cupola faster than melted, if it is the practice to stop in for ladles and pouring, but must not be of a diameter that will admit of slag running out with the iron and the blast blowing out almost as soon as tapped. But the hole must be of a size that will admit of all the iron being drawn from the cupola, occasionally to prevent it accumulating in the cupola, up to the tuyeres, when the system is stopping in and tapping out.

Tap holes are always made round for this has been found to be the shape that is easy to stop in and tap.

Slag Tap Hole.

A slag tap hole is an opening placed a few inches below the level of the tuyeres, for the purpose of drawing off slag from the cupola in long heats.

This opening is generally made on the opposite side of the cupola from that of the iron tap hole, and placed between two tuyeres that the chilling effect of the blast upon the molten slag may be reduced to a minimum.

The placing of this hole directly opposite the front is not arbitrary, and it may be placed at any point, between two tuyeres, found most convenient for the removal of the slag, or placed in the front directly over the iron tap hole. In this case, a partition is placed in the spout to prevent the slag running into the ladle with the iron and a lip or short spout provided for running it off at the side.

For this hole, a round opening three to four inches in diameter is cut in the casing, and a shallow cup-shape depression cut in the lining for the tap hole, and the rough edges of the brick are smoothed over with cupola daubing and no front such as is put in for the iron tap hole is required.

A tap hole is cut through the brick lining of a proper size, which depends upon the size of cupola and amount of slag to be drawn out. The hole should not be more than one and a fourth inches in length, and to obtain this length, the lining must be cut away on the inside of the cupola. This should be done in the shape of a basin, and not an enlarged hole, for slag chills very readily, and when hot is tough and difficult to get a hole through it and keep it open, and a failure to draw slag may be due to this cause.

Slag is too sluggish to flow in a spout like iron, and a broad apron with turned up edges is attached to the cupola shell to carry it out over the cupola bottom plate and it is permitted to fall to the floor or into a receptacle provided for catching it as it runs out.

This apron is given a coating of cupola daubing to prevent it from becoming rough and slag adhering to it, or it may be lined with split fire brick, which makes it more permanent and less repairing is necessary.

Melting

CHAPTER V

Lighting Up

The cupola having been properly lined, the sand bottom put in, spout and front arranged, we are now ready for melting a heat, and in order to do this we must have some fire, and the first important thing to be considered is the starting or making of a fire in the cupola. This is termed lighting up.

For lighting up, wood shavings, waste paper, straw, prairie grass or any substance that will burn freely and ignite wood may be used. This material should be evenly spread over the sand bottom. On top of this a layer of soft, finely split wood should be placed, and then a layer of coarser split wood, and on this a layer of dry hard wood.

Green wood or large knots should never be placed in a cupola, for these burn too slow, and the smoke from them cannot be burned off before the bed is ready for charging, and smoke interferes with the proper placing of iron and fuel. Only dry free-burning wood should be used.

When refuse wood is used, this should be cut into proper lengths and split to suit the purpose for which it is used. The wood when placed in the cupola should be arranged to burn freely and evenly, and when all in should be level on top. To arrange the wood in this way in cupolas of small diameter the wood should be dropped in from the charging door a few pieces at a time. In large cupolas it is the practice for the melter to go in and arrange the wood, as his helper throws it in to him or hands it down to him from the charging door.

This care in placing shavings and wood in a cupola for lighting up may seem absurd to many, but they should remember that many men cannot start a good fire in a stove or range, and a man that cannot start a fire in a stove certainly cannot start a fire in a cupola for the melting of many tons of iron, and when a foreman is breaking in a new cupola man this is a matter to which he should give special attention, that the bed may be burned up evenly, and melt evenly, and to be sure that this has been done he should look into the cupola just before charging and see if the bed is burning evenly, and not white hot on one side, or in spots, and no appearance of fire at other places. In a bed when properly burned the fire should show through evenly over the entire top, and this will be the case if the wood has been properly placed.

One time I put a man to work to light up a thirty-inch cupola without any instructions or attention, and when the time came for putting on the blast I found that he had put in the shavings and on these only four-foot sticks of hard cord wood on end, and shoveled in coke; the result was that there was no fire when the time came for charging, and none could be made, and the bottom had to be dropped and the heat postponed until the next day.

When wood is placed in a cupola in this way, the coke falls through it to the sand bottom, where it cannot be burned, even after the blast is put on, and causes dull iron by absorbing heat from the molten iron; and if any considerable quantity of it falls through in this way it will cause dull iron throughout a heat.

The putting on of the blast when the bed is only burned up on one side, in hopes that the blast will burn it up on the other side, is a very poor practice, for if there is any considerable quantity of coke that has not been ignited before the blast is put on, the cold blast will prevent it being ignited, and I have seen some very poor heats melted or partly melted, due to this cause; and it is better to give the bed more time to burn up before charging, and if it cannot be burned up satisfactorily, drop the bottom.

When only one or two tuyeres are a little dark, and there is a good fire at all the others, the fire may equalize itself before the blast is put on, and charging may be begun. But there is a risk even in this if the iron is required to be very hot and of an even temperature throughout the heat.

The best way to prevent these troubles occurring is to look after the placing of the lighting-up material in the cupola, and see that it is properly done.

Some foundrymen fill the cupola with fuel and iron before lighting the fire. This may be done very successfully if the cupola has a strong draft, but if there is a very poor draft it should not be done, and even with a good draft there is an uncertainty which may result in the dropping of the bottom before the blast is put on, or give a very poor heat. I do not consider this good practice and would not advise it in any case.

Lighting Up With Oil

The oil torch commonly used in foundries for drying molds, etc., is now being quite extensively used for lighting up in place of wood; the torch is laid in the spout with the nozzle in the front opening, and the flame thrown into the coke.

In lighting up a cupola of very small diameter it is only necessary to throw the torch flame into the front, but in cupolas of large diameter this does not penetrate to a sufficient depth to give an even light up, and an opening has to be provided through the coke for the passage of the torch flame to all parts of the cupola. This opening or flue is provided by building up coke on the sand bottom to form a flue from the front opening to near the back of the cupola, and in very large cupolas putting in flues on either side of the main flue into which the flame of the torch can penetrate and ignite the coke. The flame of the torch is thrown into these flues until the coke is evenly ignited and there is a good fire at the tuyeres.

One gallon of oil has been found to be sufficient to light up a fifty to sixty inch cupola when the flues are properly arranged. In case the bed is not burned up to the extent desired, when the oil is exhausted, it is the practice to permit the compressed air to blow into the cupola from the torch, without oil, until the bed is properly burned up. The blowing of air into the bottom of the cupola in this way, when the bed is not fully burned up, has an entirely different effect than the blowing of air into the tuyeres under like conditions, and has proven very satisfactory.

The cost for lighting up with oil is the price of one-half to two gallons of oil, depending upon the size of the cupola, which is much less than the cost of wood, when wood has to be purchased for lighting up. But it is a little more expensive if refuse wood is abundant and has to be gotten out of the way.

Another advantage of lighting up with oil is the elimination of wood smoke, which is sometimes very objectionable and complained of when the foundry is located in a built-up section of the city.

The fuel for a bed should all be put in before lighting up, except a few shovelfuls kept for leveling up the top of the bed in case it settles unevenly.

Burning the Bed

The wood, as before explained, should be placed to burn the bed evenly, and the same precaution must be taken in arranging the flues on the sand bottom, when oil is used in lighting up, that the bed may be burned evenly.

When the smoke is burned off a bed, and the fire begins to show through the top, it is ready for the charging of iron, and this should be done at once. Never wait for the top of the bed to become red or white hot all over before charging iron, for this is a waste of fuel, and may result in a very poor heat, due to the bed being burned out to such an extent before charging as to greatly reduce its efficiency.

It is not necessary to burn up a bed for the purpose of warming a cupola for melting; all that is necessary is to have a good fire at each tuyere, and the blast, when put on, will soon warm the cupola from bottom to top. The lining will burn out fast enough without wasting fuel to warm it up.

The Bed

The bed in a cupola is the fuel placed in the bottom of the cupola for the purpose of supporting the iron to be melted, and the amount of fuel that must be placed in it is a quantity that will bring the top of the bed up to the top of the melting zone, when the wood has all burned out, and the bed settles and is ready for charging the iron to be melted.

No definite weight of fuel can be stated for a bed in a cupola of any given diameter, owing to the wide variation in height of tuyeres above the sand bottom. The old rule is to put in a sufficient quantity to bring the top of the bed twelve to fourteen inches above the top of the tuyeres, when melting with anthracite coal, and eighteen to twenty inches above the top of tuyeres when melting with coke.

But this rule does not always hold good, owing to the variation in volume and pressure of blast, which places the melting zone higher with a strong blast and lower with a light blast. Every cupola is therefore a law unto itself, and conditions must be studied to determine a proper height of bed.

The best guide in determining a proper height of bed is the time in which molten iron appears at the tap hole after the blast is put on. With a bed properly burned, and iron charged on it two hours before the blast is put on, iron should appear at the tap hole in from five to eight minutes after the blast is on. If a longer time than this lapses before molten iron appears, then the bed is too high, and if it appears in a shorter time, then the bed is too low or has been burned to too great an extent before charging began.

A minute or two either way does not signify; but when iron comes down in one or two minutes, or does not appear until fifteen to thirty minutes, then something is radically wrong, and dull iron or slow melting will generally appear before the end of the heat.

In raising or lowering a bed, it should always be done gradually and not more than five to ten per cent of the total weight of the bed taken off or added at a heat. This lessens the risk of a poor heat, due to changes, and enables the melter to feel his way by noticing the effect of the change in melting.

Another matter that must be considered in obtaining a bed of a proper height is the weight of iron charged upon the top of the bed. This must sometimes be changed to suit the bed. The guide for this is the manner in which the iron melts throughout the charge placed on the bed. If the iron come down dull, and remains dull throughout the charge, the bed is too low; if it comes down hot, but becomes dull at the latter end of the charge, the charge is too heavy and it has gotten too low for proper melting by burning away the bed.

The remedy for the first of these troubles is to increase the bed. This, like decreasing it, should be done gradually and no radical increase made.

For the second, the best method is to note the amount of iron that has been melted before the iron begins to change to a dull iron; this may be done approximately by counting the number of ladles taken out before the iron begins to change and reducing the weight of iron in the charge to an extent that gives a hot iron throughout a charge.

In determining the weight of iron placed on a bed, the weight of iron should not only be varied, but the height of the bed should also be varied until the heaviest charge of iron the bed is capable of melting and giving an iron of a desired temperature is learned. The bed should then be maintained at this height, and in order to do so a means of measuring the height of bed for each heat should be provided.

This may be done by a half-inch rod, with a square bend on each end, of a foot or more in length. In measuring, one bend of this rod is placed on the fuel in the bed and the other on the bottom of the charging door; if the rod rests on the bed and touches the bottom of the charging door, the bed is of a proper height.

Another way of measuring is with a chain, upon one end of which is placed a disk, to be placed on the bed, and near the other end is placed a mark for the proper height to the charging door. I very much prefer the rod to the chain measure.

The measuring of the bed, in this way, is a very important matter; for the same weight of fuel does not fill a cupola to the same height when burned out as when newly lined, and the light-weight fuel fills a cupola to a greater height than a heavy-weight fuel, and to maintain the same height it is necessary to measure it.

With a light-weight fuel the height of bed may be increased to a limited extent, but when the fuel is very light it is better to reduce the weight of the iron on the bed than to attempt to make up the units of heat by increasing the fuel, as this places the iron too high in a cupola for melting, and the extra fuel has to be burned away before it settles into the melting zone, and there is a waste of fuel.

Charging Iron

When the fire has burned up to an extent that a small blue flame is beginning to show through the top of the bed, and heavy smoke is burned off, the bed is ready for the charging of iron.

The front should then be put in, if it has not already been done, and all the tuyeres except one should be tightly closed to shut off the draft, so as to restrict further burning of the bed until the blast is put on.

The one tuyere is left open to reduce the suction of the blast pipe and prevent the escape of blast from the cupola into the pipe, which is liable to explode when forced back into the cupola by the blast the instant it is put on. The tuyere left open should be one nearest to the blast pipe.

It is good practice to place on the bed a thin layer of stove plate or other plate scrap; this protects the coke and prevents it being broken up by heavy iron when thrown in, and also prevents pieces of pig sinking into the bed, as heavy pig frequently does when thrown upon the bed from a high charging door.

The pig should be thrown around the side of the cupola first, with the ends toward the lining, and then in the center and evenly distributed over the bed, and upon the pig place the remelt and old scrap to be charged. And when all is in have the charge as level as possible on top.

Pig and scrap should be charged close so as to utilize all the heat in melting, but not so compact as to prevent the blast and heat passing through the charge, as this retards the melting and throws an excess of flame and heat against the lining in passing around the charge, in place of through it, and causes an excessive destruction of lining and slow melting.

The rule for the weight of charge of iron upon the bed is three to one. That is, three pounds of iron to each pound of fuel in the bed. This rule is a good one and generally gives very satisfactory results, but, like all rules in cupola practice, does not hold good in all cupolas, in which case the weight of the bed charge has to be varied and generally decreased, for with excessively high tuyeres this makes the charge of iron too heavy for the bed and the top of the bed is burned away to too great an extent in melting it.

To determine the weight of iron that should be charged on the bed, get the bed to a height that will bring down the iron in from five to eight minutes and melt good hot iron; then vary the weight of the charge to an extent that will give good hot iron throughout the charge, and after melting the heaviest charge that can be melted leave the bed in good condition for melting the next charge.

After the bed charge the rule is to charge ten pounds of iron to each pound of coke in the coke charge.

The coke charge should have a depth of four to six inches, the former for small cupolas and the latter for large ones. This depth of fuel gives a more prolonged heat than a very thin layer that scarcely covers, and separates the charges of iron.

The charge of fuel, when all in, should be level on top and as near of an even depth as possible. The iron should be placed on the charge of fuel, the same as on the bed, and the top of it as near level as possible. Each charge of fuel and iron should be made in the same way.

Some founders make it a practice to vary the weight of fuel in different parts of the heat; this is not good practice, and is not at all necessary when a proper system of charging has been attained.

The putting in of what is termed a split charge in the middle of a heat is sometimes of advantage. By this term is meant an extra heavy charge of fuel, or a full charge of fuel with only a half charge of iron placed upon it. This is done to restore the top of the bed to a proper height when it has become a little low, about the middle of the heat, and the iron is beginning to show a little dull.

The reducing of fuel near the end of a heat or at the last charge is a matter that depends upon the character of work to be cast. If a good hot fluid iron is required, the fuel should be maintained at the same ratio as in the early part of the heat; but if there is heavier work to be cast, for which very hot iron is not required, it may be reduced.

Heavy pieces of pig should not be charged flat against the lining, as they are not melted so readily in this position as when one end extends toward the center of the cupola or out into it; the heat then passes all around it and is more readily melted than when one side is against the lining. This is indicated by pig, charged in this way, having been found lodged in slag and cinder over the tuyeres.

The cupola should be filled to the charging door before the blast is put on, and kept filled to this point until the heat to be melted is all in. This utilizes the heat to the greatest possible extent, keeps the flame down and makes charging easier and cooler.

Mixing Iron in Charging

To obtain an even quality from a mixture of radically different irons, the irons must be mixed in charging in a way that they will be brought in contact with each other as soon as melted and in their descent to the bottom of the cupola.

To illustrate the mixing of iron in melting, I might cite the falling of drops of rain upon a window pane; the first drops adhere to the glass, other drops falling upon them make them too heavy to adhere. Then they slide down until two or more adhering drops unite, making them so heavy that they run down the pane of glass in a stream, taking all other drops in their line of descent with them, and so mixing the drops that even if they were of different colors, no one of them could be identified, for the blending of colors in mixing would destroy the color of each.

This theory applies to molten iron when melted in a cupola the same as to water, and if a hard iron is charged only in contact with hard iron, the result at the bottom of the cupola will be hard iron. But if a soft iron is charged in contact with a hard iron, the drops from each will come together, and a small stream formed by them in working their way through the bed to the bottom of the cupola. The stream will take up other drops and different streams will unite, and the result will be a totally different iron from either the hard or soft iron charged, due to a thorough mixing of the iron.

If a hard iron and a soft iron are melted in the same heat, and the hard iron charged on one side of the cupola and the soft iron on the other, there will be no mixing of the iron in melting, except at the point of contact of the two irons in the center of the cupola; and the molten iron will be hard on one side of the cupola and soft on the other, with the only chance to mix them when drawing the iron out of the cupola. A hard iron in one ladle and a soft iron in the next may result.

To prevent this occurring, mix the iron in charging in a way that the different irons in melting come in contact with each other in their descent through the bed to the bottom of the cupola.

This is done by placing the pig and heavy iron on the fuel and the light iron and scrap on top of it. The reason for doing this is that the heat is more intense on the fuel than higher up, and more time is required to heat a large or heavy piece of iron to the melting point than a light piece. The placing of the iron in this way not only gives a more intense heat on the pig, but also a more prolonged heat, as the heat strikes the pig first, and the result is that the pig and scrap melt together and an even and thorough mixture of the pig and scrap is effected.

In melting a high per cent of scrap with a low per cent of high silicon, to soften the scrap, the pig should be broken into short pieces and distributed evenly over the bed and charges of fuel, and the scrap placed upon them. This gives a more even mixture than when the pig is charged in large pieces, and is a more effective softener.

Charging Shot Iron

Shot iron is the name generally given to small pieces of iron recovered from the dump and gangways, by means of tumbling in the tumbling barrels or mills.

This iron is a good soft iron when melted from soft iron, but the small particles expose so high a per cent of surface in proportion to the body of iron to the oxidizing flame in the cupola that it generally runs hard when melted alone, and the loss in melting is very heavy.

The best way that has been found to prevent this hardening is to charge it through the heat with a soft mixture; it then mixes with the soft iron, drop by drop, takes up carbon from the soft iron, and its hardening effect is not noticed in the soft iron, except when an excessive per cent of it is melted, in which case the hardening effect may be offset by an increase of the silicon in the mixture.

In melting this iron, place a few shovels of it on top of each charge of iron, including the bed charge. This gives better results than charging it on only the last few charges or all on the last charge. When charged only on the last charge, many small particles get locked up in the slag and are not melted, and have to be again recovered from the dump.

This iron should be recovered after every heat and melted in the next heat when bright and clean, and not permitted to accumulate and get badly rusted, for rust greatly increases its hardening tendency, and also reduces the per cent of iron obtained from it when melted.

Charging Heavy Iron

When melting very heavy pieces of scrap alone, an excessively high bed should be put in for the purpose of heating the iron and preparing it for melting before it settles into the melting zone. Coke should be placed around and over it, to concentrate the heat upon it, and melt all or as much of it as possible before it settles below the melting zone, which will be indicated by very slow melting or dribbling of iron from the spout. The bottom should then be dropped, and if not all melted the pieces should be put in again in the same way for another heat. In this way the largest pieces of iron that can be gotten into a cupola may be entirely melted.

When melting moderately heavy pieces with other iron, these should be charged in the second or third charge after the bed charge. This gives them time to become heated through, and they melt more readily than when charged on the bed. If the piece is so heavy that there is danger of not melting all of it, put it in toward the end of the heat, and if not all melted, drop it through and put it in again. This will prevent dull iron through the heat, due to unmelted iron settling below the melting zone, where it cannot be melted.

When melting scrap of about the same size and weight as pig, it may be charged with the pig on the fuel and mixed with it; and if remelt pig is heavy, it may be charged in the same way. Gates and other remelt are generally placed upon the pig and light old scrap on top of this.

Charging Turnings and Borings

Iron turnings and borings should be put up in joints of stove pipe, of no more than three to four inches in diameter, with a head in each end, and charged with the scrap on the pig. This is the latest and possibly the best method of charging this iron. This material gives a very uncertain quality of iron, as it is liable to run separate and distinct from other irons, and be very hard. The best results I have obtained in melting it have been with about five per cent of it to the other iron melted.

Putting on the Blast

When the cupola has been charged to the charging door, or the full heat put in, if a small one, the cupola is ready for the blast. This may be put on at once, or the cupola may be held in this condition until blast time and for many hours by carefully closing the tuyeres with sand to exclude all air. Cupolas have been held in this way overnight, after fully charging, and as good melting done as if the blast were put on as soon as charged. This is accident practice, and not to be done regularly. In such cases the tap hole is left open to give sufficient air to keep the fire alive.

Before the blast is put on the tuyeres are all closed and any leaks carefully luted with clay or stove putty.

It is the general practice to permit the blast to blow out at the tap hole until the iron comes down, and permit it to run out until the iron is sufficiently hot for pouring. In hand ladle foundries this iron is used for warming ladles, and when it comes down sufficiently fast, pouring is begun without stopping in. If the stream is small, it is stopped in for a few minutes to accumulate sufficient iron to give the desired stream. In this way heats of thirty-two tons for soil pipe have been run off without once stopping in throughout the heat. When the castings are all poured the cupola men pig out, and the bottom is dropped.

Another way that is now being used to a considerable extent is to fill the tap hole with dry parting sand and lute it with a thin layer of clay on the outside, and not permit the blast to blow out at all. The first tap is then timed, or the tuyeres are watched for molten iron to rise in the cupola, before the tap is made.

The parting sand is placed in the hole to prevent iron filling the hole and chilling in it, and is pushed well back, and this holds the iron; a thin layer of clay is applied with the thumb on the outside to hold the sand in place. A quarter-inch tap rod is used for the first tap, to open the hole and loosen the sand which is all washed out by the stream, and floats upon the surface of the first ladle of iron, from which it may be skimmed off.

This system has proven very satisfactory and saves the remelting of the iron that runs out before becoming sufficiently hot for stopping in, but does not give as hot an iron in the first tap as when the blast is permitted to blow out until the iron comes down hot.

Tapping Bars

A tapping bar is a bar of iron used for opening the tap holes to admit of molten iron flowing from the cupola.

Three or four of these bars are generally provided for each cupola. For ordinary floor tapping they are generally made about five feet long, and vary in diameter from one-half inch to an inch, depending upon the size of hole that is to be opened.

The bar is bent at one end to form a rounded handle for the purpose of rotating the bar in the hole in breaking away from the bod, and the other end is drawn down to a long square point for opening the hole. The square point is preferred to a round point, for the rotating of the bar cuts away the bod more freely than the round point, and even when the rod becomes heated by the molten iron and burned away, the square shape is retained to a greater or less extent.

The points of these bars frequently become bent and twisted in tapping, and an anvil or iron block and hammer should be provided for shaping them up if necessary after the tap is made.

Tapping bars are made of various sizes, shapes and lengths to suit the method of tapping, and vary in length from three to ten feet. When the sharp sand and clay bod was almost exclusively used, a short, stiff, straight bar was provided for sledge tapping, but since the use of molding sand bods this bar is seldom provided or found necessary. In place of this, a flat pointed short bar is sometimes used for cutting away the bod before opening the hole with the square pointed bar. This is a common practice of many tappers.

A rack should always be provided near the cupola for holding the bars and bod stick side by side. This may be done by nailing a short board or a stick to a post or wall, with notches in it for bars and bod stick.

Tapping bars should always be straightened after using, and set on end with the point up, immediately after tapping, to prevent the point becoming bent when hot and damp and rusted when cold.

A wet, rusted or frosted tapping bar causes molten iron to explode and fly if suddenly thrust into it. To prevent this, heat the point of the bar before bringing it into contact with molten iron.

Bod Sticks

Bod stick is the name given to a round or octagonal piece of wood used for closing the tap hole and stopping the flow of iron from the cupola. These sticks are made from one and three-fourths to two and a half inches in diameter, and from three to ten feet in length. The shorter sticks are used for stopping in from a tapping platform placed alongside of the spout, when the cupola is placed high and spout long, and the larger ones are used for stopping in over a large ladle that is being filled.

For stopping in from the floor, under ordinary spout and ladle conditions, they are generally made about five feet long, and when they burn thin near the end are sawed off and used until they become too short for use, when they are replaced by new ones.

Iron bod sticks or better, stopping-in rods as they were called, were very extensively used years ago, but have now about entirely gone out of use, as has also the combination wood and iron bod stick, which consisted of a stick with an iron rod six to twelve inches long in one end of it, and a button upon the other end of the rod for holding the bod. This was designed to prevent the wood being burned and reduced in size by the heat of the spout.

A long bod stick of this design, in which the iron rod was three to four feet long, was also used for stopping in over long spouts and large ladles.

These combination bod sticks and also the iron bod rods are still used to some extent, but have generally been replaced by the wooden bod stick, which is lighter and more convenient, and the wood holds the bod better than the iron button, from which it is very easily displaced.

At least three bod sticks should be provided for each cupola and a bod kept on each one of them ready for immediate use in case a bod falls off or fails to stop the stream, and the sticks should be used turn about or fresh bods frequently put on to prevent them becoming dry and falling off when used.

Bod Material

There are two kinds of bod materials that may be used; these are the combination fire clay and sharp sand bod, and the new molding sand bod.

The combination material makes the strongest bod for stopping the stream and holding a large body of iron in the cupola, but if there is any great length of time between taps is very liable to bake in so hard that a short, heavy tapping bar and sledge is required in making the tap, and it is sometimes difficult to keep the hole open after the tap has been made, due to the tendency of the adhering bod to melt and form a tough slag that swells up and closes the hole.

New molding sand makes a bod that cuts away more freely, and is equally as safe as the combination bod if properly shaped and pressed into the hole, and does not adhere to the sides of the hole so tenaciously as the other material, but is washed away by the stream and the hole kept open, and is preferable to the combination material.

Should the molding sand prove to be too friable, this may be remedied by wetting it up with clay wash. The sand should only be wet up to the extent of molding sand, when tempered for molding.

Stopping In

For stopping in, a small quantity of the bod material is taken in the hand, securely pressed upon the end of the bod stick and worked into the desired shape with the hand.

The shape the bod should be made depends upon the length of time the hole is to be closed. If the hole is to be closed for some time, to collect iron for a large tap, the bod should be long and pointed, that it may be pressed far back into the hole, to exclude iron from the hole and give the bod a good hold on the sides of the tap hole.

Should the object be to only hold the iron for a few minutes, the bod should be small and rounded, so that it may not be pressed too far back, and more readily tapped through than the long pointed bod.

If the object is only to hold the stream for the changing of small bull or shank ladles, a very thin bod is placed upon the end of the stick, and this pressed against the hole and held there by the stick until the full ladle is taken away, and the one to be filled is put in place. The stick is then removed, and the light bod is pushed out by the iron, and no tapping is necessary.

In this operation the bod stick is held high, and the men, in removing the full ladle and placing the one to be filled, pass under the stick.

In stopping in, the bod is placed directly over the stream and a few inches from the tap hole, and by a quick downward and inward thrust of the bod stick is thrust into the hole and held there for a few seconds until the force of the stream has been stopped and the bod attached to the sides of the hole.

While holding the bod in this way, a thud may be felt on the end of the stick. This is due to the cold, wet bod coming suddenly in contact with the molten iron, and a slight explosion of the iron occurring. This phenomenon is more noticeable when the bod is a little wet, and were the bod not firmly held it would be forced out of the hole by this light explosion.

After the bod has been firmly placed into the hole, the bod stick is removed and the end of it at once placed in water for an instant to deaden any fire that may have taken hold upon it and to prepare it for holding the next bod. A bod is then placed upon the end of the stick, and it is set in the rack in readiness for the next stopping in.

Tapping Out

This is a term used to indicate the opening of the tap hole to admit of molten iron flowing out of the cupola.

This is a far more important operation than many melters appear to realize, for if the tap hole is not properly opened the stream does not flow smoothly from the hole, or is not of its full size, or may jump over the sides of the spout, or form an arch after leaving the hole before it strikes the spout, and continual poking at the hole with the bar is frequently necessary to keep it open.

In making a tap, the surplus bod material should be first removed with the end of the tapping bar or a flat pointed bar provided for that purpose, and this refuse removed from the spout before tapping.

The tapping bar should be of the size of the hole that it is desired to make, and the point inserted in the center or near the lower edge of the bod. After inserting it should be held in line with the bottom of the spout and worked in by turning until the full size of the rod is in the hole before withdrawing it. This operation should be done quickly, to avoid burning away the point of the bar by the molten iron. This method leaves a smooth hole of a proper size, and there is no trouble with the stream or closing up of the hole if a good material is used around the hole when the front is put in.

A great deal of the trouble with tap holes is due to the manner of holding the tapping bar in tapping. When the handle of the bar is held high, the point is liable to penetrate the spout lining and cause the stream to shoot upward as it leaves the hole. When held sideways, the point may penetrate the sides of the hole. When inserted at the edge of the bod it may cut away the sides of the hole in place of the bod, and if it chances to be inserted at the other side of the hole in the next tap, a similar condition results. The first bod then has no support, is forced out and the others do not hold, and the result is an enlarged and uncontrollable tap hole.

This illustrates the haphazard way many melters have of tapping. Forcing the tapping bar in at any place the point happens to strike, with above results in a more or less exaggerated form.

To avoid such troubles, insert the point of the tapping bar in the center of the bod, holding the bar in line with the spout, and work it in until the full size of the bar is reached, and withdraw it in line with the bottom of the spout.

Pigging Out

As soon as the molds are all poured off, the cupola men draw all the molten iron from the cupola and pour it into the pig molds provided for this purpose. This is termed pigging out.

When the heat has been accurately made up, this is a very small job, for there will remain in the cupola only a very small amount of iron after the molds are poured off. The blast is at once taken off, and after the few ladles of molten iron remaining in the cupola are drawn out and pigged, the tap hole is left open, and any iron that may melt before the bottom is dropped is permitted to fall in a pool formed in the sand under the spout.

This is very good practice, as it removes all molten iron from the cupola before the bottom is dropped and greatly reduces the liability of men being burned, and also fire due to the molten iron exploding and flying in all directions the instant it strikes the floor under the cupola, when the bottom is dropped with any considerable body of molten iron in the cupola.

Some foundrymen make it a practice to pig out all the iron that has been charged for the heat, but I do not consider this good practice; for unmelted iron may be recovered from the dump, and in blowing until the last drop is melted the slag and cinder is frequently chilled to an extent that the dump hangs up and places the cupola in a very bad condition for the next heat. This is one of the objectionable features of melting refuse iron at the end of the heat.

Dropping the Bottom

After the pigging out has been done, or while it is being done, the melter removes all the light props for preventing springing of the doors, and puts them in a place provided for them when not in use, and as soon as the molten iron is all out the main prop is withdrawn and the doors dropped. This is always done as soon as possible after the blast is taken off, for the dump falls out more freely when hot and fluid than when permitted to remain in the cupola for some time after the blast is taken off.

The removal of the main prop is effected by means of a one-inch bar, eight to ten feet long, with an oval handle on one end and a short crook on the other. The crook is placed on the floor, a foot or more behind the prop, and by a sudden jerk of it against the bottom of the prop it knocks the prop down and the bottom doors fall. The dump falls, throwing out a cloud of flame and dust, to avoid which the operator must get away as quickly as possible after the prop falls.

Should the sand bottom not fall out when the doors drop, it must be broken away by a bar from underneath; and should only a limited amount of the dump fall out, a few buckets of water is thrown upon this, to deaden the heat, and the tuyeres opened and poked with a bar in an effort to make a greater amount fall out and get a hole through. After a hole is gotten through, the slag and cinder adhering to the lining cools off rapidly and is more easily broken away when cold than when hot, and the cupola is left to cool off until next morning.

Should a hole not be gotten through by poking at the tuyeres, it may be broken through by throwing in a few pieces of pig iron from the charging door; but this is seldom effective if there is any great depth of stock in the cupola, in which case it is better to throw in water to put out the fire and permit the hang up to cool off until next morning, when a bar can be worked through about the center, and the loose matter dropped through the hole; after this the bridge may be rapidly broken away with a small sledge and the lining trimmed up, with a cupola pick for daubing.

The bridging and hanging up of the cupola is largely due to an improper height of the bed. Either a high or low bed tends to promote it; but it is more generally due to a high bed and an excessive use of fuel in charges, which promotes slow melting and dribbling of iron, which lodges and chills the slag and half-burned fuel.

Another cause for bridging is in the shaping of the lining, which prevents even settling of the stock, and fast melting.

To prevent it, shape the lining for an even settling of the stock, and arrange the bed and charges for rapid and free melting.

Before dropping a bottom, the melter should always be sure that there is no water or dampness under the cupola, for water and dampness cause both molten iron and slag to explode when suddenly dropped upon it.

Should there be any water or dampness, remove the water and shovel in a liberal amount of dry sand to cover up the dampness, just before knocking down the prop. If there is no dry sand at hand, take sand from the molders' sand heap.

Removing the Dump

Many plans have been devised for removing the dump from under the cupola, such as cars or trucks, crates to receive the dump and to be handled with the crane, etc., have been tried; but the use of all such devices has proven impractical, and about the only device now used is a frame or rack to be placed under the cupola to receive the dump and be drawn out by a crane or windlass when the dump is hot, to break it up and scatter it. Even this simple device is seldom used.

The method commonly practiced is to pick out the large pieces of coke and iron, then break up the dump with a sledge and bar, and as it is being shoveled into the barrow for the tumbling barrel, recover such large pieces of iron and coke as may be of value. The remainder is then broken up in the tumbling barrel, and all smaller pieces of iron recovered; and if a water tumbling barrel is used, also the small coke, which may be used for core oven fuel, heating stoves or sold to employees for domestic use.

Chipping Out

Chipping out is a term used to indicate removing the adhering slag and cinder from the lining, after melting a heat, to prepare it for melting the next heat.

When the cupola is badly bridged or hung up, this is no easy matter, for iron has combined with the slag or is mixed with it, which makes it very difficult to break down when strengthened by the circle it forms around the cupola, and a heavy sledge and repeated blows are frequently required to dislodge it.

The best way is to break down this ring back to the lining at one point; this destroys the strength given to it by the circle, and it may be broken down in larger pieces and more rapidly than if broken away all around the circle before reaching the lining.

After breaking away the adhering part of the dump, to near the lining, with a sledge or heavy hammer, the remainder is removed and the lining trimmed up with the cupola picks.

For this purpose two or three picks of different sizes and weights should be provided. These should be made of the best of steel, and frequently dressed, tempered and ground, for the work may be done more rapidly with a sharp pick than with a duller one, and there is no jarring and destruction of lining.

The one great objection to the average cupola pick is the smallness of the eye and wooden handle; this prevents or renders useless the pick as a lever in prying off cinder and slag that can be more readily removed in this way than any other, and also reduces the force of the blod when the handle becomes loose, as it invariably does.

All picks should be provided with an iron handle, riveted or welded into the pick, or have a large eye into which a good stout wooden handle may be inserted. The common dirt or trench pick makes an excellent pick for large cupolas, in which there is room for using it, and is quite extensively used for this purpose.

In picking out a coupla it is not necessary that every particle of cinder and slag should be removed and the brick exposed, for in many cases this material is as refractory as the fresh daubing put on, and it is only necessary to remove the fragile, loose material and sufficient of the hard material to give the cupola the desired shape.

Before going into a cupola to chip out or break down adhered matter, the cupola should be slushed with one or more buckets of water to wet the ashes and lay the dust.

Cupola Daubing

Cupola daubing is a material composed of fire clay and sharp sand, used for repairing the cupola lining after the melting of each heat.

The mixing of these materials in propor proportions is a very important matter to realize their full refractory properties, for if the clay is in excess the daubing cracks in drying and may fall off, and if it does not, only partially protects the lining, due to the large cracks in it. If the sand is in excess, the daubing melts and runs down and tends to clog up the cupola to a greater extent than to protect the lining.

It is the common practice to throw a desired quality of clay into a box or mixing trough with sufficient water to wet it up, and permit it to soak overnight to soften it for mixing with the sand. The sand is then shoveled in, and the clay and sand hoed over to mix them.

This is a very uncertain way, and also frequently a very expensive way of mixing daubing, for a cupola man can put in more time hoeing over a trough of daubing than at any other work around the cupola, and the daubing is very likely to contain an excess of sand, as this makes it more easily and quickly mixed.

This in many cases results in the lining of one cupola lasting much longer than that of another, both using the same lining and daubing material and melting the same sized heat. This has been noticed in cupolas of the same size in the same foundry and handled by different melters and helpers.

To prevent this waste and loss of material, many of the leading foundries have installed wet daubing mixers, and others have installed dry mixers.

The wet mixer consists of a round trough with a pair of heavy cast iron rollers revolving in it. The per cent of sand and clay that gives the best results is determined by testing in a cupola; and when this has been learned, this per cent is placed in the mixer, wet up and rolled over until thoroughly mixed and tempered for application.

The dry mixer consists of an old-fashioned stave tumbling mill; the fire clay is dried in or around the core oven or stove, and when dry is placed in the tumbler with a few pieces of pig to break it up. As it is broken up fine it falls through the cracks between the staves; it is then mixed with a proper per cent of sand and put through the mill again. This thoroughly mixes it, and it has then only to be wet up and hoed over when it is ready for application.

The advantage of the dry mixer over the wet mixer is that a month's or more supply may be prepared at one time, and placed in bins or barrels for use when wanted, while the wet mixer must be run every day for a greater or less length of time. One method of mixing gives as good results as the other.

In many locations fire clay is not obtainable at a reasonable price, and common yellow or blue clay is used for daubing. Some of these clays have very limited refractory properties, while others are comparatively good.

Any of these clays may be greatly improved as a daubing by the addition of a certain per cent of refractory sharp sand. The per cent to be determined is by test in the cupola.

Brickbats, recovered when relining, make excellent daubing material when pulverized. This may be done by breaking them up and placing in a tumbling barrel with a few pieces of pig iron to break them up to an extent that they fall through the crevices or cracks between the staves. This material is then mixed with sufficient fire clay to make it plastic.

These bricks are also of value as lining material when broken up or split and pressed into daubing after it is applied to the lining. This stiffens up the daubing, especially in places where it has to be put on thick to fill up holes, and makes it much more durable.

In applying daubing, the lining should first be brushed with water, to remove the dust, and make the daubing adhere more firmly to the lining. The daubing should then be thrown on, in small handfuls, with considerable force; this makes it penetrate the small crevices and holds better than if put on with a trowel, or in large balls and spread with a trowel or with the hand.

After as near as can be judged the requisite amount of daubing has been thrown on, it should be smoothed up with a round pointed trowel, and if necessary to get it even and true more daubing should be thrown on. After it is smoothed up, it is then the practice of most melters to brush it with a wet molder's brush to give it a smooth even appearance. Molder's brushes, when worn out as molder's brushes, are collected and used for this purpose.

A daubing should not be put on more than one inch in thickness, for when of a greater thickness it is not fully dried out in lighting up, and when the blast is put on and intense heat created, the moisture in it is converted into steam and forced back against the lining, where it expands and forces the daubing away from the lining, and it is carried down with the stock and clogs the cupola to a greater extent than it protects the lining.

I have seen iron running from the tuyeres when there was no iron at the tap hole, due to a heavy daubing being forced off in this way, all around the cupola, and forming almost a complete bridge upon which the molten iron landed and ran down through the tuyeres in place of the tap hole.

When a lining is burned out in spots, to an extent that a greater thickness of daubing than one inch is required, fill it in with split brick or with daubing packed full of broken fire brick to lessen the moisture and make it stand up better.

The shaping of a lining will be treated under the next chapter heading.

Relining and Repairs

The ordinary cupola daubing, when properly mixed and applied, is sufficient to keep a lining in good melting condition until it is burned away and becomes very thin. It then has to be replaced or repaired to a greater extent than can be done with cupola daubing alone.

The point at which the daubing burns away most rapidly is in the melting zone, a space a short distance above the tuyeres. This is the point at which the blast creates the most intense heat in a cupola when fully charged with iron for melting. This is the point at which daubing should be more freely applied when making up the cupola for a heat, that it may be prevented from becoming thin. Above and below this point, which is indicated by the lining burning away or bellying out, the lining is not burned away so rapidly, and repairs may be made in this area without disturbing the lining above or below it.

This is done by taking out the lining at this point and replacing it with an entirely new lining, and connecting it with the lining remaining in the cupola.

When the casing has been provided with angle irons or brackets for support of the lining, this entire belt may be taken out at once and rapidly replaced; but if no provision has been made for the support of the lining, in such cases the lining must be taken out and replaced in sections, and not more than one-half of it should be taken out before the new lining is replaced in a manner to support the old lining.

Another way of repairing a lining is by the use of straight or split fire brick. A split fire brick is one-half the thickness of the straight standard fire brick, and of the same length and width. In repairing a lining with this material, daubing is thrown upon the lining, and the flat side of the brick is firmly pressed into it, and this is continued around the cupola in the melting zone, and as many rows put in as found necessary to build out the lining to the desired shape. All cracks between the bricks are filled with daubing, and any offset between the old and new lining filled in with daubing and shaped up.

This form of lining lasts equally as long in proportion to its thickness when properly put in, and with good daubing, as the lining regularly made up.

Holes burned in the lining due to improper charging or shaping of the lining may be filled in in this way, and a lining given a proper shape for good melting.

Cupola Linings

CHAPTER VI

Shaping a Lining

The shape of a lining in all melting furnaces is of far greater importance than many of the operators of these furnaces appear to realize, for if the lining is not of a shape to concentrate the heat of the fuel upon the metal to be melted, there is a loss of heat and waste of fuel.

In the melting of iron in a cupola the iron and the fuel to melt it are placed in the cupola in layers which are designated charges.

A bed of coke, the main function of which is to support the iron to be melted, is first put in, the top of this bed is placed on the level with the top of the melting zone, the first charge of iron is placed upon this bed and in melting it the top of the bed is lowered and the charge of fuel on top of the charge of iron restores it to its former height, and this process goes on through the entire heat and entails the settling of the stock to replenish the bed and melt the iron.

To have this stock settle evenly and maintain the layers or charges in the relation in which they are placed in the cupola, there must be no projections or shelving of the lining upon which the fuel and iron may lodge and cause a tumbling over and mixing of the fuel and iron, and there must be no depressions in the lining that will deflect the heat from a straight upward course.

The condition of the lining below the melting zone is even more important than that above it, for the iron after melting has to work its way down through the bed of fuel and slag formed in melting, and if there are shelves and projections upon which the slag and iron can lodge and become chilled there is a gradual building out of these materials until the blast is deflected from its upward course, and irregular uneven melting results in dull iron and difficulty in dumping at the end of a heat.

To guard the student of cupola practice against unsatisfactory shapes I have prepared a few illustrations of the most common bad shapes in linings I have found in visiting foundries for the purpose of locating trouble in melting. I might give many more bad shapes in which I have found linings, but as in each case I give the proper lines for restoring an ill-shaped lining for a good one, these will probably be sufficient.

In Fig. 1 is shown two shapes of lining, one on the right and one on the left side of the illustration. The ragged lines show the shape in which I found the lining and the smooth even line the shape I put it in for good melting.

On the left side of this illustration is shown a lining almost completely burned out and ready for re-lining, as represented by the rough and crooked line which represents the condition of the lining all around the cupola.

This shape of lining formed a pocket for the lodgement of slag and molten iron just over the tuyeres, where it was chilled by the cold blast of the tuyeres and built out very rapidly. After it once began to chill at this point, which resulted in the iron melting slower as the heat progressed, and difficulty in dumping, due to almost complete bridging of the cupola.

This condition was aggravated by the iron being melted too low in the cupola, and an excess of heavy slag being formed by oxidation of the iron. The heavy destruction of lining at so low a point in the cupola was due to the damage in breaking down the bridging and by chipping out, rather than to melting, for no cupola melts iron to an extent so low in a cupola as to destroy the lining at this point.

To remedy this trouble, I removed the small point that had been built out of daubing just over the tuyere and built up the lining perfectly straight for six inches over the tuyeres, I then sloped it back to the lining with a long slope indicated by the curved lines.

This put the lining in a shape for an even settling of the stock, and gave fast melting and a clean dump and restored the lining to such an extent that the brick that had been procured

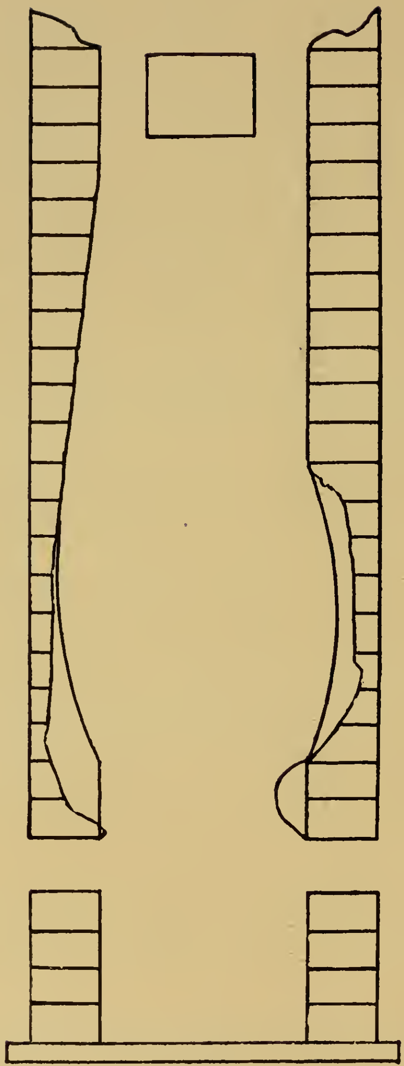

FIGURE 1

for relining laid in the yard for a number of months before being placed in the cupola as a lining.

The point at which a new lining begins to burn out above the tuyeres indicates the lower edge of the melting zone, and this is the point at which the upward taper of the melting zone begins, and should be maintained as long as the lining lasts, and the lining between this point and the top of the tuyeres should be kept perfectly straight.

This point varies with the volume of blast, but should never be less than six inches above the top of the tuyeres, and a cupola should be carefully inspected for a few heats after a new lining is put in to get its exact location, which may be eight or ten inches above the tuyeres.

On the right side of this illustration is shown a newly lined cupola, in which the lining had been badly burned out at the melting zone in only a few short heats, and was almost ready for relining at this point, while above and below the zone the lining scarcely showed signs of having been heated.

This condition was due to improper charging. The charges of iron had been packed so close that the heat, in its upward course, could not pass through it, and was thrown against the lining with the force of a blowpipe and cut out the lining very rapidly.

This is a condition that I have frequently found in investigating troubles in melting. In some cases I have found it due to small scrap, packing close, and in others due to plate scrap being charged flat in large pieces, in layers one on top of another; and in some cases due to steel plate being charged in this way in the making of semi-steel.

In a number of instances the charging of steel plate in this way has not only resulted in heavy destruction in lining, but also in welding the plates together to an extent that it could not be melted, and the lining had to be removed before it could be gotten out of the cupola.

To avoid such trouble in melting steel plate for semi-steel, bend the plate in such a way that the heat may pass through, set it on edge, or place coke between the plates in such a way as to keep it open.

In melting cast plate scrap, break the plate small, and mix sufficient small coke with it to keep it open, if there is danger or indications on the lining of it having been packed close. The same practice may be followed in the melting of small scrap, either cast or steel.

Holes and uneven burning out of lining, frequently found in the lining after a heat, are due to this cause, and they may be prevented by taking the above precautions in charging.

This cupola with the melting zone shaped up to the curved line, shown on the right side of the illustration, did excellent melting, and when properly charged there was no trouble with the melting zone cutting out in the shape shown in illustration.

In this illustration is shown a very common and bad practice melters have of building out the lining with daubing just over the tuyeres, to prevent iron running into the tuyeres.

This hump forms a lodgement place for slag and iron so close to the tuyere that the cold blast passing over it chills the slag rapidly and causes it to build out and bridge the cupola, and many hangups of the dump are due to this cause.

In no case is this hump necessary to prevent iron running into the tuyeres, if the lining is kept perfectly straight for at least six inches above the top of the tuyeres. It is just as bad practice to slope the lining back from the upper edge of the tuyere as it is to place a hump over it. The lining should be kept straight and smooth at this point.

In Fig. 2 is shown a large cupola I saw in a foundry in the South a few years ago. This cupola had a 12-inch lining, which was burned out on one side to a depth of 8 to 9 inches, forming an almost square offset or shelf just over the tuyere, from which the stock could not help but lodge as it settled.

The other side was burned out lower down, but not to so great an extent and did not form so complete a shelf. While at other points around the cupola humps extended out beyond the lining when new, and at other places deep holes were cut in the lining. This indicated that the stock in settling had lodged upon the shelves formed in the lining and the charges had been completely upset, throwing the blast in various directions against the lining.

The heats melted in this cupola were about twenty tons, for light castings, and the iron came down hot and dull in different parts of the heat, and at times so dull that the castings could not be poured with it.

This was about the worst shape of lining I had ever met with in all my experience as an expert, and a peculiarity about it was

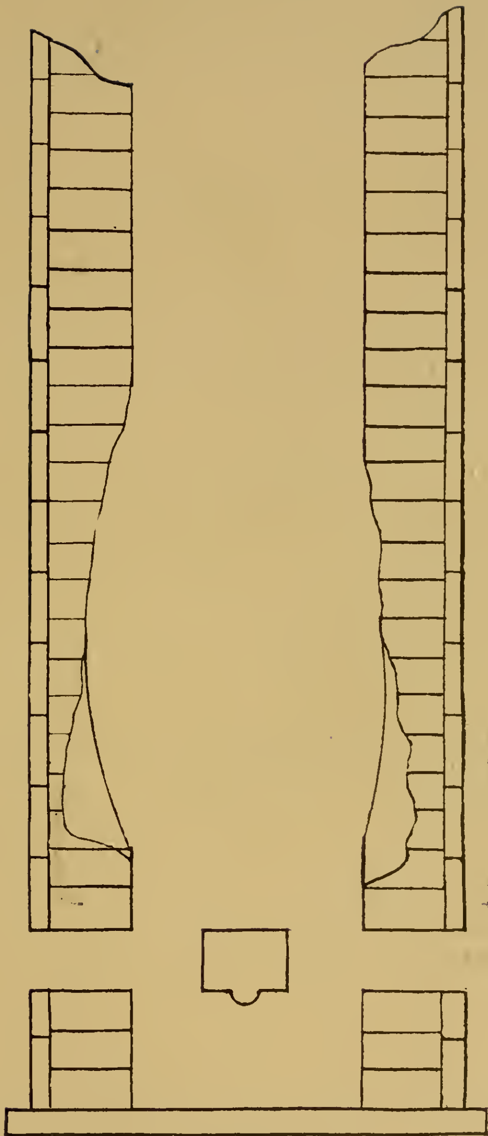

FIGURE 2

that neither the superintendent, foreman or melter knew anything about the shape a cupola lining should be kept in. The whole aim of the melter was to get it chipped out, throw in sufficient daubing in the thin places to prevent the lining burning through to the casing, and get the cupola ready for the next heat; which I learned was no easy matter, as the cupola was badly bridged and bunged up after each heat.

It had been found necessary to reline this cupola in the melting zone about once a month, and six months was considered to be the life of the lining up to the charging door.

At another foundry in the same city, having a cupola lined to the same diameter, and melting twenty-four tons to the heat, with no short heats or lay-offs, for this was a State's prison foundry, they had not relined in eighteen months, and their lining was still in good melting condition, and during this time they had melted hot even iron for hollowware and other light castings, and never had a bad heat.

This was due to the management of this foundry realizing that their convict help could not be depended upon, and their putting of a competent cupola man in charge to instruct the cupola men and see that the work was properly done for each heat.

The cupola, shown in Fig. 2, when the lining was filled out to the curved line just above the tuyeres, which was the best that could be done with it before the time for lighting up for the heat, did very good melting, although a little lopsided and uneven higher up.

This unevenness righted itself in a few heats with the aid of a little daubing at points where the lining was a little hollow, and chipping off of a few projecting knobs, and became a very even and rapid melter.

In Fig. 2 is shown the method of putting in a false or safety lining, of straight fire brick or common red brick. These bricks are set on end, in daubing, around the cupola, before the lining brick are laid up, and may be put in for safety, against the casing becoming heated or burned through, or to reduce the diameter of the cupola for small heats, in which case one or more thicknesses of red brick may be put in to serve as a backing for the fire brick lining.

In the illustration is also shown a safety overflow tuyere. This is an oval depression one inch in depth placed in one tuyere to admit of melten iron flowing out, and giving an alarm before the iron has risen to so great a height as to flood all the tuyeres.

It was the practice of old foundrymen, when constructing their own cuploas, to place one tuyere one inch lower than the others to serve as an overflow alarm, and this depression or trough is designed to take the place of the low tuyere.

It may be placed in any shaped tuyere, and in all of the tuyeres if desired.

Boshing a Lining

In Fig. 3 is shown a boshed cupola lining from the bottom plate up to the taper of the melting zone. This boshing is formed by putting in an extra thickness of lining up to this point, and tapering it back to the regular thickness of lining with a long taper.

This was the way in which all large cupolas were lined in the days of poor blowers and insufficient blast, and was done to get the blast more to the center of the stock.

After the improvement in blowers and strong blast, this method of lining rapidly disappeared, until at the present time but few cupolas are lined in this way. Even with the most improved blast many of the seventy-two and eight-four inch cupolas do not melt the number of pounds of iron to the square inch of melting surface they should, which may be due to an insufficiency of blast or failure to force it to the center of the stock.

That the failure of these cupolas to melt as rapidly as they should is due to failure to force the blast to the center of the stock has been clearly shown by the placing of the Zippler and other overhanging and boshed tuyeres in these cupolas, and obtaining more rapid melting by forcing the blast to the center of the stock, and that is all there is in an overhanging boshed tuyere, for when this tuyere, with its boshing or reducing of diameter of the cupola, is placed in a cupola of small diameter it has proven a complete failure.

The boshing of the cupola from the bottom up has exactly the same effect upon the melting as the Zippler tuyere, and has the advantage over this manner of boshing in the saving of considerable fuel in the bed, due to reduction in diameter of the cupola at this point by the boshing.

The two great objections in boshing the cupola from the bottom plate up to the lower edge of the melting zone are the reducing of the melting space below the tuyeres for holding molten iron and the tendency of a boshed cupola to bridge and hang up. The first of these objections is not valid, for iron can be kept

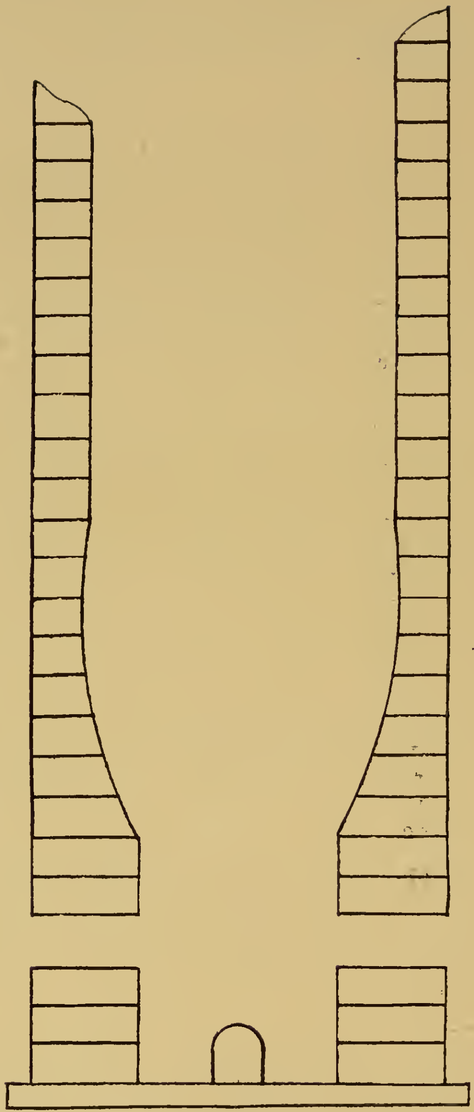

FIGURE 3

hotter in the ladles than in a cupola, and with the present method of running a continuous stream or making short taps there is no occasion for holding molten iron in a cupola, and it is only in case of pouring iron with a large crane ladle and holding the iron while the ladle of iron is being poured and the ladle returned to the cupola for refilling that the holding of iron in a cupola is necessary.

The second reason, that of promoting bridging and bunging up of the cupola, is more imaginary than real, for straight linings and an overhanging bosh bridge and hang up. The prevention of this condition is only a matter of shaping the lining above the tuyeres, and slagging and bridging is no more liable to occur in a boshed cupola than in a straight one.

All blast furnaces are boshed and kept in blast as long as the lining lasts, which is seldom less than one year, and may be two or more years, and heavily boshed cupolas have been kept in blast day and night for two weeks without any signs of bridging; and I have not found a boshed cupola any more liable to bridge than a straight one.

One of the most rapid and hot iron melting cupolas in this country is one in the foundry of Abendroth Brothers, Port Chester, N. Y. This cupola is lined to seventy-two inches in the melting zone and boshed to fifty-four inches diameter from the bottom plate up to the lower edge of the zone, and the melting of many of the large cupolas now in use could be greatly improved by boshing in this way.

It is not necessary or advisable to bosh a cupola of a less diameter than fifty-four to sixty inches, as blast, with a good blower, can readily be forced to the center of the stock in cupolas of these diameters and less.

Overhanging Bosh

An overhanging bosh in a cupola is a reducing of the diameter of the cupola lining at the tuyeres, while retaining the full diameter of the lining, above and below the tuyeres.

This shape of lining was originally designed and patented by Mr. Ireland, an English cupola inventor, in the year 1856, but does not appear to have been generally adopted by English foundrymen.

Mr. Ireland's plan of constructing the bosh was to begin a few courses of brick below the tuyeres, and extend each course of brick out a half or three-fourths of an inch further than the course below it, until the desired reduction in diameter in lining was effected.

From this point the lining was built up straight, until the desired tuyere space was reached, for a single or double row of tuyeres, and from this point sloped it back to the full diameter of the lining with a long taper.

The objection to this form of construction is that the brick burn or break away, and it is difficult to maintain the bosh in its original shape, and for this reason this manner of constructing an overhanging bosh has been practically abandoned.

Mr. Voisin, another English cupola inventor, appears to have improved upon this method of construction by placing a cast iron plate of a desired diameter of a bosh upon the lining brick below the tuyeres, for the support of the bosh, and constructing his boshing lining upon this plate. This makes the boshing lining more stable, and the circle of the plate serves as a guide for keeping the boshing up to the desired diameter.

Mr. Zippler improved on this method by using one or more courses of cast iron blocks, each cast to extend out further at the top than at the bottom, and in this way forming his boshing diameter for the Zippler tuyere, which is an overhanging boshed tuyere.

Either of these plans may be adopted in constructing an overhanging bosh for the holding of molten iron in a cupola.

Theory of Melting in a Cupola

In 1871 I organized a stock company at Tippecanoe City, Ohio, and built a small foundry for the making of grey iron and malleable casting. At that time the theory of melting was that a cupola melted from the tuyeres up to the charging door, and the fuel and iron were mixed by putting in a few shovels of coke and a few hundredweight of iron, and in this way mixing the fuel and iron for melting.

About that time I learned that a few founders were putting in their coke and iron in layers, designated charges of coke and charges of iron, and claimed better results from this method than the mixing method.

To determine which of these theories was correct, I placed in one of our small cupolas bars of pig iron a few inches apart, from below the tuyeres up to the charging door, across the cupola, and fastened the end of them in the lining, so that they could not settle with the stock in melting, and around them placed fuel and iron for the heat in the mixed plan of charging fuel and iron.

In this test all the iron that was permitted to settle with the fuel was melted, but the pigs fastened in the lining only melted at one point, which I designated the melting zone. This zone began about six inches above the tuyeres in this cupola and extended up about ten inches. Below this point none of the pigs was melted out, and below the tuyeres they showed very little sign of having been heated to any great extent.

Above and near the fifteen-inch melting point some of the pig had been highly heated and bent by their own weight, but none had been melted, and still further up the pig showed but little indication of having been heated.

Further experiments along this line showed the cupola to be a space furnace, where iron was only melted in a given space, and at the lower edge of this space, which is designated the melting zone, iron in melting is struck by the blast, oxidized and converted into slag, and if melted at the upper edge is roasted and burned, due to being held at the oxidizing point, while the excess of fuel that supports it at this point is being burned away.

When the financial panic of 1873 came on this plant was closed down indefinitely, and I started out as an expert melter to introduce this new theory of melting, and for a number of years followed it up, during which time I had an opportunity of observing its workings in cupolas of all sizes and shapes, with all the various pressures and volumes of blast, and in all cases found this theory to be correct, and that both the height above the tuyeres and the depth of the melting zone varied with the volume and pressure of blast.

This variation was more pronounced with volume of blast than with pressure of blast, for I found the increased pressure on an air gauge may be due to the close packing of iron in a cupola in charging, or to bridging and clogging up of the cupola when working badly, and was very deceptive as an indicator of the number of cubic feet of air entering the cupola.

The various tests that I have made indicate very clearly that the cupola is a space furnace, in which iron is only properly melted within a given space. Above this space any iron that may be melted is burned off rather than melted, and the quality of the iron materially reduced, whether hard or soft, but more marked in a soft iron, from which the carbon is burned out and the iron materially hardened.

Iron melted below this space or on the lower edge of it is struck by the blast, oxidized and a large per cent of it converted into slag, and if this process is continued for a sufficient length of time, foaming slag may appear in the cupola to an extent that it may run out at the charging door.

Slag flowing from the tap hole, toward the end of a heat, that looks like iron and cannot be identified from iron until an attempt is made to skim and pour it, is an indication of this condition, as is also a heavy black slag of almost the weight of iron, drawn from the slag hole toward the end of a heat, or when a cupola is working badly.

No measurements can be stated for the location of a melting zone, in cupolas, for its location varies with the volume and pressure of blast. A strong blast places it higher, and also increases its depth, and a light blast places it lower and decreases its depth, which accounts for a cupola with a strong blast melting faster and requiring a heavier charge than one with a light blast.

The only practical way of locating the melting zone of the cupola is by varying the height or top of the bed above the tuyeres until this point is found.

A proper height is indicated by the length of time required to bring the molten iron down after the blast is put on; this should appear in from five to eight minutes. If a longer time than this is required to bring down the iron, then the bed is too high and fuel is being burned away to bring it down to the melting zone.

If the iron comes down almost as soon as the blast is put on, this indicates the bed is too low or has been burned on too great an extent before charging iron, or the tuyeres have not been properly closed to shut off the draft when charging begins. In either case the result will be that the bed will not melt a full charge of iron, and if placed in the cupola the latter end of it will come down dull.

The top of the bed should be at the top of the melting zone when the blast is put on, and this point is indicated by the length of time the blast is on before the iron comes down, which should not be more than five to eight minutes. If fifteen to thirty minutes is required, then the bed is too high, and this extra time is consumed in burning it away to an extent that will permit the charge of iron to settle into the melting zone.

In the melting of a charge of iron on a bed of proper height, the bed is burned away and the top of it pressed down by the weight of iron upon it. The weight of iron that can be melted on a bed before the iron begins to turn dull is the weight of iron that should be placed in the first charge, for dullness of the iron indicates that the lower edge of the melting zone is being reached, and if the charge is excessively heavy it will sink below the melting zone, where it cannot be melted and melting will stop.

In melting a charge of iron the bed is lowered from the top of the melting zone to near the lower edge of the zone, and a charge of coke is designed to replenish the fuel thus burned out and bring the top of the bed up to the top of the melting zone.

If this charge of coke is too heavy, it raises the bed above the melting zone, and this has to be burned away before melting can be done, and there is a stoppage or slackening up in the melting.

If the charge of iron is too heavy for the charge of coke, the latter end of the charge will come down dull, and if excessive, the same result will be observed as when a charge of iron on the bed is too heavy.

This will be the case even when the charges of both fuel and iron are too heavy, for the excess of fuel is burned out before the iron reaches the melting zone, without melting any iron.

It will thus be readily seen that the cupola is a space furnace in which the iron must be placed within a certain space to be properly melted, and iron melted upon the upper or lower edge of this zone is injured in melting.

It will also be seen that neither an excess or deficiency of fuel gives good results in melting, for an excess of fuel places the iron above the melting zone, and a deficiency of fuel places it below the melting zone, and in either case injury to the iron results.

To determine the location of the melting zone in any cupola, first get the bed of a height that brings the iron down in from five to eight minutes after the blast is put on; place on this bed the heaviest charge of iron it will melt before turning dull. The first indication of a change in the temperature of the iron is the point at which the weight of the charge should be reduced to such an extent that no change is noticeable.

The first charge of coke should be the amount that will restore the top of the bed to its height before melting the first charge of iron; this point is indicated by a continuation, in the melting, of a stream of the same size as that in melting on the bed charge. If there is a marked decrease in the size of the stream for only a few minutes, the charge of coke is too heavy, and should be reduced the next heat.

If the charge of coke is so light that it does not fully restore the bed, the latter end of the charge of iron placed upon it will come down dull, the top of the bed will be lowered to a great extent in melting it, and if the same ratio of fuel and iron charges are continued through the heat, the bed will become so low that black heavy slag will appear, and if the heat is a long one, melting will either stop or foaming slag will appear in the cupola.

The same phenomenon will be observed if the charge of coke is right and the charge of iron is too heavy to be melted by the charge of coke. For it is only a matter of exhausting the bed to an extent that the new charges of coke do not restore it to a proper height for good melting.

To determine whether the coke charge or the iron charge is too heavy, first learn the proper height of the bed, in the manner before described, place on the bed the heaviest weight of iron the bed will melt without showing any change in temperature of the iron.

On this charge of iron place a charge of coke that will continue the melting at the same temperature without any slacking up of the melting, as indicated by the size of the stream.

Should there be a slacking up in the speed of melting at the end of a charge, the charge of coke is too large; and if the iron comes dull, it is too high for the charge of iron, and the charge of both coke and iron should be varied until a stream of an even temperature and size is obtained.

A light friable coke does not contain so great a number of heat units as a heavy, dense coke, and burns away more rapidly than a heavy coke, and the same bulk of light coke will not melt so heavy a charge of iron as a heavy coke.

In the case of a light coke it is better to reduce the weight of the charge of iron than to increase the charge of coke, for the excess of coke has to be burned away before the iron can settle into the melting zone and will be wasted.

Taking Up the Heat

The finding of the weight of iron required to be melted to pour off the molds that have been put up for a heat is designated by various terms in different sections of the country, but is most commonly designated, "taking up the heat."

The taking up of a heat is a very important matter, for if there has been an excess of iron charged into the cupola it has to be poured into the pig bed or recovered from the dump if not melted, and there is a loss of fuel, iron and labor. If there is not sufficient iron melted the molds have to stand over until the next heat, and the floor space is occupied without an output of castings, this is also a loss. The accurate taking up of a heat is considered the mark of a good foreman.

The method of doing this varies with the line of castings and changes made in the patterns from day to day. In stove plate and benchwork foundries, where the castings are duplicates from day to day, and all hand ladle work, it is the practice to take up the heat by ladles. The foreman ascertains the number of ladles each molder requires to pour off his floor, and by adding together the number taken by each, and multiplying this by the weight of iron carried in each ladle, gives the total weight required for the heat, including castings, gates and the average weight poured into the pig bed as dull iron. It is only necessary to add the weight of iron necessary to insure the last iron to be poured being hot.

Some foremen go around every day and inquire of each molder the number of ladles wanted. A better way is to make out a list of the molders, and place opposite each name the number of ladles taken. It is then only necessary to look over the floors and see if they are all up, and deduct the number of ladles taken by molders not at work, and for floors not all up. This system has proved very satisfactory for duplicate castings, whether hand or bull ladle, but cannot be so satisfactorily applied to castings for which the patterns are frequently changed.

In jobbing foundries it is the practice to estimate the weight of castings from the number of cubic inches in the pattern, in which case one-fourth of a pound of iron is allowed for each cubic inch in the pattern, and dividing the number of cubic inches in the pattern by 4 gives the weight of a casting. But the figuring out of the square inches in a complicated pattern is quite a tedious operation, and this method is seldom resorted to except in large castings. The weight of smaller ones are generally estimated by comparison with the casting of similar weight and size, the weight of which is known. When the weight of castings are determined by either of these methods, an allowance must be made for gates, runners, sink heads, etc.

The systems are generally combined with the ladle system, even in jobbing foundries, for if a molder requires a certain number of ladles to pour off his floor, and the work is not changed, he will require the same number the next heat. After determining the weight of iron required for castings, gates, etc., an allowance must be made for dull iron poured in the pig bed and over iron to insure the iron at the last of the heat being sufficiently hot and fluid to run the castings.

With hot even iron, the only iron poured in a pig bed is small amounts left in the ladle after pouring that would become too dull before catching in the ladle again. The average weight of this can readily be learned by weighing it for a few heats. In case of trouble in melting and dull iron, the amount poured into the pig bed can only be learned as the heat progresses, and when found to be excessive more iron must be charged to avoid running short.

The weight of over iron required to insure the iron being sufficiently hot at the end of the heat to run the casting depends upon the size and working of the cupola, and also the character of work to be cast. If the work to be poured is light, thin casting, or heavy castings to be machined, the iron should be as hot as in any part of the heat; but if there is common heavy casting to be poured at the end of the heat, this is not necessary, as the cupola may be drained for them, so that the weight of over iron required to insure hot iron must be determined by each foundry.

A foreman by looking into the cupola, when the stock gets low, can readily learn to estimate about the weight of iron in it to be melted, and by looking over the floors and pig bed, estimate the weight required. And in case the iron is likely to run short, more iron should be charged before the stock in the cupola gets too low for melting.

Charging a Cupola

CHAPTER VII

Small Charges of Fuel and Iron

The present theory or system of placing fuel and iron in a cupola in charges for melting was revolutionized to some extent with more disastrous than beneficial results by a paper written by Dr. Moldenke a few years ago and published in "The Foundry" advocating the placing of fuel and iron in a cupola in such small charges that it practically amounted to mixing of fuel and iron instead of placing it in layers of distinct charges of fuel and charges of iron.

This was a step backward to the cupola practice of fifty years ago, which was to put in a shovel or two of fuel and a hundred weight or two of iron.

This system worked out very well in the small cupola and short heats of the small foundries of those days, and no doubt was a success in the doctor's small experimental cupola in the cellar of his residence at Watchung, N. J., but when it came to applying it to large cupolas and long heats it proved a complete failure.

One of the worst failures, due to this cause, that I have been called upon to investigate was that of a foundry in the New England states.

The following reports of seven heats melted and explanatory letter of their melting and the trouble they were having with their cupola lining and castings were sent me for an opinion and remedy for their troubles.

"We are having a great deal of trouble with the iron we get from the cupola. We run a line of typewriter castings and we make another line of chucks, which also calls for a very clean grade of iron.

"Our castings developed pits and pin holes; the pin holes usually show on any machined part, this is true of both lines, but in our chucks is much more pronounced. The surface of the casting looks clean and solid, but after machining, holes the size of a pea and smaller will show all over the surface. I have prepared three tables which I inclose, and which will give you an accurate idea of our practice.

"Table 1 gives you an idea of the rate we have burned out since relining July 3rd last. We have tuvere openings in the wind belt equal to 500 square inches. We started with 441 square inches, inside cupola, and almost continuous tuyere. I found we lacked penetration, so much so that we could not keep down the flame all around the outside of cupola. I then started to cut down the tuyeres until today I have not over 159 square inches.

"This cutting down of the tuyere opening improved matters but they are not satisfactory yet. The cupola is a sixty-inch shell lined to fifty inches. It was almost a straight lining with the exception that we had a slight overhanging just above the tuyeres, formed with iron brick Zippler fashioned. That, of course, narrowed the cupola to 46 inches at this point, from which it tapered back to the 50-inch lining.

Table No. 1. The following table gives the destruction of lining as shown by measurements taken after each heat every 6 inches from 12 inches above tuyeres, to 51 inches above tuyeres. Cupola was lined to 46 inches at tuyeres and 50 inches above and below tuyeres with 5-inch circular fire brick.

TABLE I

Heat	Inches 12	Inches 18	Inches 24	Inches 30	Inches 36	Inches 42	Inches 48	51
1	48.62	50.94	50.83	50.46	50.21			
2	48.12	50.80	50.64	50.58	50.50			
3	48.35	50.37	51.41	50.85	50.85			
4	48.70	51.08	52.41	52.54	51.39	52.90		
5	49.35	52.39	54.25	54.68	53.75	53.22		
6	51.04	52.96	54.98	56.04	55.60	56.19	57.06	
7	49.56	53.21	55.04	56.25	57.25	57.46	57.75	57.87

"Table 2 gives you the pressure on water gauge and volume on Clarke Blast Meter taken at intervals of fifteen minutes during seven different heats. You will notice that we rarely melt over seven tons per hour, when we should at least be melting nine tons per hour.

TABLE II

Time	Pressure	Volume	Time	Pressure	Volume
3.15	9.75	4.400	3.15	8.75	4.400
3.30	10.00	4.300	3.30	9.50	4.350
3.45	10.00	4.400	3.45	10.50	4.350
4.00	9.50	4.400	4.00	9.75	4.350
4.15	10.00	4.400	4.15	9.25	4.400
4.30	10.00	4.500	4.40	7.75	4.500
4.45	9.75	4.500	4.45	7.25	4.500
5.00	9.00	4.500	4.50	6.75	4.550
5.10	8.50	4.500	4.55	6.50	4.650
5.13	8.25	4.500	5.00	5.25	4.700
5.15	8.25	4.600	5.01	5.00	4.700
5.17	8.00	4.600	5.02	5.00	4.700
5.20	8.25	4.600	5.03	Wind off,	
5.23	7.25	4.650	5.05	Bottom dropped	
5.25	6.25	4.700		Length of heat, 2.05	
5.27	5.50	4.700		Iron melted, 30,000 lbs.	
5.30	5.25	4.700			
5.33	4.75	4.800			
5.35	Bottom dropped,				
Length of heat, 2.35					
Iron melted, 39.000 lbs.					

TABLE III

Analyses of Iron

Table 3 gives the analysis, mixture, strength, and deflection of metal in two heats.

Heat	Phos.	Sulp.	Sil.	Mang.	G. Carb.	C. Carb.	Tr. Stren	Defl.
1	.605	.070	2.510	.730	3.00	.48	2.700	.120
	40% Scrap, 6.6% Steel Scrap, 53.4% Pig Iron							
2	.572	.070	3.030	.680	3.00	.29	2.600	.150
	60% Pig Iron, 40% Scrap							

The scrap in each of these heats was principally remelt from the former heat, and the analysis and mixture should have produced a sound clean casting but did not do so for the reason that the iron was injured in melting by being oxidized.

"Now as to our practice: We light up with a torch, commencing at 11.30 A. M. and continue until noon. We first put on 800 lbs. coke, and allow that to burn through uniformly. We then add 600 lbs. more coke, which brings the bed up to 30 inches above tuyeres. At 1 o'clock we begin charging, our charges are 1500 lbs. of iron and scrap with 150 lbs. of coke, but I have found that in order to have our 2 iron hot enough I have to put as high as 200 lbs. on the later charges. We get our first iron as soon as four minutes but our average is six minutes.

"We break up our back stock as small as possible, also mill it to have it clean. I have the charges spread as evenly as possible, and they descend to the melting zone very evenly. I have no difficulty in slagging provided I put in enough limestone. Our iron always seems hot enough but it does seem that oxidation takes place during most or all of the heat."

The 2 iron referred to means the mixture of iron after first few charges of very soft iron for light castings. Back stock refers to remelt of bad castings.

The highest measurement above the tuyeres recorded in Table I was 51 inches, the measurement at this point was 57.87 inches and this was the condition of the lining up to the charging door. The cupola had been newly lined to 50 inches and this measurement showed a loss of 7.87 inches of lining in 7 heats leaving only 1.3 inches of the 5-inch lining around the cupola and very little more than this thickness down to 36 inches above the tuyeres, and as the destruction of lining was the heaviest at the highest point, it was not safe to melt another heat, and the cupola had to be relined with a 5-inch lining after melting only seven short heats.

This was the heaviest destruction of lining I had ever met with in all of my forty-five years of experience as an expert melter. I had seen a 4-inch fire brick lining burned out in the melting zone in one heat, in which from 80 to 100 tons of iron was melted in an all day heat, but this was something to be expected and provided for, but the burning out of 4 inches of lining all around the cupola clear up to the charging door of the cupola in seven heats was something I did not think possible to do, but it had been done and I was called upon to solve the mystery of this heavy and uncommon destruction of lining.

The first thing I noticed was that the charges of iron were 1500 lbs. and the charges of coke were 150 lbs. This was the correct proportion of iron to coke, that is 10 to 1 on charges, but the charges of both coke and iron were too light for a 50-inch cupola.

The Clark Blast Meter showed that from 4400 to 4800 cu. ft. of blast was entering the tuyeres per minute. This was sufficient to melt nine tons of iron per hour, and the report showed it was only melting about seven tons per hour, which indicated that the cupola was receiving an excess of blast for the tons of iron melted. The blast was passing up through the stock to the charging door and burning the scattered coke between the charges all the way up to the door, which accounted for the cupola lining not showing any melting zone.

The heat from this coke and blast being held down by the charges of closely packed iron naturally passed to the lining where the iron was openly packed and escaped up along the lining causing its destruction all the way up.

This same action takes place in the melting zone causing an increased destruction of lining at this point, and to reduce this destruction of lining to a minimum, the iron should be more closely packed close to the lining than in any other part of the charge.

The blast gauge, it will be noticed, showed a decrease in pressure of blast about the middle of each heat, and a gradual decrease from this point to the end of a heat. This is a change that should not have taken place until near the end of the heat when the stock became low in the cupola.

This indicated that the blast was passing freely through the cupola and no doubt oxidizing the iron, which was the cause of the pitting, small blow holes and dirt complained of in the castings.

The trouble with this cupola was the small charges of fuel and iron and an excessive blast. A 50-inch cupola should have at least a charge of 3000 lbs. of iron and 300 lbs. of coke, and a cupola of this diameter with so strong a blast should have a charge of 4000 lbs. of iron and 400 lbs. of coke. This would give a layer of coke of sufficient thickness to hold down the blast, consume its oxygen in passing through this thick layer of coke to an extent that would prevent the next charge of coke becoming ignited before settling into the melting zone.

Another Small Charge Trouble

Another small charge trouble that I was called upon to investigate was in the Pennsylvania foundry. The cupola in this place was an old-fashioned, home-made cupola of fifty-four-inch diameter, with a low charging door for this diameter of cupola.

This cupola has been modernized to an extent of putting on an outside belt-air chamber and putting in six tuyeres of a proper area for the cupola, which made it a very good melter for the height of cupola.

The trouble complained of was dirt and blow holes found in casting when machining. The castings were medium heavy hydraulic castings, required to be a close metal and absolutely clean when machined, and 50 per cent. of them were being condemned after partial or complete machining, due principally to small blow holes found under the outer scale of the castings indicating an oxidized iron.

I observed this cupola melt a heat before making any changes and found that the iron came down apparently hot but had no life and soon become dull in the ladles, and there was trouble in dumping the cupola at the end of a heat.

The cupola was charged as follows: Coke bed, 1300 lbs.; iron charge on bed, 2000 lbs.; coke charged, 200 lbs.; iron charged, 2000 lbs., and these charges were continued throughout the heat. Limestone was charged for slagging, and the slag hole opened after a few tons had been melted and permitted to remain open during the remainder of the heat.

For the next heat I had 4000 lbs. of iron placed on the bed and 400 lbs. of coke in the charges and 4000 lbs. of iron placed on the charges of coke. I also had the lining shaped up over the tuyeres as shown in illustration, Fig. 1. These charges gave a much hotter iron and longer lifed iron. There was no trouble in dumping the cupola and the pitting and blow holes in the casting entirely disappeared.

The addition of 10 per cent. steel scrap to their mixture for hydraulic castings closed up the grain of the iron, and they had no further complaint of the castings sweating when pressure was put upon them.

While making these tests a new carload of coke arrived, which was of an inferior quality, and in the first heat with it and the 4000 lbs. charges the iron began to come dull, and I at once had an extra basket of coke put in with each charge. This brought the iron up at once, and through the remainder of the heat the extra basket of coke had to be put in each heat to get hot iron with this coke.

Excessive Slag Due to Small Charges

Another case in which I was called upon to locate trouble due to small charges was at a Philadelphia foundry. The trouble complained of at this foundry was totally different from that of the two foundries just described. They had no complaint to make of heavy destruction of lining, or of pits, blow holes or dirt in castings, which was probably due to their line of castings requiring very little machining and defects due to oxidation in melting not showing on the surface of castings.

Their trouble was excessive slag boiling and foaming in the cupola and flooding the cupola room when the bottom was dropped, dull iron, hanging up of the dump when the bottom was droped, and difficulty in getting a hole through to admit of the cupola cooling off for the next heat.

The cupola in this foundry was an old-fashioned straight cupola with a square brick stack supported on iron columns that had done good melting for many years. But the cupola casing gave out and had to be replaced with a new one, in which the tuyeres were raised 6 inches. Trouble then began.

The cupola was lined to 48 inches and had burned out to 54 inches in the melting zone. Blast was supplied by a Baker-Green Positive Pressure Blower, through six tuyeres of a proper area from a belt air chamber. No slag hole was provided.

The cupola was charged as follows: Bed coke, 1030 lbs.; anthracite coal, 800 lbs.; total fuel in bed, 1830 lbs.; iron on bed, 3000 lbs. Charge of fuel: Coke, 250 lbs.; coal, 125 lbs.; total charge fuel, 375 lbs. Charge of iron, 3000 lbs. This was the charging throughout the heat. Heat melted, 15½ tons, the first five charges melted was hot iron, after this the iron became dull and remained dull during the remainder of the heat. When the bottom was dropped, slag flooded the cupola room and the dump hung up. This was their regular charging and results.

To overcome these troubles the foreman had reduced the tuyeres to more than one-half their original area, and did everything he could think of to overcome the trouble without obtaining any satisfactory results.

For the next heat I had the clay all removed from the tuyeres and the tuyeres restored to their proper size. The same amount of fuel was put in for a bed and iron on it increased to 4000 lbs. Charges of fuel were increased to 400 lbs. with the per cent. of coke and coal the same, and charges of iron 4000 lbs. This was the charges throughout the heat. This gave a hotter iron, more rapid melting and less slag.

For the next heats the fuel in the bed was gradually reduced and the lining shaped up and there was no further trouble with excessive slag or in dumping.

Here are three cupolas of practically the same size, all these foundrymen were placing small charges of iron in their cupolas in which the melting was greatly improved by increasing the weight of the charges of iron and charges of fuel to an extent that gave a proper charge for the cupola. A charge of fuel sufficient to properly separate the charges of iron and give a layer of fuel of sufficient thickness to melt the charge of iron properly without increasing the per cent. of fuel consumed in melting the iron.

I have been called many times to locate troubles in melting which I have found to be directly due to small charges of fuel and iron, but have selected these three cupolas of about the same diameter, and the trouble complained of totally different as an illustration of the troubles that may occur from this method of charging.

The complaint in the first of these cupolas was heavy destruction of lining and imperfect castings due to the cupola melting all the way up to the charging door and oxidizing the iron in melting.

The second was dull iron and imperfect castings due to insufficiency of fuel between the charges and oxidation of the iron in melting.

The melting in all three of these cupolas was greatly improved simply by an increase in the weight of charges of fuel and iron, without any increase in the per cent. of fuel consumed in melting, and some slight changes in the shape of lining and variation in the height of bed made them good melting cupolas.

It will be noticed that in two of these cupolas the tuyeres were reduced in area in an effort to overcome the trouble. This was a mistake, for if a cupola has done good melting with its tuyeres there is no reason why they should be changed when trouble occurred in melting, and this is the last thing that should be done.

Protecting a Lining by Charging

I have done a great deal of experimental work in the way of placing fuel and iron in a cupola for melting, with a view of saving fuel, protecting the cupola lining and doing faster melting. In fact, I have tried out every method suggested to me by foundrymen, whether in their cupola or that of other foundrymen, and will give to the student of cupola practice the results of a few of the methods most frequently suggested by foundrymen.

The method of mixing the fuel and iron in charging or loading the cupola as it was termed was the common practice of foundrymen long before my day as a foundryman, and I have melted many heats in this way with varying results. This system gives very good results in small cupolas and short heats. But in large cupolas and long heats it has proven a complete failure due to an excessive use of fuel, heavy destruction of lining and a strong tendency of the cupola to bridge and bung up when charged in this way.

At the time that I was introducing the charging system in place of the mixed fuel system, many suggestions were made to me for improving this system. One was to place all the iron in the center and fuel around the outside.

This system was tried and gave better results in hot iron and a clean dump than many heats I had seen melted with the mixed fuel system. But the destruction of cupola lining was soon found to be much greater and higher up than with the mixed fuel system.

The next system tested was to charge all the fuel in the center and iron around the outside. This proved to be a better system than with the fuel on the outside, as it gave a hotter iron and less destruction of lining.

But in a number of test heats of each of these systems I did not find that either of them gave as good results in the economy of fuel as the separate charge system or as hot and even iron.

In these heats the fuel and iron was not kept fully separate and distinct from each other, for this could only be done by the use of a casing or ring to hold the fuel or iron up around the lining, while the center was being charged. The test was made by placing the fuel and iron around the outside and filling in the center. This resulted in the mixing of iron and fuel in the center to a greater or less extent with only the greater part of either around the lining.

These tests led to new thoughts and I decided to try these systems in a modified way, with the charges of fuel and charges of iron system.

I first tried putting in a regular charge of fuel for the charge of iron and piling it up a little around the lining. This gave a thinner layer of iron over the fuel around the lining than in the body of the cupola, and as the fuel burned out left an open space for the escape of heat, and flame appeared freely at the charging door all around the lining.

I tried this with a cupola lined with red brick and the destruction of lining was so great above the melting zone that the entire lining would have been burned out in three or four short heats.

For the next test I piled iron and scrap up a little around the lining and placed the fuel level over the charge of iron. This gave a thinner layer of fuel over the iron around the lining than in the body of the cupola. The appearance of heat and flame around the lining at the charging door was not so great as when the fuel was raised around the lining, and measurements after the heat showed very little burning out of the red brick lining.

From these tests I concluded that the best way to protect the lining was to prevent heat escaping up in contact with the lining by charging the iron close around the lining to prevent heat passing up freely through it.

To do this I made it a rule to place the iron charges as level as possible and fill in all space between the pig and the lining with small scrap.

I have found that a lining lasts much longer when the cupola is charged in this way than when large open spaces are left between the pieces of pig or scrap to be filled in with coke.

A fire brick lining should last from one to two years, melting a two to three hour heat each day, with only a little patching in the melting zone. I have known a lining to last seven years, melting two to three heats a week, and still be in good condition for melting.

Reducing a Cupola Lining for Short Heats

As high a bed is required in a cupola to melt one ton of iron as to melt ten or more tons of iron, and about three to one is the weight of iron that can be melted on a bed and ten to one on the charges. It will readily be seen that the greater the number of charges the more economical the melting.

This was fully understood by foundrymen of early days, and all the large foundries were provided with three cupolas of different diameter and the one best suited to the size of heat put in blast to save bed fuel.

At the present time this system has been practically abandoned and one cupola installed to do the melting regardless of the size of heat.

This leads to an extravagant consumption of bed fuel in dull times and light heats, and to overcome the extravagant cost in melting founders have placed an extra thickness of lining in their cupola or a reducing lining inside of the regular lining to reduce diameter of cupola and save fuel in the bed. This has resulted in many cases to trouble in melting and loss of castings to an extent far greater than the saving effected in the bed fuel.

These troubles are generally due to the diameter of cupola being reduced and the tuyere area and volume of blast not being reduced to correspond with the decrease in diameter of cupola. In other words, the cupola gets entirely too much blast, which results in a higher bed being required and generally oxidation of iron in melting, and in place of saving being effected a heavier loss is caused.

When a cupola is reduced in diameter the speed of the blower and tuyere area must be reduced to correspond to the reduced diameter of cupola.

To reduce the diameter of cupola entails considerable expense for fire brick, labor in putting them in, reducing speed of blowers, etc., and when the smaller heats are only temporary it will generally be found more practical to continue with the large diameter than to reduce the diameter to save fuel in the bed only.

In case trouble occurs in handling the iron as fast as melted, due to a shortage of moulders, the blast may be reduced to an extent that will give slower melting.

Cupola Fuels

CHAPTER VIII

Anthracite Coal

For many years anthracite coal was the only cupola fuel used in the eastern section of this country, and also in some parts of the west, more especially along the lakes and rivers, where it could be obtained at a low freight rate by water.

With the improvement in the manufacture of coke from bituminous coal, anthracite coal almost disappeared as a cupola fuel, both in the eastern and western section, and even in the anthracite coal fields, when used, its use is generally restricted to the bed fuel, charging being done with coke alone, or in a mixture with anthracite.

In these times of high price and scarcity of coke, founders may find it necessary to resort to anthracite as a cupola fuel, and a few points on its quality and manner of using may be of value.

There are three distinct varieties and grades of this coal that may be used as a cupola fuel, they are known as Lackawanna or Wyoming, Schuylkill and Lehigh.

The first of these are mined in the Lackawanna and Wyoming valleys, in the vicinity of Wilkes-Barre, Pittston and Scranton. The coal at times is given the name of these various places in different markets. This coal is the softest and most free burning of all the marketable anthracite coal. The second is mined in the Schuylkill valley in what is known as the Pottsville coal fields and is a harder coal than the Lackawanna and Wyoming coal.

The third is mined in the Lehigh valley and is the hardest and longest burning of any of the anthracite coals.

The deeper mines produce a harder coal than the surface mines in all these regions, and each district had its preferable mine as a cupola fuel in the market in which it was sold, and Old Mine Lehigh was considered the best of them all.

The following heats melted at a time when anthracite was the only cupola fuel used in the section in which they were melted, and the coal used in melting the most economical fuel in this section.

The following heat was melted at the foundry of Jackson & Wooden, Berwick, Pa., a small town located on the edge of the Wyoming coal fields, with coal from nearby mines. The iron melted was for car wheels and car castings, and not required to be very hot.

Bed Coal	1900	Charge Iron	4350
Charge Coal	500	" "	4350
" "	600	" "	4350
" "	700	" "	4350
Total Coal	3700	Total Iron	17400

Per cent. fuel 21.26+.

Heat melted at the foundry of the American Stove & Hollowware Co., Philadelphia, with Schuylkill coal for hollow ware and stove plate iron required to be very hot.

Bed Coal	1500	Charge Iron	4000
Charge Coal	350	" "	4000
" "	350	" "	4000
" "	350	" "	4000
" "	250	" "	2000
Total Coal	2800	Total Iron	18000

Per cent. fuel 15.55+.

This heat was melted at the foundry of the Wolf Stove Wks., Troy, N. Y., with Old Mine Lehigh coal. The lightest of stove plate was made at Troy at this time, and iron required to be very hot to run the plate.

Bed Coal	1400	Charge Iron	4000
Charge Coal	300	" "	4000
" "	300	" "	4000
" "	250	" "	3000
" "	250	" "	3100
Total Coal	2500	Total Iron	18100

Per cent. fuel 13.81.

It will be noticed that the weight of iron in charges of the first heat remained of the same weight through the heat, while the weight in charges of fuel is increased in each charge. This was found to be good practice with this soft coal, as the bed burned away more rapidly than with hard coal or coke.

I tried decreasing the weight of iron in the charges after the bed by dividing the iron into four in place of three charges with the five hundred pounds charge of coal but found that this did not give any faster melting or hotter iron and required more fuel to melt the heat.

I have never tried this method of charging with coke, but it might give excellent results with a very soft combustible coke in short heats.

In the heat of the American Stove & Hollow Ware Co. it will be seen that the charges of coal and iron are not so heavy with the hard coal, and the last two charges of coal were decreased. In the last two charges of coal and in the heat of the Wolf Stove Wks., both the charges of coal and iron were decreased. This was the common practice with the harder coal, and it was only with the soft anthracite coal that the charges of coal were increased.

It will be noticed that the per cent. of fuel decreased with the harder grades of coal, the Wyoming required 21.26%, Schuylkill, 15.55%, and the Lehigh, 13.81%, or pounds of coal, to melt each one hundred pounds of iron.

Any size of anthracite coal may be used to melt iron in a cupola for short heats, but the size to be preferred for either short or long heats is broken coal of about the size of a man's fist.

The following heat was melted at a large stove foundry in Albany, N. Y., in a straight cupola 60″ in diameter, with 5 oval-shaped tuyeres, 7½ x 3½″, tuyeres 4″ above sand bottom, at back of cupola, cylinder blast, large anthracite coal fuel, fire light at 12 M. iron charged at 1 P. M., blast on at 3 P. M., bottom dropped at 5 P. M.

Coal			Iron		
Bed	1800	lbs.	Charge Iron	4400	lbs.
Charge	350	"	" "	4400	"
"	350	"	" "	4400	"
"	350	"	" "	4400	"
"	350	"	" "	4400	"
Total	3200	"	Total	22000	"

This was regarded as a fine heat and about the best that could be done with this melting fuel.

Founders wishing to use this fuel have only to put in a bed 14″ above top of tuyeres, and reduce or increase charge of fuel and iron to correspond to diameter of cupola in which melting is to be done.

Foundry Coke

The term foundry coke is designed to indicate that it is a superior quality of coke to that used for smelting iron from iron ore in blast furnaces and other smelting and melting of metals.

In the melting of iron in a cupola the iron is melted in direct contact with the melting fuel and takes up impurities from the fuel, and it is important that a cupola or foundry coke should be as free from sulphur and other elements detrimental to the quality of iron desired as it is possible to obtain it.

Another important matter to be looked for in a foundry coke is its combustible qualities. A high carbon, free burning coke, burns away too rapidly in a cupola, and does not carry the burden or melt the high per cent. of iron that a low carbon, more dense and harder coke does.

A high ash and low carbon coke does not contain the units of heat requisite for fast and economical melting and the ash clogs up the cupola and retards melting as the heat progresses.

High sulphur is an undesirable element in a foundry coke, as its effect upon cast iron is both to harden and weaken it, due to the iron absorbing sulphur from the coke in melting, and the aim should be to get a coke as free from sulphur as possible.

Volatile matter in a foundry coke is of but little importance. as it is volatilized by the heat and driven off without detrimental or beneficial effects upon the iron, and the per cent. of it in a foundry coke is so low that it is not worth considering.

Moisture in coke was claimed by foundrymen to be a destroyer of sulphur and a heat produced, and for many years it was the practice to permit coke to lay out in the weather and when dry to wet it before charging.

Scientists claimed that heat was required to drive off the moisture and the wetting of coke was a waste of heat, and the practice of wetting coke was discontinued. But since the discovery that water may be used to advantage in the making of both illuminating and heating gas, the correctness of the scientific theory of moisture in coke has been very much doubted and the matter is now being taken up and investigated.

The following analysis shows a desirable composition for a foundry coke, and foundrymen should aim to get as near this analysis in their coke as possible.

Desirable Composition for Foundry Coke

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

Coke Districts of the United States

The following extract from reports published by the bureau of mines gives the coal fields of the country and the average composition of foundry coke made from the coal of the various fields.

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

Coal from all the mines of these various coal fields does not make a good foundry coke, and this is the case with even the great Connellsville district of Pennsylvania as well as other fields, and foundry coke should only be purchased by analysis to insure it being of a desired quality.

Alabama Coke

Average Composition of Alabama Coke

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

The analysis shows up better for coke made from washed coal.

Kentucky Coke

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

New Mexico Coke

New Mexico is becoming an important factor in the coke production of the west as one sees on visiting its coal region. The coal is so dirty, however, that for coking purposes it must be washed, and when so treated some analysis showed nearly 10 per cent of ash. The sulphur contents is rather low being between 0.6 and 0.7 per cent.

The great coke plant at Dawson, New Mexico, is interesting. The gas from the modified beehive ovens is used for steam for the plant but the other by-products are lost.

Ohio Coke

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

For the past forty years to my knowledge they have been trying to make a good foundry coke from Ohio coal, and probably more money has been spent in new devices, ovens and methods of coking in this state than in any other state or coke fields.

Pennsylvania Coke

Pennsylvania is, of course, the banner state for coke. Coke is made in ten districts that are geographically distinct. The amount of slack that is washed before coking is considerable, but not so large as in other coke fields.. Nearly all of the coal mined in the Connellsville district is used for coke making. The most of the coal so used is unwashed run of the mine.

As detailed statements of the statistics can be found in the volume of Mineral Resources annually issued by the United States Geological Survey, it will be sufficient here to give the range in composition.

Range in Composition of Pennsylvania Coke

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

The poorer grades of this coke are 48 hours beehive oven coke, made from inferior coal, and designed for blast furnace smelting. The better grades are 72-hour coke, made from good coking coal and sold at a higher price than furnace coke.

Colorado Coke

Practically all coal from Colorado used for coking purposes is washed; average analysis is about as follows:

Average Analysis of Colorado Coke

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

This coke could be improved with respect to its high ash by better development of the washing process.

Illinois Coke

The Illinois coal itself gives a rather poor coke, even when washed, though doubtless it may be used to advantage by mixing with other coal possessing better coking properties. An analysis of a coke made from a washed Illinois coal is as follows:

Analysis of Coke Made From Washed Illinois Coal

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

In spite of its quality, this coke has its uses, though probably one would do well to keep clear of it for ordinary foundry work.

Foundrymen will recognize in the above analysis a material much like that they sometimes get during coke famine.

Tennessee Coke

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

Range in Composition of Tennessee Coke

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

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

Virginia Coke

The southwestern portion of Virginia is rapidly becoming an important coke center; the coals are high grade, producing a coke comparable with those from the flat top and new river district of Virginia. The range of the following analysis indicates what excellent material this state produces.

Range of Composition of Virginia Coke

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

Washington Coke

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

Composition of a Washington Coke of Unwashed Coal

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

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

West Virginia Coke

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

Range of Composition of West Virginia Coke

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

The foregoing descriptions and analysis of coke are principally extracts from Bulletin No. 3, "The Coke Industry of the United States as Related to the Foundry," by Richard Moldenke, a copy of which may be had by addressing Bureau of Mines, Washington, D. C.

This is a pamphlet of thirty-three pages, containing a great deal of valuable information to foundrymen on Cupola Coke. Price, five cents.

By-Product Coke

A by-product coke is a coke made in closed retorts for the purpose of obtaining certain valuable elements in the coal from which the coke is made.

The value of the by-products are greatly enhanced by the purity of the coal from which they are obtained, as is also the value of the coke as a fuel; and some of the very best foundry cokes are now being made by by-product coking process.

The location of these plants does not always indicate the coal from which the coke is made, for many of them do not use the coal of the district in which they are located, but obtain their entire supply of coking coal from the very best veins of coking coal in the various coal fields.

Solvay Coke

One of the leading manufacturers of by-product foundry coke is The Solvay Co., Syracuse, N. Y. This company has coking plants at Syracuse, N. Y., Dunbar, Lebanon and Steelton, Pa., Wheeling, W. Va., Ensley and Tuscaloosa, Ala., Chicago, Ill., Milwaukee, Wis., and Detroit, Mich.

They make a special effort to make a good foundry coke at all their plants, and supply the principal part of the foundry coke used in these various districts.

The following average monthly analysis of coke, made at their Detroit plant, shows the average analysis of their coke for four years:

Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur
.168	1.56	88.56	9.79	.722
.102	2.11	88.00	9.50	.709
.104	1.765	90.12	8.09	.67
.104	1.161	90.69	8.07	.646

It will be observed that this analysis corresponds very closely with the analysis of a desirable foundry coke. Its uniformity is also an important matter, as it enables the foundryman to make his mixture of iron to suit the coke.

New England Coke

New England foundry coke is also an excellent by-product coke. This coke is made near Boston, Mass., and is a very popular foundry coke in this district.

There are a number of other excellent by-product foundry cokes made in different sections of the country, but all by-product cokes are not good foundry cokes. It is only those made from selected coal that are superior or equal to beehive oven coke made from good coal.

Ash and Sulphur

Ash and sulphur are the two most important elements in a cupola coke. A high ash coke does not possess the units of heat of a low ash coke, and the ash tends to clog up the cupola, and it is only possible to run a long heat with a very high ash coke by the liberal use of the limestone flux and drawing off slag to carry the ash out of the cupola.

A low ash coke is too open and readily crushed and does not carry the burden or melt so high a per cent. of iron to fuel as a medium ash coke. Investigation along this line has shown that a nine to ten ash coke gives the best results in melting.

The great dread of the foundrymen is high sulphur coke, with its hardening effects upon the iron.

This is a matter that may be readily controlled by the foundrymen by destroying or offsetting the hardening effect of sulphur on iron, by the liberal use of a metalloid having a softening effect upon iron.

Silicon is the softener of iron, and to offset the hardening effect of sulphur it is only necessary to increase the silicon in the mixture of iron to a point that counteracts its hardening effects. This may be done by increasing the high per cent of silicon pig in the mixture, or using an excessively high silicon pig.

Gas House Coke

Gas house coke is generally a soft open coke that burns away rapidly and melts only a very small charge of iron, which makes it an undesirable cupola fuel; but I have frequently melted small heats with it when other coke could not be procured, and it may be used in an emergency for heats in small cupolas.

In melting with this coke, I found that an extra high bed and light blast gave the best results, and heavier or higher charges of coke were necessary to insure hot iron.

I would not advise the use of this coke in large cupolas or long heats.

Coke and Iron

There are two ways of obtaining a desired quality of iron in melting. One of these ways is to have the coke suit the iron; the other is to have the iron suited to the coke.

In the early days of foundry practice in this country it was the practice of foundrymen to make their own coke from coal of nearby mines, and no attention was paid to sulphur in the coal or coke. The only object was to get a coke of sufficient density to melt their iron, and have it of a uniform quality; and a pig was selected by test in melting with this coke that would carry the desired per cent of scrap and produce an iron of a desired quality in casting when melted with this coke.

In my young days I was employed at the foundry of Joseph King & Co., Sharon, Pa., where this was the practice, and we had no trouble in casting stove plate and other light casting with iron melted with coke made from coal from this district, which later on was found to contain from one to two per cent sulphur in the coke.

The pig iron was what was known as Briar Hill, smelted from black band iron ore. This iron contained a high per cent of silicon and carried a good per cent of scrap, and gave a soft casting when melted with this high sulphur coke.

At that time there was located in Sharon a blast furnace called the Kimberly Furnace. This furnace melted principally Lake Superior ore, and when they made an extra open soft pig would come around and want us to try it for castings. This was done several times, but in every trial it run white in our light castings when melted with this coke.

The secret of this was the high silicon in the Briar Hill pig, which neutralized the high sulphur of the coke.

Later on, Pittsburgh coke made from Pittsburgh coal came upon the market. This was tried, but the different shipments proved so variable that we went back to home-made coke, and it was not until the Connellsville coke came upon the market that the home oven was entirely abandoned. These tests of iron and coke gave me my first insight into the true system of manipulation of iron and coke in cupola melting, and enabled me to successfully melt condemned iron and use condemned coke that had laid in foundry yards in some cases for years, when traveling as a foundry expert.

Nothing was known about silicon in iron at that time, but I acquired the knack of picking out a soft iron by fracture indications which later on proved to be a high silicon iron, and to judge coke by its weight, fracture and dark or brown spots upon it, which indicated high or low sulphur, according to size and shade of color.

When coke is so high in sulphur as to harden iron, increase the per cent of silicon in the iron to an extent that will offset the effect of the sulphur upon the iron, and the iron will come down soft as with low sulphur coke.

This can be done by an increase of high silicon pig in the mixture or by the use of a special high silicon pig. Foundrymen making soft castings should keep a four to five per cent silicon pig in their yards for this purpose.

A coke suited to the iron is a coke that imparts to the iron desired qualities for work to be cast; many of the foundries making hard castings prefer a high sulphur coke to a low one, for sulphur in coke imparts to this iron a peculiar hardness that cannot be attained in any other way.

Moisture in Coke

It was the common practice of foundrymen for years to permit their coke to lay out in the weather the year around, and it was only in deep snow districts that it was housed in the winter months.

This was done to admit of the rain, snow and atmosphere removing sulphur and other impurities detrimental to the iron from the coke, and to admit of the coke absorbing moisture, burning longer and making a hotter fire than perfectly dry, free burning coke.

This theory was so thoroughly believed in and practiced that hose or buckets were provided on cupola scaffolds for wetting coke in dry weather before charging, and dry coke was only placed in cupolas for lighting up, when obtainable. For this purpose it was the practice of melters to place a few barrows of coke on the scaffold overnight to keep it dry or dry it out for lighting up, and coke for the greater part of the bed and charges, if not wet, was wet before placing in the cupola.

That the quality of coke was improved by laying out in the weather was many times proven by the improvement in condemned coke permitted to lay out in the weather over winter. In a number of cases that came to my notice coke that made iron hard, after being treated in this way, gave a soft casting from the same iron or mixture of iron.

I had one experience of this kind in my own foundry practice with an Ohio coke high in sulphur, from which the sulphur was no doubt washed out or greatly reduced.

But scientists stepped in and said that moisture in coke required heat to drive it off, and that there was a waste of fuel by wetting coke, or permitting it to lay out in the weather and absorb moisture, and the practice of permitting it to lay out in the weather or wetting it before charging was generally abandoned and cupola coke securely housed and kept dry.

Since the claim of some of the coke manufacturers in the Connellsville coke district a few years ago that high sulphur in their coke was due to the dry season and water being so scarce that they were compelled to extinguish the fire in coke when drawn from their ovens with water from the mines or small streams that were so highly charged with sulphur that the sulphur was taken up by the coke.

The practice, which has now become general, of washing high sulphur coking coal with water before coking to eliminate sulphur, and the use of water in the manufacture of both illuminating and heating gas, has caused the claims of scientists that moisture is detrimental to coke and heat is wasted in driving the moisture out to be very much doubted, and I have received a number of letters recently making inquiry about this matter, which indicates that it is being investigated; but I have not yet received any reports of results of such investigation.

From my own experience, I am a firm believer in exposing coke to the weather, and wetting it, if dry, before charging.

Per Cent of Fuel Required in Melting

The per cent of fuel required to melt iron in a foundry cupola, for castings is the per cent of fuel that will bring down a hot even iron suitable for the work to be cast. Any less amount results in loss of castings, and is a waste of fuel and labor and loss to a foundryman.

A great deal has been said and printed about high per cent of iron to fuel melted in cupola, and it is not an uncommon thing to hear claims of melting 9-10 and as high as 15 to 1. That these claims are absurd is manifest to any practical foundryman, for melting in a cupola is done upon fixed principles, which are as follows:

To melt iron in a cupola, a bed of fuel must be put in that will fill the cupola from the sand bottom to the top of the melting zone.

The function of this bed is principally to support the stock in the cupola, as only the top of it is consumed in melting the charge of iron placed upon it, and if this charge is too heavy the bed is lowered to so great an extent in melting it that it is not replenished to an extent by the next charge of fuel that admits of good melting and hot iron during the remainder of the heat.

The weight of fuel required for a bed varies with the height of tuyeres above sand bottom and also with a single or double row of tuyeres. The per cent. of iron to fuel that can be melted upon a bed and leave the bed in good condition for melting the following charges, therefore varies with the weight of fuel in the bed, and has been found to be from one to three pounds of iron to the pound of fuel, and in one charge heats two to four pounds.

For charges of iron after the bed charge, the practice is to charge ten pounds of iron on the fuel to each pound of fuel in the charge of fuel.

The higher per cent. of iron on charges brings the per cent. of iron to fuel in the bed and charges up as the number of charges increase, and the greater the number of charges the higher the per cent. of iron to fuel, but this increase grows smaller each charge and no number of charges will bring the melting ratio of the heat up to 10 to 1, the number of pounds claimed to be melted by some foundrymen.

The claim is made by some founders that they place 12 to 1 on their charges. This weight may be melted in short heats if the iron is not required to be very hot and the coke is of an excellent quality, but even with 12 to 1 on charges a large number of charges are required to bring the ratio of the heat up to 10 to 1. And in a long heat, with 10 to 1 on charges, a split charge is frequently required to keep to the required standard of heat with the best of coke.

Claims are frequently made by founders and foremen of some secret in melting that gives them a very high ratio of iron to fuel. I have heard such claims made for the past forty years and never found anything in them and I regard all such claimants as fakirs pure and simple.

For the saving of fuel various designs of cupolas have been constructed, various shapes and arrangements of tuyeres have been tried and various methods of placing stock in a cupola tested. The present construction, tuyeres and system of charging have been found to be the most economical in fuel.

To derive the full benefit of this construction and system the tuyeres should be placed at the lowest point consistent with the system of handling the iron.

Cupolas of large diameter should be boshed from the bottom plate up in place of an overhanging boshing to save fuel in the bed, and the charging should be reduced to a system that will utilize all the heat of the fuel in melting.

In my first work on cupola practice, published in 1877, I stated that seven to one was good melting, and eight to one the limit that could be done in a cupola with the best of coke.

This statement is as accurate now as it was then, for in visiting foundries I am frequently shown cupola records and given inside information on their melting, and from these and observations of charging in various foundries I have concluded that the average melting in a fair sized heat for the size of cupola is between five and six to one. In some few foundries

I have found seven to one being melted and vary rarely eight to one.

In every case where I found a higher ratio in melting I have noticed they have hotter and more even iron than in foundries where their ratio is low.

This I have found to be due, in many cases, to their method of charging rather than poor coke. By poor charging I mean open and uneven distribution of fuel and iron that admits of heat escaping without being utilized for melting.

The stove and bench work foundries, as a rule, melt the highest per cent. of iron to fuel of any of the foundries. This is probably due to their careful manner of charging to insure a hot even iron throughout the heat and their heavy remelt of small round and flat gates, packing close in the charges and utilizing all the heat of the fuel.

Cupola and Ladle Fluxes

CHAPTER IX

Cupola Flux

The term flux as applied to metals means a substance that gives additional fluidity to a metal when in a molten state; separates dirt and dross from metals; separates one metal from another; promotes the mixing of two or more metals to form a homogeneous alloy or metal.

This term, when applied to a cupola, means the purifying of iron in melting, giving to iron greater fluidity and flowing properties, forming a fluid slag that is capable of absorbing and keeping in a fluid state in a cupola or carrying out as a slag the ash of the melting fuel, and any non-metallic substance in or upon the iron when placed in a cupola for melting.

Iron is so quickly melted in a cupola and falls to the bottom of the cupola so rapidly after melting that there is but little opportunity for improving its quality by the use of fluxes in a cupola, and it is only in keeping a cupola in good condition for melting that a flux is of value.

The most efficient substance that has yet been found for this purpose is the carbonate of lime in the shape of limestone, marble spalls, shells, etc. These substances have been used by blast furnaces for hundreds of years as a flux, and the drawing off of slag from a cupola, when in blast, is upon the same principal as that of a blast furnace.

When limestone is used it is broken into small pieces and evenly distributed over either the fuel or iron, it does not make any difference which, but is generally placed upon the iron. The amount required is generally about twenty pounds to each ton of iron in the charge, but this amount is not arbitrary as a lean stone requires more, as does also unmilled remelt and very dirty iron or scrap, and each founder must determine by tests the amount required.

Shells are almost exclusively used as a cupola and furnace flux by foundries and furnaces near the seacoast, where they can be had for the hauling. The shells used are principally oyster and clam shells, but any kind of either fresh or salt water shells may be used. They are charged into the cupola in the same manner as limestone and the amount used varies in the same way.

For tapping slag in long heats flux is not generally charged until the third or fourth charge of iron. It is then placed upon each charge until near the end of the heat, when it may be omitted on the last two or three charges. In case the slag does not flow freely increase the quantity of flux, and in case it is too fluid, reduce the flux.

In using flux in short heats when slag is not tapped, for giving a clean dump and brittle slag for chipping out, it is the practice to charge the flux on the second or third charge of iron in about the same quantity as for tapping slag, and in case there is an excess of slag in dumping reduce the quantity of flux.

The fluxing of very small cupolas for the tapping of slag in long heats and slow melting, as in bedstead foundry practice, is done in the same way as in large cupolas, but the formation of slag in these cupolas is not so rapid or abundant as in larger cupolas, and it is not the practice to leave the tap hole open through the heat but to close it after the slag has been drawn off until sufficient has collected for another tap.

Fluor-Spar Flux

Fluor-Spar is a very high carbonate of lime and a very powerful cupola flux, in fact, entirely too powerful, as it fluxes the lining out of the cupola as well as the stock in the cupola.

This material was at one time quite extensively used as a cupola flux in the middle west, where it was obtained from the lead mines of Illinois and Missouri at a nominal cost. But it was found to destroy the cupola lining so rapidly that its use as a flux has been almost entirely abandoned.

There are some few founders who use it in very small quantities for the purpose of improving the quality of their iron in various ways, for this purpose a pint cup full is placed in the cupola with each charge or ton of iron, and some very extravagant claims of benefit from it have been claimed, but these claims have always appeared to me to be very doubtful, as there is nothing in Fluor-Spar to benefit iron any more than there is in limestone.

Fluor-Spar has been used as a base for a number of manufactured fluxes that have been placed upon the market from time to time, but all such fluxes proved so destructive to cupola lining that they soon went out of use, or their use restricted to a tin cup full to a charge. In which case the benefit of all such fluxes are more imaginary than real.

As a ladle flux Fluor-Spar, when ground to a powder, is the very poorest kind of a flux, as it melts readily and floats upon the surface of the molten iron as a very fluid slag, which it is almost impossible to entirely skim off, and if poured into the mould with the iron floats upon the surface of the iron in the mould making imperfections in the top of the castings.

Milling Remelt

The milling or tumbling of gates and remelt scrap is a matter upon which there is a difference of opinion among foundrymen. Some making it a practice to mill or clean all remelt, even brushing off the over iron pig with a steel brush, whiie others mill or clean none of their remelt but place it in their cupola with only the loose sand rapped off.

Either of these methods give good results, and it is only a question of conditions which is the best.

For small cupolas, in which the slag is not tapped, I have found the milling of remelt gives the best results both in melting and dumping of the cupola.

In large cupolas and long heats, in small cupolas from which slag is tapped and drawn out freely, I have found that it does not make any difference in the quality in the iron or dumping of the cupola whether the remelt is milled or not milled.

It is the practice of many of the large stove foundries to melt all their gates and remelt scrap amounting to from forty to fifty per cent. of the heat without milling, and the same is the practice of many other foundries having a high per cent. of remelt, and they have found this practice to be no detriment to either the melting or quality of the iron.

The moulding sand adhering to gates and other remelt is composed largely of Silicon and there is nothing in it that is detrimental to a good soft machinable foundry iron, and the only objectional feature to it is the clogging of the cupola and retarding of melting. This objectionable feature may readily be overcome by the liberal use of limestone or shells to form a slag, which absorbs and liquifies the sand and carries it out of the cupola through the slag tap hole, and it is a much cheaper and more effective process than the milling process which only partially removes the sand, still leaving a heavy scale which can only be removed by an acid bath.

In all cases where slag is tapped I would advise the non-milling of gates and other remelt and the liberal use of flux as a matter of economy.

In case of small cupolas, from which slag is not drawn off, it is a matter of length of time required to melt the heat whether the remelt should be milled or not, to prevent the cupola becoming clogged with this sand and ashes of the fuel.

This is a matter that must be determined by each foundryman from the manner in which his cupola melts and dumps, in case the melting and dumping is not satisfactory, mill the remelt or slag the cupola.

Milling Old Scrap

The milling of old scrap is a matter of far greater importance in the quality of iron than the milling of remelt.

This scrap is frequently covered with a heavy coating of rust or oxide of iron, which has a decidedly oxidizing effect not only upon the iron contained in the scrap but also upon the iron with which it is melted.

This is illustrated in the case of old stove plate scrap which is made of the softest of iron but when remelted with a heavy coating of rust upon it frequently produces the hardest of iron, which makes it the cheapest and most undesirable scrap of all the scrap irons.

This is also the case of small shot iron made from the softest of iron, which when badly rusted produces only a very small per cent. of hard iron and plenty of slag.

The free use of limestone or shells forms a slag that rapidly absorbs this oxide and destroys its oxidizing effect upon the iron and a softer iron is obtained than when the rust and dirt is permitted to form the slag alone.

Ladle Fluxes

There has been a great many native substances and manufactured fluxes tried out for fluxing iron in ladles, many of which have proven a complete failure, due to the heat extracted from the iron in melting them rendering the iron too dull for pouring, or the formation of excessive slag on top of the molten iron.

I, myself, have been the manufacturer of a cupola and ladle flux for the past forty-five years during this time. I have seen many fluxes introduced, tried out and abandoned, while my flux is the only one that has stood the test of years.

A ladle flux to be of value must be one that adds fluidity to the molten metal in place of abstracting heat from it to melt the flux, form no liquid slag, and concentrate dirt and dross from the iron in a mass upon the surface of the iron, so that it may be readily skimmed off before pouring.

My compound flux does this and has been used by foundrymen making finished castings for many years to insure clean iron and sound castings for finishing.

Oxide of Iron Slag

An oxide of iron may be formed in a cupola by a strong blast striking the iron when in a semi-molten state, before all the oxigen of the blast has been extracted from it by the melting fuel.

A slag formed in this way is composed largely of iron, and there is a heavy loss of iron in melting which is indicated by the heavy weight of a black hard slag frequently drawn from the cupola when slag is tapped.

A very strong blast or a continuation of the blast through this slag for some time burns the iron out, and it becomes very light and fluid and boils and foams in the cupola and is termed boiling or foaming slag, which raises above the stock in the cupola towards the end of the heat, and may become so abundant as to flow out of the charging door.

This condition of the cupola is due to a deficiency of fuel in the cupola and the iron settling so low that it is struck by an oxidizing blast before melting. This may occur in the early part of a heat, in which case the top of the bed is too low for the weight of the iron charged upon it, and the fuel in the bed should be increased or the weight of iron placed upon it decreased.

Should this slag not appear until late in the heat, then the charges of fuel are too light for the charges of iron, and the preventive remedy is to increase the charges of fuel or decrease the charge of iron.

This phenomenon may also occur when the volume of blast is too great for the diameter of cupola, which places the melting zone higher up and requires a higher bed and also heavier charges of fuel.

It is not necessary to wait for the appearance of boiling and foaming slag, for this slag only appears at or near the end of a heat, and all the damage has been done before it appears. The indication of the formation of such a slag is what should be looked for and steps taken to prevent its formation.

A heavy black slag drawn from a slag tap hole indicates the formation of such a slag, as does also an excess of slag. Such slag generally appears about the middle of the heat or near the latter end of the heat. The remedy for this is an increase of fuel between the charges or a full charge of fuel and a half charge of iron upon it, a charge or two before this slag appears.

When a heavy slag flows from a tap hole with the iron that looks like iron and cannot be distinguished from iron until skimming and pouring begins, indicates that the iron is being oxidized, and fuel should at once be increased. A high pitched bottom throws out slag freely, and this slag should not be mistaken for oxidized iron slag.

Foundrymen who attempt to melt twelve to one on their charges should look out for this condition in their cupola, for they may be loosing more iron than their saving in fuel would pay for.

Alloying Metal With Iron in a Cupola

A great deal of experimental work has been done in attempts to alloy all the metallic elements and metals with iron in a cupola, and although it has been demonstrated many times that this is impractical, owing either to the impossibility of holding the molten alloy metal in contact with the molten iron for a sufficient length of time to have it absorbed by the iron, or lack of affinity of the alloy metal for the iron.

But there is an attraction about this kind of work, due to the apparent great possibilities of improving the strength of the iron and fineness of the casting, and this kind of experimenting is still going on to a greater or less extent.

Whenever a new metal has been discovered or a new process found for recovering or producing an old metal, at a very much reduced price, there has been a rush to melt it with iron in a cupola.

When a new process for recovering aluminum from clay in large quantities was proclaimed, it was said to be superior to all other metals for anything and everything that metals are used for, and was extensively tried in cupolas and ladles for improving the quality of cast iron.

But it was soon found to be impossible to have this metal taken up by the iron in cupola melting to an extent that produced any perceptible effect upon the iron.

The next attempt to incorporate it with iron was to place it in a ladle and tap the iron upon it. This also proved a failure, due to the low specific gravity of the aluminum and it floated upon the surface of the molten iron with no affinity for the iron.

An aluminum alloy was then made in the electric furnace and sold for strengthening and softening cast iron. This was represented to be an alloy of aluminum and iron, but analysis showed that it contained only a trace of aluminum and soon went out of the market.

With the discovery of vast deposits of vanadium in the west, this metal came into prominence as an improver of the quality of cast iron; and this metal was extensively tried out in both cupolas and ladles with no perceptible effect upon the iron.

Dr. Moldenke published the results in melting this metal with burned cast iron, in which he claimed to have produced in the iron a crystalline structure and softer iron. This was probably the most absurd matter the doctor ever put into print, for what foundrymen would care to melt expensive vanadium with worthless burned iron merely to get a crystalline structure in the little hard iron obtained from it.

The Ingersol-Rand Co., Phillipsburg, N. J., had an expert visit their plant and try out this metal in their cupola and ladles at an expense of fifteen dollars per ton of iron without any perceptible effect upon the iron.

The only man that I have ever met who claimed to have improved the quality of iron by the use of vanadium was a metallurgist at the plant of the Illinois Steel Co., Joliet, Ill. This man claimed to have produced a very superior automobile cylinder packing ring by the use of vanadium in the ladle at a rate of cost per ton of iron of thirty-five dollars. This would make a rather expensive iron.

Manganese is the only metal that I have ever known to be successfully alloyed with iron in a cupola, and this is only done at an extravagant loss of manganese.

Ferro-Alloys in a Cupola

Not many years ago there was a great flurry among foundrymen in the use of ferro-alloys in both cupola and ladles which soon died out, owing to the failure to obtain any satisfactory results from their use in either cupolas or ladles.

In a cupola such alloy failed to come in contact with the molten iron in such a way as to be absorbed by the molten iron, and by practical foundrymen it is generally considered to be a waste of material and money to use any of them in a cupola.

Ferro-Alloys in Ladles

Nearly if not all the ferro-alloys are made in electric furnaces at a very high temperature, and to remelt them many of them require a temperature double that found in molten iron.

When placed in a ladle the heat to melt such alloys must be extracted from the molten iron in the ladles, and in doing so the temperature of the iron is reduced to so great an extent that it is unfit for pouring before the alloy is absorbed by the iron, and if poured before it is absorbed the alloy only makes a dirty casting. It is only when so small a quantity of alloy is used that it is of no benefit to the iron that this is not the case.

In the making of steel ferro-alloys have been used to good advantage, but the metal for steel making is put through a refining process which makes it a commercially pure iron before the ferro-alloy is added to it, and its temperature is much higher than that which may be obtained in cast iron. While cast iron is the crudest of iron, it contains a high per cent. of combined and graphite carbon and many metalloids or elements, which makes the absorption of ferro-alloys an entirely different proposition from that of iron in steel making, and foundrymen should not anticipate the same results from the use of ferro-alloys in their iron as may be obtained in steel.

Cupola Blast

CHAPTER X

It has been determined by scientific investigators that 30,000 cu. ft. of air is required to melt a ton of cast iron in the cupola. This amount of air may be supplied to a cupola by the strong draft of a high stack, by a jet of steam thrown into a contracted stack to form a vacuum, or by a fan or positive pressure blower, which is termed a forced blast.

A forced blast is most commonly used, for it supplies the required volume of blast more rapidly than either of the other methods and the more rapidly the blast is supplied, the more rapidly the iron will be melted.

A cupola should melt ten pounds of iron to each square inch of melting surface in the diameter of the cupola, at the melting zone, per hour. If it does not melt this amount, when supplied with 30,000 cu. ft. of air per hour, for each ton of iron placed upon this surface, then the cupola is not doing its best melting, and there is something wrong with the fuel, or manner of placing the stock in the cupola.

A low carbon, high ash, open coke does not contain so great a number of heat producing units as a hard low ash coke, and more of it must be used to consume the oxygen of 30,000 cu. ft. of air per ton of iron melted, or the volume of blast should be reduced.

When a good hard coke is used, and the cupola does not melt one ton per hour for each 30,000 cu. ft. of blast, then the method of charging should be varied until it does. If this amount of iron cannot be melted per each 30,000 cu. ft. of blast, then the cupola is receiving too large a volume of blast, and the speed of the blower should be reduced.

The atmosphere or blast for all practical purposes may be assumed to consist by volume of 21% of oxygen and 79% nitrogen. The oxygen is a supporter of combustion, but the nitrogen is not, and passes through the cupola unchanged.

A fire is started in a cupola and burned until there is a hot bed of coke in front of the tuyeres, the blast is forced into this hot bed of coke, and its oxygen at once begin to separate from the nitrogen and enter into combustion with the carbon of the coke, aiding more rapid combustion and greater heat.

The nitrogen being heavier than the oxygen and having no affinity for the carbon in the fuel, sinks to the bottom of the cupola after its separation from the oxygen, where it so completely checks combustion of the fuel under the tuyeres that this fuel is not consumed even by the molten iron of the entire heat falling upon it and working its way between the pieces of coke in its descent to the bottom of the cupola, and this fuel is not consumed in the longest of heats.

The separated excess of nitrogen has the same effect, to a modified extent, immediately in front and directly over the tuyeres, and this fuel cannot be entirely consumed until the stock gets low in the cupola and the nitrogen escapes freely up the cupola, unchanged, and has neither a beneficial or detrimental effect upon the iron.

The oxygen in the blast is absorbed by the carbon of the fuel and converted into carbon monoxide and carbon dioxide, neither of which have any effect upon the iron above the melting zone in melting.

But in case the blast is too strong for the height of bed, or the charges of fuel are too light to maintain the bed at a proper height, then the oxygen is not entirely extracted from the blast and converted into carbon monoxide and carbon dioxide, but we have an oxydizing flame above the melting zone which attacks the carbon in the semi-molten iron and an oxydation of the iron takes place, which results in dirty iron and unsound castings, as was the case in the heat described under the heading of small charges, in which 50% of the machined castings were lost, due to this cause.

It will be noticed in Table No. 2 that the blast meter indicated that this cupola was receiving sufficient blast to melt nine tons of iron per hour, while the cupola was only melting about seven tons per hour.

This cupola was not receiving an excess of blast for the size of it and the trouble was not in the blast, nor in the fuel, but in the distribution of the fuel, which was not placed in the cupola in a sufficient body to concentrate its heat upon the iron or to extract all the oxygen from the blast and result was there was no melting zone in the cupola and the fuel burned and iron melted all the way up to the charging door and blast probably escaped still containing sufficient oxygen to support combustion.

It will thus readily be seen that the discovery of scientists that 30,000 cu. ft. of blast is required to melt a ton of iron is of little value to a foundryman without instructions as to how this amount of blast is to be utilized in melting the ton of iron, nor is the information that eight pounds of iron may be melted in the cupola by one pound of coke, of value without instructions as to how the heat units of this coke is to be developed by the blast and utilized for melting the iron.

The first requisite for the utilizing of all the oxygen of the blast is a bed of fuel in the cupola of sufficient height to extract all the oxygen from the blast before reaching the top of the bed and consume all the carbon in the fuel. Above this point the blast does not contain sufficient oxygen to support combustion, and fuel placed in the bed above this point cannot be consumed or iron melted until the fuel under it is consumed and permits the surplus to settle to a point where there is sufficient oxygen to support combustion and consume it. An excessively high bed is therefore a waste of fuel.

In case the top of the bed is too low, all the oxygen of the blast is not extracted from it, and we have an oxydizing flame above the bed, and there is a waste of iron due to oxydation.

A proper height of bed is, therefore, a very important matter, as is also the maintenance of the bed at a proper height, which must be done by having each charge of fuel of a depth that will restore the bed to its former height, after melting each charge of iron.

The height the top of the bed should be above the top of the tuyeres is a matter that depends upon the volume of blast, and the velocity with which it enters the tuyeres. A very strong blast with the force of a powerful pressure blower behind it passes through the bed fuel very rapidly, and the bed must be of sufficient height to extract from it all of its oxygen before reaching the top of the bed. This accounts for one cupola requiring a higher bed than another.

Not long ago I was called upon to visit a foundry and locate trouble in melting. I found them placing a 38-inch bed above the tuyeres, in a 35-inch cupola. This was entirely too high a bed for a cupola of that diameter, and iron could only have been melted in it, with such a high bed, with double the volume of blast that is required for this size cupola.

The melting ratio of this cupola was only about 4 to 1, and by decreasing the speed of the blower, reducing the bed fuel and also the charge fuel, I was able to bring the melting ratio up to 7 to 1.

The great tendency of foundrymen at the present time is to do fast melting and to attain this object they have increased the speed of their blowers and volume of blast to a point at which there is an extravagant use of fuel and power without attaining the object in view.

The foundryman's best guide for a proper volume of blast and consumption of fuel is the melting of ten pounds of iron to each square inch of melting surface in the melting zone per hour. When he is doing this he is doing the very best melting that can be done in his cupola.

Blast Pressure Gauge

A cupola blast pressure gauge is a U-shaped glass tube, to one leg of which a small rubber tube is attached for connecting it with the blast pipe. The other leg of the tube is graduated to indicate the pressure of blast in ounces. This tube is partially filled with water or mercury, and as the pressure of blast raises this in the graduated leg of the tube, the pressure of blast is indicated in ounces.

The tube is attached to a metal plate or board to hold it in position, and the graduation may be placed on this instead of on the tube as in weather thermometers.

The gauge is generally attached to the blast pipe near the cupola, as this shows more accurately the pressure of blast entering the cupola than at some distance from the cupola. The gauge may be had as a simple U-shaped tube attached to a board which answers every purpose, or placed in a highly polished box with a tight-fitting door to keep it clean.

This gauge is designed to show the pressure of blast being forced into the cupola by a fan or positive pressure blower, and indicates the amount or volume of blast entering the cupola, but it does nothing of the kind; it only shows the resistance to the free passage of blast through the cupola.

When the tuyeres of the cupola are of a proper area for the cupola and blower and there is no stock in the cupola, no pressure whatever can be shown on a pressure gauge, and it is only when a cupola is filled with stock that offers resistance to the free passage of blast through the cupola that any pressure is shown upon the gauge.

A high cupola when fully charged, offers greater resistance to the free passage of blast than a low cupola when fully charged, and the pressure shown on the gauge is higher.

The close packing of stock in charging, in either a high or low cupola, gives a higher pressure on the gauge than open charging, and the bridging over and bunging-up of a cupola shows a higher pressure and also a variable pressure on the gauge as the stock settles unevenly and leaves openings for the free passage of the blast.

It will thus readily be seen that the pressure shown on a blast gauge gives no indication of the volume of blast entering a cupola, and it is the volume of blast that does the melting, and not the high pressure of blast.

In visiting foundries I have found one cupola showing 16 to 18 ounces blast pressure and another of the same diameter showing only 6 to 8 ounces blast pressure, and each cupola doing good melting.

This was due to different conditions, that is, height of cupola, method of charging, kind of iron melted, etc. This shows that the pressure of blast required for one cupola is no indication of the pressure that may be required for another cupola, and a foundryman has no occasion to worry if his pressure gauge does not indicate as high a pressure as his neighbor's.

That a high pressure of blast does not indicate a large volume of blast entering a cupola is shown in Table 2, under the heading of small charges, in comparison with the Clark Blast Meter, in which it is shown that from 300 to 400 cu. ft. more blast entered the cupola per minute when the pressure gauge showed only about five ounces pressure than earlier in the heat, when it showed ten ounces, which indicates the uselessness of a pressure gauge as an indicator of the volume of blast that is entering a cupola.

The pressure gauge is therefore more ornamental than useful as an indicator of the volume of blast entering a cupola, as I have always claimed in my writings on cupola practice.

But a pressure gauge may be made of value by treating it as a guide or indicator of the inside working of the cupola.

A high pressure indicates great resistance to the free passage of the blast through the cupola.

A very low pressure indicates lack of blast or free passage of blast through the cupola, due to a low cupola or very open charges.

A variable pressure on the gauge indicates uneven settling of the stock, poor melting, and final clogging up of the cupola, if kept in blast for a sufficient length of time.

To make the gauge of value, these indications should be carefully noticed and the method of charging varied until the cupola is doing its very best melting that it is capable of doing. The pressure then shown on the gauge in various parts of the heat should be taken as a standard pressure for that part of the heat, and an effort made to maintain it at that standard each heat.

Should the pressure vary from this standard, then the blower should be inspected, to see that the proper volume of blast is being delivered; if so, then the method of charging should be looked into, and also the quality of the fuel, and the method of charging varied to show the standard pressure on the gauge, or establish a new standard. The good melting of the cupola being taken as a guide.

As before stated the oxygen of the blast separates from the nitrogen when it comes in contact with the fire from the coke of the bed, and the nitrogen sinks to the bottom of the cupola and entirely stops combustion under the tuyeres. This same phenomenon occurs when the high pressure shown upon a blast gauge is due to close packing of the stock and choking down of the blast, for the greater part of the blast so choked down is nitrogen, which has a deadening effect upon the fuel, and a hot iron cannot be melted under these conditions.

I have frequently noticed that cupolas melting with a high blast pressure do not make a real hot iron in any part of the heat, and this in many cases is the cause of it. This does not apply to a high cupola filled with stock, but even such cupolas should be charged in a manner that will admit of the blast passing through the stock freely, and escaping from the cupola after its oxygen has been extracted.

Blast Meter.

In my various works on cupola practice I have always endeavored to point out the uselessness of the blast pressure gauge as an indicator of the volume of air entering a cupola when in blast, and claimed it was the volume and not the pressure of blast, that did the melting.

A blast meter has now been invented and placed upon the market by Charles J. Clark, of Chicago, Ill., which measures the volume of blast accurately, when properly adjusted and kept in order.

This meter has shown clearly that my claim that the pressure guage was no indicator of the volume of blast entering the cupola as will be seen by reference to Table 2, in which it is shown that from 300 to 500 more cu. ft. of blast entered the cupola per minute with about five ounces pressure than entered it with a pressure of ten ounces and above, yet the high pressure has always been taken to indicate the larger volume of blast, while it only indicates a greater resistance to the free passage of blast through the cupola.

Many of these meters have been installed in foundries, but I have found in many cases the full benefit of the meter has not been realized owing to lack of knowledge in applying the information gained by the meter.

The purpose of this meter is to indicate the number of cubic feet of blast entering the cupola per minute, a multiple of this number by sixty shows the number of feet per hour. Thus 4500 feet per minute would give 270,000 feet per hour, 30,000 feet per ton of iron shows this to be the proper volume of blast for a cupola melting nine tons per hour, and if the cupola only melts seven tons per hour, then it is receiving 60,000 feet too great a volume of blast per hour.

It will be seen in Table 2, from which these figures are taken, that the blast varied from 4300 feet to 4800 feet per minute, which was sufficient to melt from 8½ to 9½ tons per hour and the cupola only melted about seven tons per hour, with the result that the iron was oxidized in melting, and many castings condemned.

To apply the information gained by this meter, the number of tons melted per hour should be taken as a guide, and if one ton of iron is not melted for every 30,000 feet of blast entering the cupola, then the method of charging should be changed to utilize the excess of blast and melt a ton of iron for every 30,000 cu. ft. of blast. If this cannot be done, then the speed of the blower should be reduced to lessen the volume of blast, for in no case is more than 30,000 cu. ft. of blast to be supplied for each ton of iron melted.

The pressure gauge may be used to advantage in connection with the meter to indicate the inside working of the cupola, and show whether this blast is passing through the cupola freely without doing its work and oxidizing the iron, or is being held down by the stock in the cupola until all the oxygen has been extracted.

Accident to a Blast Pipe

To attend the Boston, Mass., Convention of the American Foundrymen's Association, I left Philadelphia in the afternoon by train, arrived in New York City in time for the Fall River night boat, and arrived at Fall River at 5 o'clock the next morning.

Having some business at the Kilburn & Lincoln Company's foundry, and being desirous of catching the 7.30 express for Boston, I got out early and was at the foundry at 7 A. M., and was very much surprised to find them lighting up for a heat at such an early hour.

I knew it was their practice to cast in the afternoon, and remarked that they must have a rush of business to be lighting up at such an early hour, and was informed that their blast pipe had worn out and been replaced by a new one on Sunday.

The men who put up the pipe had neglected to solder, or otherwise secure the sections of pipe together, and shortly after the blast was put on the previous afternoon the pipe had been blown to pieces in such a way that it could not be put together in time for the blast, and the bottom was dropped.

This cupola could have been held over until the next day by carefully closing the tuyeres with sand to exclude all air from the cupola. But this was probably not known or thought of and the bottom was dropped with the cupola full of stock.

This was an accident due to carelessness on the part of the foundryman in not having a man on hand to instruct the men, who had probably never put up a blast pipe before and knew nothing about the pressure of blast passing through it, as to how the pipe was to be put up and secured in place.

All work done in or about a foundry by men not familiar with foundry practice should be done under the direction of a foundryman or his foreman.

Explosions in Blast Pipes.

When a cupola is in blast, there is a gas created in the cupola by combustion of the fuel, which when heated to the temperature of the cupola is not explosive, but when cooled and again forced into the cupola is highly explosive.

When the blast is taken off the cupola in any part of a heat, this gas may be drawn from the cupola into the blast pipe by a suction towards the blower through an elevated or long blast pipe, and when the gas becomes cooled and forced back into the cupola it is liable to explode and tear the blast pipe to pieces from end to end, and there have been many explosions of this kind.

To prevent such an explosion, the blast gate, if near the cupola, should be pushed in the instant the blast is taken off, or one or more tuyere doors opened nearest to the blast pipe. When one or more tuyeres are opened, this gives draft to the cupola, and the gas passes up the stack.

This gas is also dangerous to inhale. Only a few months ago a part of the lining above the stock fell out of the cupola in a Norristown, Pa., foundry. The blast had only been on a few minutes, and the stock at the charging door had not yet become heated.

The blast was at once taken off, and the melter went into the cupola to repair the lining, and was at once overcome by the gas. His son, who happened to be near at hand, jumped into the cupola to save his father's life, and before they could be gotten out both men were dead.

Explosion of Iron and Slag.

Molten iron may be poured into clear deep water without danger of exploding.

Molten cast iron may be poured into a clean wooden bucket, or a clean cast iron pot, half filled with water, without danger of exploding. But if there happens to be a little mud or clay wash in the bottom of the bucket or pot, or the pot is rusted, an explosion may occur.

At a foundry in Lewisburg, Pa., it was the practice to heat water for washing up in the winter months by pouring a little over iron into water in this way. One evening, when casting, this was done, and a violent explosion occurred that broke every window in the building and almost wrecked the foundry, with probably not more than a pound or two of iron poured into the water. This put a stop to heating water in this way for washing up at this foundry.

The best way to prevent this kind of an explosion occurring is to heat the wash water on a stove and pour over into iron into the pig bed.

Molten iron and slag are liable to explode when dumped from the cupola into mud or water, and it is only when the sand bottom falls out in such a way as to completely cover the mud and water that it does not explode.

At the plant of the Ohio Foundry Co., Steubenville, Ohio, molten iron ran into a tuyere box, to chill this iron and prevent the box being burned through, water was thrown upon it. The excess of water ran down under the cupola and all disappeared in the sand and cinder underneath the cupola but converted it into a mud which was not noticed and no attention given to it.

When the bottom was dropped a violent explosion occurred that blew all the windows out of the foundry, wrecked the scaffold, shook a cloud of black dust from the beams and girders of the foundry that rendered it as dark as night, and created a panic among the men and a number of them were injured in getting out of the building.

At the foundry of North Bros., located near the banks of the Schuylkill river, Philadelphia, Pa., the water of the river was rising very rapidly and threatened to flood the foundry, and the heat was run off in a hurry before the water would get in on the moulding floor, but not before it had seeped into the cupola pit to an extent that converted it into mud.

The bottom was dropped without noticing this and a violent explosion occurred that almost wrecked the building, which resulted in the foundry being removed to higher ground.

To prevent such explosions, remove all water in sight, and shovel in sufficient dry or tempered moulding sand to thoroughly cover the mud and dampness under and around the cupola just before dumping, and knock the prop down from the top in place of drawing it from the bottom.

A wet, rusted or frosted skimmer causes molten iron to explode when suddenly thrust into it. To prevent such an explosion heat the skimmer before using it. I have many scars from an explosion of this kind, due to a skimmer boy placing a skimmer in the snow after I had heated it red hot and plunging it into the iron before he could be prevented from doing so.

Always heat skimmers during the winter months just before using to remove frost or dampness.

An explosion in a mould may occur due to wet sand and molten iron be thrown out of the gate with great violence. To prevent such an explosion see that the moulding sand is of a proper temper, and never set a sponge pot on top of the mould. This may leak or be upset and water run into a gate without being noticed by the moulder.

Molten iron may be exploded and fly in all directions by a wet or rusted tapping bar in tapping.

To prevent this occurring, set all tapping bars on end with the point up, and see that they are not wet or rusted before using.

A wet bod may cause an explosion when the cupola is tapped very soon after stopping in.

To prevent such an explosion and flying iron burning the moulder around the cupola, use the bod as dry as possible.

Molten iron when it falls from the cupola spout upon a hard or damp floor explodes and flies in all directions. To prevent this, cover the floor under and in front of the spout with dry moulding sand. A pile of sand tempered for moulding is frequently used for setting ladles upon under the spout of a cupola and prevent such explosions.

Violent explosions have occurred from iron escaping from a mould through the joint of a flask and falling upon a wet moulding floor or gangway.

To prevent such an explosion see that the flask is properly clamped, remove all water that may have been spilled in the gangway or upon the floor, and cover the dampness of the floor with dry sand or moulding sand.

Explosions In Cupolas.

There have been numerous explosions in cupolas, some of which did considerable damage, while others did very little damage to either the cupola or its surroundings.

Many explosions of this kind occurred in the cupolas of foundries in the Southern and border States after the Civil War, that were due to loaded shells picked up upon battlefields, being sold in scrap iron, and charged into the cupola as solid shot.

I chanced to be upon the scaffold of a Baltimore, Md., foundry when one of these explosions occurred in the cupola, and part of the shell passed out through the open door of the cupola and up through the roof of the scaffold. This did not disturb me very much, for I had been a soldier in this war, and saw many shells explode and dodged the pieces of some of them.

This foundry plant had a cellar under part of it that was half-filled with water, and as a preventive to such an explosion occurring again, all scrap iron having the shape of artillery ammunition, whether solid shot or shell, found in old scrap was thrown into this water, where it probably remains to this day, if not all rusted away.

At a foundry in Erie, Pa., a violent explosion occurred in their cupola that almost wrecked it. There was no strike trouble at this time, and no reason to suspect a bomb had been placed in the cupola, and no apparent cause for such an explosion.

A lot of old small steam cylinders were being remelted at the time, and it was supposed that the ports of some of the steam chests in these had been closed by rust when the steam chest was filled with water, for which there was no escape, and when heated, steam generated from it and caused the explosion. This was the only explanation ever given for the cause of this explosion.

To prevent such an explosion occurring, all scrap that might contain water locked in should be broken at the point where water might possibly be found before placing it in the cupola, and cylinders are not the only castings in which water may become rusted in.

At a foundry in Buffalo, N. Y., a very violent explosion took place in a sixty-inch cupola seven minutes after the blast was put on for the heat. This explosion must have occurred near the bottom of the cupola, for the front was blown out, the heavy cast iron bottom doors broken, and the iron doors in front of each tuyere blown off, and a number of men were severely burned, but none was killed or died from his burns.

The bottom of the cupola was so completely wrecked that it had to be dropped at once, and could not again be put into blast until extensive repairs were made. Many theories for the cause of this explosion were advanced, but none of them was ever proven to be the cause. One theory was that gas had formed in the cupola and had been exploded by the oxygen of the blast combining with the carbon of the fuel, and creating an intense heat, that exploded this gas. This could hardly have been the case, for the cupola had been in use for a number of years, and charged in the same way, and no explosion had occurred.

Another theory was that of water confined in some piece of scrap, which possibly might have exploded, but the explosion was rather violent for this cause.

Another theory was that a high explosive had been placed in the cupola. This might readily have been caused, unintentionally, by a bomb thrown away by an anarchist being picked up and sold as scrap iron, and charged into the cupola without being detected by the melter.

In these times of anarchists and bombs, all old scrap should be carefully inspected before placing it in the cupola for melting.

Protecting a Melter.

When chipping out a cupola, in making it up for a heat, slag and cinder adhering to the lining is frequently so difficult to remove that a sledge or heavy hammer is required to break it down, and such heavy blows are sometimes required that the lining is jarred from the bottom of the cupola to the top of the stack.

The lining below the door becomes glazed and solidified, so that there is little danger of it falling out, but from above the door to the top of the stack there is no glazing of the lining, but a gradual building out by adhering oxide of iron and sulphur, which gives to the stack lining a rough, shaggy appearance.

Very little attention is paid to a stack lining after it is once put in, and it may not be examined for years. The adhering matter may fall off and the lining may become shaky, and part of it fall out. Melters have been killed or injured when chipping out by such material falling from the stack.

The danger to a melter of being injured or killed in this way may be greatly reduced by covering the cupola at the charging door. This may be done very effectively, at little expense, by placing a stout board or plank, the width of the door, in the cupola at the charging door, with hinged circular wings on each side, to be let down to cover the entire inside diameter of the cupola. The end of this board should be rounded off to fit the diameter of the cupola, and may be supported upon a projecting lining at this point, or by using a board eight or ten feet long it may be supported by a few pieces of pig placed upon the outer end of the board.

This device may also be made of boiler plate and supported in place in various ways, but the board construction is more commonly used, as it is lighter, and more quickly adjusted, and when not in use, may be set on end against the wall, and takes up very little room.

Foundry Devices

CHAPTER XI.

Foundry Tram-rail.

As a means of foundry transportation, the tram-rail system has been installed in many foundries for the removal of castings, gates, scrap, over iron, flasks, etc., and the bringing in of flasks, sand and other supplies, and also for the carrying of molten iron from the cupola to the moulders and floors for distribution by small bull and hand ladles in pouring.

As a means of carrying molten iron to a distance from a cupola it has proven more rapid and satisfactory than the rail and truck upon which the ladle is set, or truck-ladle system. For, with the tram-rail, there is no jarring of the ladles and spilling of iron by little obstructions on the track, and ladles can be filled fuller, without danger of spilling the molten iron.

For hand ladle work, separate hanger may be placed upon the rail, and a hand ladle of iron taken to a floor as fast as the moulder chooses to run, without having the ladle to carry, or spilling iron or, as it is frequently called, feeding the chickens as moulders frequently do at each step when carrying a full ladle.

This system has the advantage of getting the iron to the mould more quickly than by carrying it, and having hotter iron for the pouring of light castings, which saves many castings that are lost by dull iron.

Hotter iron may also be delivered to the hand ladle floors by this system, in large ladles, by constructing a long or deep ladle in place of a flat, shallow ladle, which exposes a large surface of iron to the atmosphere.

Holding Iron When Changing Ladles.

In running a continuous stream from a cupola, it is necessary to have some means of catching the stream as soon as the ladle is filled. This may readily be done by catching with hand ladles and small bull ladles, but cannot be done with large ladles, and some device must be used to catch the stream while the ladles are being changed.

One of the most practical devices now in use is the spout ladle. This is an ordinary shank ladle, constructed with a spout on the side on the level with the bottom of the ladle, no front or tap hole is put in, but a large opening is left for the iron to flow out at the spout into the carrying ladle.

This is placed under the spout and supported on trestles or swinging brackets, and when not in use for holding iron forms a continuation of the cupola spout, as the molten iron flows intc it, runs out at the ladle spout as fast as it falls into the ladle from the cupola spout.

When used for holding iron, the ladle is tipped back until the ladle spout is on a level with the top of the ladle upon the opposite side, when it may be filled with iron to this extent for holding and changing ladles, and when the ladle to be filled is in place, the spout ladle is tipped forward, and the large opening in it at the spout admits of the iron being dumped into the ladle to be filled at once, and the stream runs through the holding ladle filling the carrying ladle to the point desired.

These ladles, of any desired holding capacity, may be obtained from foundry supply houses, and the only requisite for their use is the placing of a cupola at a sufficient height above the floor to admit of the carrying ladle being placed under them.

Another device used for holding iron while changing ladle is the basin drop spout. This spout is made in two sections, the basin section is placed under a short cupola spout, and receives the iron from the cupola. It is hinged at the front, and the back part arranged with a lever for raising and lowering it. When in place it forms a continuation of the cupola spout, and when let down forms a basin for holding the iron while ladles are being changed, and when raised into place throws the iron out into the ladle very rapidly.

The objection to this system is that the holding capacity of the basin is very limited, and it cannot be used for a large stream or a long wait for a ladle.

Another plan that is sometimes used for tram-rail ladles, when the ladle to be filled is at hand, is to place a very light bod of moulding sand on the bod stick, and hold the bod in place with the stick while the ladles are being changed. When the ladle is in place, the bod stick is removed and the iron forces the bod out. No tapping is necessary.

The combination iron and wood bod stick should be used for this purpose, as the heat of the spout burns away the wood stick very rapidly.

For filling large truck ladles with a continuous stream, the cross spout is most commonly used. This is a spout attached to the end of the cupola spout with a swivel, that it may be tipped to throw the iron into a ladle placed on either side of the spout. When one ladle is filled, the spout is tipped to throw the iron into the other.

This spout is made of any length required to reach the ladle, and I have seen them in use varying in length from twenty inches to four feet.

Hot Iron.

There are many grades and qualities of cast iron, due to the per cent. of combined and graphite carbon they contain, and also due to the various metalloids they may contain, which gives to them various melting points.

There is a still wider variation in the melting point of steel, malleable iron and wrought iron, and in a promiscuous lot of cast scrap all these metals may be found.

Mixtures are generally made of different grades of pig, with more or less old scrap. In the melting of such a mixture the temperature of the melting furnace must be sufficiently high to melt to fluidity the metal having the highest melting point, and if this is not done, then this metal cannot mix with the other metal drop by drop, as it works its way through the bed to the bottom of the cupola, to form a homogeneous metal of the mixture.

Metals having almost the same melting point, but of a different composition, do not mix well with each other when only melted to a molten state, and to make a thorough mixture of iron of different grades and composition they must be melted not only to a molten state, but to a very fluid state.

Many foundries do not seem to know what a hot molten iron really is, and never melt what would be termed a hot iron in foundries making exclusively light castings, and this, in many cases, is the cause of uneven, spotted and dirty iron so frequently complained of in castings.

Iron, melted from a mixture of iron, should always be melted hot and at a white heat when drawn from the cupola to insure a homogeneous iron in casting, and should be poured hot to insure clean castings.

A mould should always be made to suit the iron and the iron not melted dull or chilled down to suit the mould. If the moulding sand or facing will not stand hot iron, get a sand and facing that will stand it, and melt and pour iron hot. This gives sounder castings than iron poured dull.

The great objection made by many foundrymen to pouring iron hot is shrinkage of the iron in cooling. It is generally considered that iron poured hot shrinks to a greater extent than iron poured dull.

On the other hand, it is claimed that a hotter iron has greater fluidity and hence more time to adjust its molecules to conditions before solidifying and draws more iron from a riser or sinkhead while hot, and the shrinkage in a casting is no greater when poured with hot iron than when poured with dull iron, and the casting is more solid and free from shrink holes.

Both these theories have been proven to be correct, and the one to be adopted probably depends upon the thickness of section and shape of castings, and is a matter to be determined by each founder for various castings. But when a sharp, clean, even, sound casting is desired, melt the iron hot and pour it hot.

The foregoing suggestions are designed for grey iron sand casting and do not apply to all iron or methods of casting. For a stove plate, hot iron does not give the deepest chill and best results in chilled castings, and there are certain grades of iron that, when melted only with their remelt, do not require to be melted extremely hot to effect a thorough mixture.

These irons are principally irons designed for chilled castings, such irons have a temperature and appearance of their own, familiar to founders casting these lines of castings, that give the best results, both in life of chill and depth of chilling.

There are also certain lines of castings, such as heavy sand cast rolls, and heavy, chunky pieces, that do not require extremely hot iron. But sounder castings are made with hottest iron that can be poured for the line of castings, whether heavy or light.

Devices for Charging Cupolas.

To save labor, in charging a cupola, which has always been done by hand, and obtain more rapid charging of large and rapid melting cupolas, many devices have been designed and installed for doing this work at a less cost and more rapidly.

Among these devices that I have seen was one at the foundry of the Norfolk & Western R. R., Roanoke, Va., which I saw in use a few years ago for the melting of car wheels and other iron.

This device consisted of an endless chain incline-plane elevator, upon which the pig and scrap was placed and dropped upon a steep inclined steel chute, from which it slid down into the cupola, and the coke was taken up in barrows on an elevator and shoveled into the cupola.

The objectionable feature of this device was that it dropped the iron all in one place or pile in the cupola. To overcome this objectionable feature, the cupola was charged to the door by hand, and a man stationed at the charging door with a long hook to scatter and place the pig and scrap as it was dropped into the cupola. This device was reported to give very satisfactory results in melting for their line of castings, the iron for which was tapped into large ladles, and carried to the floor by cranes, where it was transferred to the pouring ladles, which effected a thorough mixing of the iron and also gave to the iron an even temperature, which was not required to be very high for their line of castings.

At the Carnegie Steel Works, Homestead, Pa., the stacks for their cupolas were supported by short cast iron columns placed upon the top of the cupola. This gave a charging opening all around the cupola, and the stock, both fuel and iron, was brought up in front-dumping, two-wheeled barrows and dumped directly into the cupola.

The iron for their converters was not required to be very hot, and this method of charging appeared to be perfectly satisfactory for their melting. None of the iron I saw melted was sufficiently hot and fluid for foundry castings, but this objectionable feature might have been overcome to some extent by the use of a larger per cent. of fuel.

There are in use at the present time in a number of large foundries a system of track-dumping cars, upon which the pig and scrap is loaded in desired proportions and dumped directly into the cupola through a large charging opening placed low, near the scaffold floor, and the melting fuel is dumped into the cupola in the same way.

In foundries where this system is used the castings are generally, or principally, heavy ones, and the iron is tapped into large ladles and not required to be extremely hot.

In England a system of placing the charges of fuel and iron in a cupola from the top, in place of through a charging door, has been tried and said to have proven a success.

By this system a two-railed track is placed over the cupola and a round car of the diameter of the cupola constructed, with drop-bottom doors the same as the cupola bottom. The charge of iron is placed in this car in the yard. A desired mixture of pig and scrap and arranged as it would be in charging by hand. The car is then elevated to the track, and run over the cupola, and the doors dropped and the charge falls into the cupola in the same, or very nearly the same, position as placed into the car, and the fuel is charged in the same way.

This system should, and no doubt does, do even melting, and gives more satisfactory results than any of the systems before described. but it can only be used when the cupola is placed outside of the foundry, and in a neighborhood where a low cupola and sparks are not at all objectionable.

It does not appear to me that any great saving in labor would be effected by this system, for a man would have to be kept at the top of the cupola, or sent up with each car to dump it, and put up the doors for the next charge, and probably the same number of men would be required in the yard for loading and arranging the charges as would be required for charging on the scaffold.

A great objection to all the systems of charging yet devised, other than by hand, is that they do not distribute the charges of fuel and iron evenly, which results in the iron not melting of an even temperature throughout the heat, and an even mixture of iron is not effected.

For this reason the only foundries in which they have claimed to be a success have been in foundries in which the iron is handled in large ladles, and not required to be very hot for pouring, and even in these foundries I have never learned that any of them were kept in use for any great length of time.

Getting Up Cupola Stock.

The term getting up cupola stock means the placing of fuel and iron upon the cupola scaffold convenient for charging into the cupola, and the elevating of it to the scaffold.

In the days of low cupolas and small heats, the practice was to construct one or more platforms upon which the stock was placed by hand, and when the first platform was filled, the cupola man got upon it and lifted or threw it upon the next platform or scaffold.

When the cupola was low and heats light, the scaffold was sometimes placed as low as four or five feet below the charging door, and no platforms were used. The stock was thrown upon the scaffold, and from this was thrown into the cupola. I visited a small foundry at Bethlehem, Pa., not long ago, where this was the practice, and some of the double platforms are still in use in small foundries in the New England and Southern states, but this practice is too slow and laborious and has generally been abandoned and more modern methods of getting up cupola stock adopted.

The Wheelbarrow System.

With the enlargement of foundries and heavier heats, the platform system of getting up stock was entirely too slow and laborious and some other means had to be devised for placing stock upon the scaffold, and an incline runway upon which the stock could be taken up in wheelbarrows was designed.

This runway was constructed of a length to give easy wheeling, and when there was not sufficient room for this in one direction, it was run up half-way, and a turn made for the other half, and the lower end of the runway always placed near the stock to be taken up, to give a short wheel.

This system is still in use at many small foundries, and is a very satisfactory system for plants at which a better one cannot be installed for lack of capital, or room for constructing.

Track Runways.

This is an incline runway upon which rails are laid for the car, in place of a wheelbarrow, for carrying the stock, and the car drawn up by a cable or chain.

This was a great improvement on the wheelbarrow system, and admitted of the placing of stock upon the scaffold more rapidly, and also more convenient for charging, at a less cost for labor.

This system admits of tracks being laid in the yard and the mixture of irons being made in the yard by moving the car from one pile to another and placing the desired number of pigs from each pile desired in the mixture upon the car, and when a sufficient number of cars are provided, they may be unloaded directly into the cupola and the labor of a second handling of the iron saved.

The cars or trucks are generally constructed entirely of iron or steel to carry a ton of pig iron, and platform cars are provided for coke or scrap. The cars are generally pushed to the incline by hand, but may be drawn by a horse, if the yard is large, or there is a grade in the yard.

This is a very good way of getting up stock, when properly designed and constructed, but a very poor way when not well designed and constructed, and as liable to be out of working order when most urgently needed as in good working order.

The Elevator.

Elevators for direct lift of cupola stock to the scaffold have been used for many years. Long before the steam and hydraulic elevators were perfected and installed for lifting stock to the cupola scaffold, a platform elevator upon which a barrow could be placed was worked by hand or horse power, as was also ropes with loops or hooks for attaching direct to the barrow and lifting it with its load.

This plan was generally adopted by foundries not having sufficient yard room for a runway, and was quite satisfactory for small cupolas and light heats.

Since the perfection of the steam and hydraulic elevators these elevators have almost replaced all of the methods of getting up cupola stock just described, and it is only in very small foundries, and those of limited capital, that any of these methods are used, and they are described for the benefit of such foundry plants.

The modern elevator as a cupola stock lifter has the following advantages over other systems: It takes up less room than a runway; may be placed at the most convenient point for loading or unloading stock; lifts stock to the cupola more rapidly than it may be taken up on a runway; saves labor and time, and may be used with barrows or car and yard-track system, and in many small foundry plants the elevator is so placed that it may be used for cupola stock lifting in connection with other elevator work of the plant.

One of the greatest advantages of the elevator over the runway system is the rapidity with which stock may be lifted to the scaffold, and time and labor saved. One foundryman I met, who had just put in a new rapid-lifting elevator and was very enthusiastic over its rapid work, stated that with it he was placing his iron on the scaffold at a cost of 3½ cents per ton of iron. I did not know the foundryman's first name, but on the impulse of the moment remarked to him, you will have to come up a little on that, Bill, that's a little low for the handling of a ton of iron, but he insisted that it was the correct figure.

There are a variety of elevators upon the market, all of which are recommended for the lifting of any and everything, but very few of them are suitable for elevating cupola stock, in which case, the elevator is generally run by the workmen, who are not expert elevator operators, and frequently overload their barrows, and place the load on one side of the elevator platform, and by a sudden throwing on of the full power put the elevator out of order.

An elevator for this work must be a strong, simple, rapid-working machine, and there are a number of this type designed especially for this kind of work and workmen. One of the best of them that I have seen in operation is that made by the Craig Ridgway & Son Co., Coatesville, Pa. The following description of which is given by them in their advertising matter:

The Steam Hydraulic Elevator.

Goes by steam or compressed air, steam always to be preferred. No machine ever introduced has met with such favor as this elevator. Hundreds are being placed in the best establishments all over the land. It is the most perfect of hydraulic elevators without the use of a pump, by simply running a steam pipe to the nearest boiler. These elevators are rapid, and do their work while other elevators are getting started. How perfect the motion is can be judged by the fact that we use the same system in foundry cranes for hauling great ladles of molten iron and steel where the least irregularity of action would mean death to men and destruction to property. One of the most remarkable features of this elevator is the fact that it never gets out of order. Nothing puts it out of service but the boiler blowing up. When the boiler "lets go," no other elevator will be required.

The Double Geared.

In this style all machinery is above ground. The frame is easily and cheaply made of wood by any carpenter, or, if desired, will be furnished by us. The cage has safety catches, but the best safety is the two or three separate lifting ropes. Everything is made heavy and substantial to stand hard service and bad usage. Hundreds of this type are in daily service.

The Direct Acting.

In this style a well is required. This is dug in the old-fashioned manner by the local welldigger and walled up dry. When the water cylinder is placed upon the upper floor the head of water counterbalances ram and platform. The water cylinders can be placed anywhere. This elevator is simple and easy of erection, and great numbers of them are in daily operation all over the land.

Lifting Magnates.

The most rapid means of placing iron, both pig and scrap, upon the cupola scaffold is by use of the lifting magnet.

This magnet is a disk or flat circular iron plate, generally about three feet in diameter, to which an electric magnetic current is connected, which gives it power to attract and hold iron, steel and other metals. This disk is hooked onto a traveling or swinging crane, and when placed upon a pile of pig or scrap, with the magnetic current turned on, attaches itself to every piece of pig or scrap iron that comes in contact with it so firmly that the iron may be lifted and carried to any distance desired by crane or other device, and when over the place desired to deposit it, it is only necessary to shut off the current, which releases the iron from the lifting magnet, and it falls from it into the place desired, and the magnet may be returned to the pig or scrap pile for another load or lift.

These lifting magnets are manufactured of various sizes by a number of lifting magnet manufacturers, and are extensively used by large foundry plants for unloading of pig and scrap from cars, loading cars, placing iron on scaffold, etc.

As a means of placing iron on a cupola scaffold, it is the most rapid and economical method yet devised. The superintendent of the foundry of the Niles Tools Works Company, Hamilton, Ohio, reports his cost for labor in placing iron upon the scaffold by this means to be only 1¼ cents per ton of iron for labor. This estimate is no doubt correct, for the only labor cost to be considered was the wages of one man, the crane and magnet operator.

Some of the modern foundry plants have arranged their electric magnet to place the iron on the scaffold right at the cupola convenient for charging, while others have constructed platforms on a level with the scaffold, just outside of the foundry, upon which the iron is placed by the magnet, and conveyed to the cupola door for charging upon cars run on steel rails. This makes a short run for the car, and reduces the number of men required in charging.

By the construction of a large platform on a level with the scaffold and the use of the lifting magnet, cars of pig and scrap may be unloaded directly upon the platform, placing it up out of the mud of the yard in wet weather, and save time and labor in getting it to the elevator or other means of lifting it to the scaffold. Also in waiting for such means of lifting it to the scaffold and less men are required for getting up iron.

This plan may readily be adopted at foundries located near the side of a hill or elevated ground and the stock yard placed upon a level with the cupola scaffold and by the use of the magnet and grab bucket, both iron and coke may be placed convenient for use, and labor in handling saved.

Elevated Stock Yard.

The elevated stock yard plan has been adopted by the Brown & Sharpe Mfg. Co., Providence, R. I.

This foundry is located alongside of a sand hill, and to hold up the sand of the hill a series of stone bins, with arched roofs, were constructed for storing moulding and core sand with openings in the top for dumping in the sand. These bins are only a few feet from the foundry, which makes them very convenient for getting in sand, and the arched roofs are sufficiently strong for carrying pig and scrap iron, and the iron yard is located upon them and the adjoining side of the hill, on a level with the cupola scaffold. The coke storage building is placed on the same level.

The stockyard and cupola scaffold are connected by a narrow gauge steel rail track, arranged to run to every part of the yard, and directly in front of the cupola charging door. A sufficient number of cars are provided for unloading both iron and coke directly into the cupola when charging, thus saving labor in the piling and carrying of both coke and iron to the cupola, and reducing the number of men required for getting up stock and charges.

This system could be installed in many foundries at very little cost and a great saving effected in labor, machinery and power for getting up cupola stock.

Banking a Cupola.

Banking a cupola is a term used to indicate the shutting off of draught from a cupola after it has been lighted up, the bed burned through, and the cupola fully or partly charged for a heat with fuel and iron.

The object in banking a cupola is to prevent the burning out of a bed, and other fuel in the cupola, in case of delay in putting on of the blast at the regular time, due to accidents, or other causes, which may delay putting on the blast for a number of hours.

The banking is done by filling the tuyeres with sand and ramming it in solid to prevent any air entering the tuyeres, and putting in the front, leaving only a small taphole open to admit sufficient air to prevent a formation and accumulation of gas in the cupola or the fire going out.

My first observation of the banking of the cupola was at the foundry of William McGilvery, Sharon, Pa., where I was employed as a moulder in 1870. The foreman was William Ainsworth, who later on became the discoverer and introducer of our present steel casting process.

A dry sand roll had been moulded in sections, placed on a car and placed in the oven and dried and the car drawn out to cool off the mould for putting together. As the putting together and clamping it required but a short time, the cupola was made ready for the heat and the roll iron charged.

In taking the mould from the car it was thoughtlessly all removed from one end of the car first, leaving all the load on the other end. This caused the car to tip up, and the mould fell upon the floor, completely destroying part of it. It could not be cast until the destroyed section had been made over and baked. This required baking over night, and the roll could not be cast that day. The iron charged for it was not suitable for other work to be cast, and the question at once arose, what was to be done with the cupola? Could it be held over until next day, or would it have to be dumped?

The blast had not been put on, and the bed was in good condition for melting, and if it could be kept in that condition until the next day the heat could be run off and the roll cast with the iron already charged in the cupola for it, and it was decided to pack the tuyeres with sand, to exclude all air for combustion of the bed and put in the front, with only a very small taphole to admit sufficient air to prevent the fire going out.

This was done, and the cupola held over for twenty-four hours. When the sand was all carefully removed from the tuyeres, fire and coke was found in good condition for melting, and a front was put in with a proper-sized taphole for the size of stream of iron, the blast put on, and the heat melted as successfully as if it had been melted the previous day.

Banking Another Cupola.

The following statement of banking a cupola was prepared by the late John C. Knoeppel, foundry superintendent, of the Buffalo Forge Co., Buffalo, N. Y., and appeared in "*The American Machinist,*" December 10, 1891.:

"In the latter part of October, 1891, just as we were about to put on the blast in our foundry cupola and the fan making a few revolutions, the main pulley broke, running the main shaft to the fan or blower of our cupola. After considerable trouble, loss of time and delay in trying to get a new pulley, which was of wood pattern, we finally succeeded in getting one of the proper size, and had it put on the shaft; but the belt being a little tight, and also anxious to get off the heat, in slipping the belt on the pulley, it was cut in such a shape that it became useless for that day. By this time it was beyond our regular hour for quitting. At first there seemed no way out of the dilemma but to drop the bottom. The thought of re-handling the hot material and fuel, the extra labor attached therewith, suggested the idea of holding up the charges until next morning, when repairs would be completed. After a few moments' consultation, proceeded as follows: Let me say first that the cupola was lighted at 1.45 p. m. and at 6 p. m. began the operation of banking the cupola, having had four hours and fifteen minutes' time for burning the stock, and being charged with eleven tons of metal. The cupola was of the Colliau type 60″ shell lined to 44″ at bottom and 48″ at melting zone, having six lower tuyeres, 7″x9″, upper tuyeres being closed. Height of tuyeres from bottom when made up 18″, blast pressure 10 oz., revolutions of blower about 2100, manufactured by the Buffalo Forge Co., and known as No. 10, the adjustable bed type. The cupola bed was made up of 600 lbs. Lehigh lump coal and 800 lbs. Connellsville coke, the succeeding charges 50 lbs. of coal and 150 lbs. coke, coal being an important factor in this heat on account of its lasting qualities. We first cleaned and cleared all of the tuyeres, packed each one with new coke, and then filled and rammed them tight with floor moulding sand to prevent any draft getting through them, and had the top of charges covered with fine coal and coke dust, and tightened that also to stop the draft in that direction. The object in using coal dust was this: Should any get through into the charges, it would not cause much trouble. After all was completed, gave orders to the cupola men to be on hand at 6 a. m. next morning, clean out the tuyeres and top of cupola, and ordered the men to be ready for pouring off at 7 a. m. The next morning all were on time. I had the tuyeres poked with bars, so that the blast might have easy access to center of cupola, and started the blast at 7.15, bottom being dropped at 8.45; total time from time of lighting cupola until bottom dropped was nineteen hours. At first the iron was long in coming down and first 500 lbs. somewhat dull, but made provision for that and put it into dies, which turned out to be very good. The balance of the heat was hot enough for any kind of casting—our line being light and heavy—and had to be planed, bored and otherwise finished with some stove repair casting in with this heat engine casting, cylinder and a class of work that requires fluid metal. I am confident that if this method is carefully followed, it can be done at all times, but would not advise it in small cupolas, less than 36 inches inside measurement; and should the melt be in progress, it could not be successfully done at all. Should I be placed in a similar position, would resort to the same means with more confidence and certainty of success.

"Yours respectfully,

"JOHN C. KNOEPPEL,

"Foundry Supt. Buffalo Forge Co., Buffalo, N. Y."

Shutting Off Blast During a Heat.

Various accidents, such as the breaking down of machinery, breaking of belts, cupola stock elevator getting out of order, etc., may make it necessary to shut off the blast after it has been on, and the cupola melting at its full capacity, and the question naturally arises, how long can the blast be shut off from a cupola and melting resumed?

The instant the blast is taken off, one or more tuyere doors should be opened, to prevent an accumulation of gas in the blast pipe, and this is the practice that should be followed in all cases when the blast is taken off during a heat.

The length of time the blast may be shut off, and melting resumed, depends upon the length of time the cupola has been in blast, and the condition the cupola is in at the time the blast is taken off.

If the cupola has only been in blast for a short time, and melting just begun when the blast is shut off, all melted iron in the cupola should be drawn off at once and the taphole left open, to admit of any molten iron that may be melted flowing out, and prevent it becoming chilled at or in the taphole.

If the blast is only to be off for a few minutes, this is all that is necessary to be done, but if the stoppage is due to a breakdown and the blast is to be off for a number of hours, while repairs are being made, the tuyeres should at once be packed with sand, to shut off all draft to the cupola, and prevent further melting, which would be slow and only produce dull iron to clog up the bottom of the cupola and taphole. If the tuyeres are packed promptly, the cupola may be held over for twenty-four hours, and good melting done when the blast is again put on.

Before packing the tuyeres, each tuyere should be inspected and if the coke is found to be well back in the cupola, fresh coke should be packed in front of the tuyere to prevent the sand being rammed back into the bed coke, and facilitate its removal when the blast is put on. The fresh coke may then also be removed if deemed necessary.

When the tuyeres of a cupola have been closed in this way for a number of hours, they should be left open for a short time, to permit air to be drawn in by the draft of the cupola stack, and remove any gas that may have accumulated in the cupola before putting on the blast. This removes all danger of an explosion from such gas being made explosive by a rapid combination of the oxygen of the blast with it.

The blast may then be put on and the heat melted as successfully as if the blast had not been taken off. One time I had occasion to test this method in a fifty-inch cupola with a Root Positive Pressure Blower.

In this case the blast had been on for half an hour, and the cupola was melting freely when a pulley broke and the blower was stopped. The manager stated that he could have the pulley replaced in two hours, and as the cupola was filled with stock to the charging door and it would be quite a loss to dump it, take the stock upon the scaffold again and recharge, I decided to try and hold the cupola until repairs were made.

I at once had all the metal drawn off and all the tuyeres packed with sand to exclude air, and although nearly four hours were required to replace the broken pulley, the tuyere, when the sand was removed, was found to be bright and hot, and when the blast was put on, iron began to melt in about the same time as a cupola begins to melt when the blast is first put on, and soon began to melt hot iron, and the heat was run off as quickly as if the blast had not been taken off.

If I had had a little more experience along this line at that time I would have held this cupola over until the next morning, and I have not the least doubt but that the heat could have been successfully melted. But the only thing that would have been saved by doing so would have been the grumbling of the moulders at being kept late, and the next day's heat would have been lost.

When the blast is put on a cupola it finds openings through between the pieces of coke, through which it escapes, or passes up through the stock, these openings are kept open by the blast in a properly charged cupola throughout the heat, and also forces openings through fluid slag in a cupola for its passage.

When the blast is taken off during a heat these openings close up to a greater or less extent, and those in contact with fluid slag when the blast is taken off, become filled with slag, which becomes solid or thick and tough if the blast is off for any great length of time, and when the blast is put on again the melting may be very slow and very unsatisfactory.

I have known the blast to be taken off of a large cupola with a forced blast, for three or four hours, and good melting done when the blast was again put on, when the tuyeres have been securely packed with sand during the stoppage, but have never known this to be done with a small cupola or a fan blast.

I have learned of a number of cases where the blast was taken off near the end of a heat and the tuyeres packed, in which it proved a complete failure, and no melting could be done, due to the openings, through which the blast passed up through the stock, having been completely closed.

A cupola at this stage of a heat is more or less bridged out, and clogged up, and slag generally thick and tough, and when the blast is taken off soon becomes so clogged with tough slag that a blast cannot be forced through it, and it will be found better to drop the bottom at once than to attempt to hold it over for any great length of time, or even a short time, as a cupola should always be dumped as quickly as possible after the blast is taken off at the end of a heat.

What Can Be Melted in a Cupola

CHAPTER XII.

The cupola was modeled after the blast furnace, and originally designed for melting pig iron to be recast in desired shapes and forms for use as cast, or in the manufacture of various machinery or useful articles.

But it was soon found to be one of the most economical and rapid melting furnaces ever designed, and any metal or piece of metal that could be placed in it could be melted, and it was soon adopted not only for the melting of most all the useful metals that are cast, but also for the smelting of metals from their ores, and is still used for these various purposes. Its principal use is for the melting of foundry irons.

In the melting of foundry irons the cupola melts the iron more rapidly and with less fuel than it can be melted in any other furnace ever designed, and melts iron with as little or less change in the composition of the iron than any other furnace, when properly managed. But, like every other melting furnace, it is the poorest of melting furnaces when not properly constructed and managed.

There are few cupolas in use at the present time that are not properly constructed, and it is therefore only a question of management to obtain the best of results in melting any of the foundry irons in a cupola, and the management of the cupola is a matter that should be carefully studied, by every founder, foreman and melter.

It is claimed that in cupola melting the iron is melted in direct contact with the melting fuel, and takes up impurities from the fuel, and its quality is deteriorated by the impurities so absorbed.

This claim is a very old one, and many times has the reverberatory furnace, which is the principal rival of the cupola, replaced the cupola and the cupola replaced the furnace. Seth Boyden, the first manufacturer of malleable iron in this country, in 1826 melted his iron in the cupola and replaced it with the reverberatory furnace, and after a short use of this furnace went back to the cupola as his melting furnace.

I have melted iron in both of these furnaces and found, like Mr. Boyden, that as good an iron may be obtained from the cupola, with a good fuel and proper management, at a much less cost for melting, as from a reverberatory furnace, and that good iron for grey iron castings, malleable iron, chilled rolls, or any other line of castings, cannot be obtained from either furnace without good fuel and proper management. As much care has to be taken in getting a good fuel for a reverberatory furnace as for a cupola, to get a satisfactory iron.

Melting Iron.

In the melting of iron in a cupola the important point to be noted in getting the same or as good a quality of iron out of a cupola as placed in it for melting is a proper height for bed, to place the iron in the melting zone, and a proper weight of charges of fuel and iron, to maintain it there throughout the heat.

The only guide for this is the melting of iron of an even temperature and a stream of equal size throughout the heat. A variation in temperature of the iron indicates a deficiency of fuel at the points in the charging where the iron becomes dull. A slowing up of the melting indicates an excessive fuel at the point in the charging where the dullness occurs, and the charges should be varied to melt an iron of an even temperature and size stream throughout the heat.

When this is done almost the same quality of iron may be drawn from the cupola as is placed in it to be melted, and it is only in case of uneven melting that there is any marked deterioration in the iron.

To do even melting in a cupola the blast must be of a proper volume for the diameter of cupola, and the volume of blast can only be determined by the number of revolutions of a positive pressure blower or a blast meter that accurately measures the number of cubic feet of blast entering the cupola. For the blast pressure gauge only indicates the resistance to the free passage of blast through the cupola, and gives no indication of the volume of blast entering or passing through the cupola.

Another point in even melting is the shape of the lining. If there are projections and sudden offsets from the lining, the stock cannot settle evenly, and the charges are upset, and disarranged, which admits of the blast passing through them in such a way that the full heat of the fuel is not utilized in melting.

The bridging and bunging up of the cupola is more frequently due to this cause than any other.

Melting Steel and Malleable Scrap.

All the various steel, malleable iron and wrought iron scraps, of any kind or shape, that can be gotten into a cupola can and have been melted in cupolas.

This kind of scrap is very low in carbon, and in melting takes up carbon from the melting fuel to an extent that brings it back to a very hard cast iron which, if not melted very hot and poured quickly, sets in the ladle and cannot be poured.

In the melting of this scrap a higher per cent. of fuel is required than in the melting of cast iron, and from three to four to one is the best that can be done and get a metal sufficiently hot for pouring.

The metal obtained from this scrap is extremely hard and brittle and only fit for sash, elevator and other balance weights.

When this scrap is melted with cast iron its melting point is lowered, and it takes up carbon more freely than when melted alone, and a soft, strong metal is obtained from it. The per cent. of fuel required in melting it is lowered to an extent, depending upon the per cent. of this scrap melted and the per cent. of silicon the cast iron may contain.

In the making of semi-steel, containing from 10 to 20 per cent. steel scrap, no more fuel is required in melting this mixture than is required to melt the cast iron alone, and the metal produced is far superior to cast iron.

In the melting of this scrap for weights, its strength and softness may be greatly improved by melting it with a liberal per cent. of 5 per cent. Silicon pig, and fuel saved.

Melting Tin Cans and Tin Scrap.

In almost every large city there are sash weight foundries which melt almost exclusively tin plate and scrap and old tin cans which are very abundant and too light and bulky for shipment by rail elsewhere and can be purchased very cheaply. There are also large tin can factories which make a large amount of scrap in cutting tin plate to make cans.

Tin plate, which is a soft steel, rolled very tin and coated by dipping into molten tin, melts very readily in a cupola. Like other steel scrap, it has to be melted very hot to prevent it adhering to the sides of the ladle and freezing in the ladle.

The tin clippings were, for a long time, formed into balls for charging in the cupola by placing them in a half barrel or tub and pounding into a solid mass. This practice has generally been abandoned, and the charging door made large and the bottom of it placed on the level, or a little below, the scaffold floor, and the scrap dumped in from barrows, or forked into the cupola.

In charging this scrap the same practice is followed as in charging iron, that is, the fuel and scrap are placed in charges and the melting ratio is from three to four pounds of scrap to each pound of fuel.

These cans and clippings should only be melted when new and bright for, if badly rusted, very little if any iron is obtained from them. The same is the case with old stove pipe and other light steel plate scrap when rusted or otherwise corroded.

There is in Philadelphia a chemical plant that makes a business of recovering tin from tin-plate scrap and selling the scrap after the removal of the tin, for making steel. A Philadelphia sash-weight foundry purchased a lot of this scrap which, when melted in a cupola, produced nothing but slag, and foundrymen, in purchasing scrap, should beware of an excess of this kind of steel in the lot.

Melting Copper In a Cupola.

The cupola may be used for melting copper and, with a modified construction, is quite extensively used in the smelting of copper ores and large pieces of copper found native in the Lake Superior copper region.

For the melting of red brass it is the most economical furnace that can be used, as it requires less melting fuel, melts the metal more rapidly, and the per cent. of metal lost in melting is no greater than any other melting furnace.

Melting Brass In a Cupola.

The cupola is the most rapid and economical brass melting furnace that has yet been designed for the melting of brass.

when properly managed, but when not properly managed, is one of the most expensive.

At the Washington Navy Yard, Washington, D. C., all brass and bronze for large, heavy castings, such as propeller wheels, are melted in their ordinary iron-melting cupola, which is carefully picked out and daubed up to remove any chance of iron being taken up by the brass or bronze.

This has been the practice at this yard for a number of years, and it has proven perfectly satisfactory in the melting of large quantities of the metal. For their small castings the metal is melted in crucibles, the reason for doing this is not that the cupola-melted metal is not satisfactory, but the weight of metal is not sufficient to justify melting it in the cupola.

At the foundry plant of the Southern R. R. Co., Richmond, Va., a small cupola was installed for melting brass, and all the metal for car and locomotive bearings have been melted in this way and remelted when worn out for a number of years with perfectly satisfactory results as to the alloy of the metal and loss of metal in melting.

The molten metal is tapped and drawn from the cupola into shank or hand ladles and handled in every way the same as iron in pouring, the only difference being that before pouring is begun the ladles are heated to redness, but after the first ladle is poured this is not necessary, as the ladle keeps sufficiently hot, if in constant use, to not dull or chill the metal.

The cupola plan of melting this metal was tried at the Philadelphia Navy Yard and proved a complete failure. This was due to an excess of blast. In brass melting in a cupola a very mild blast should be used, and in case of excessive loss of metal or alloy, reduce the volume of blast.

Alloys of yellow brass cannot be made in a cupola, such alloy is made in ladles by melting the alloy metal of zinc, tin or lead separately, and adding them to the copper in the ladles. Yellow scrap brass found to be deficient in alloy or color, after cupola melting, may be brought up to the standard in this way.

Melting Lead In a Cupola.

Lead can readily be melted in a cupola without blast if the cupola has sufficient draft to make a hot coke or coal fire.

This is the most difficult metal to hold in a cupola, when melted, of any of the metals melted in a cupola. It is almost impossible to put in a front through which it will not leak, and when tapped, with a body of molten metal in the cupola, the stream is hard to control or stop-in, and it is the practice to heat the ladle and leave the taphole open, and permit the lead to run out as fast as melted.

In case the cupola does not have sufficient draft to melt the lead as fast as desired, a very light blast may be used for more rapid melting.

Care of Over Iron.

The care of over iron in many foundries is a matter that is given entirely too little attention for the profits of the foundry or safety of workman, by both management and workman.

This iron is frequently poured into the sand heap, entailing a loss of moulding sand and loss of money. This may seem a trifling loss, for the amount of sand burned out and adhering to a little over iron poured into a sand heap is very trifling, but when a new place is scraped with the foot for every little drop of iron left in a hand ladle after pouring, and the iron poured into it, and fifty or a hundred moulders are doing the same thing every day, the loss of sand in this way, in the course of a year's time, will figure up to carloads, and carloads of sand cost money.

Not only is there a loss of sand by this practice, but there is a loss of time to the moulders in removing this iron from the sand and more time and labor is required in tempering the sand. More time of a laborer is required to collect these small pieces of iron and mill them, and if not milled, more sand is placed in the cupola to be fluxed out, and a greater amount of fluxing material is required.

Another very extravagant and dangerous practice is the pouring of over iron in ladles into the gangway. The iron disposed of in this way is generally a few pounds, that is not sufficient to pour another mould, and it is poured out to avoid having it chill in the ladle and dull the next ladle of iron, and is disposed of in the quickest possible way, which is generally to pour it into the sand heap, or out along the sides of the gangway, where it frequently runs across the gangway to be trampled upon by the men. It may be exploded, by coming in contact with water, and men and clothing burned, or it makes a lot of small scrap which requires time of a laborer to gather up and dispose of.

The loss from this practice is far greater in hand ladle and small bull ladle pouring than many founders have thought to estimate. Such loss may readily be prevented and the foundry kept in better order by providing a receptacle for over iron at convenient points and requiring each moulder to pour over iron into it.

Such a receptacle may be provided in the shape of a short cast iron pig mould, or a round pot holding about fifty pounds of iron, from which the iron may be removed as soon as set by turning over, and filled again if necessary.

This collects all small amounts of iron left in ladles into a solid mass, and less time is required to collect and place it in the cupola for remelting, and it should be made one of the shop rules that all over iron in small ladles must be poured into these receptacles.

Another source of loss and danger is the slovenly way in which over iron from the cupola is taken care of in many foundries.

A sand bed, designated the pig bed, is usually provided near the cupola for over iron from large ladles, when pouring is finished. This sand bed is frequently so located that it is trampeled over by the moulders in carrying their iron, and when required for over iron, a rough hole or ditch is dug in it with a shovel, into which the iron is poured.

This iron may form a chunk or slab requiring two or three men to lift and place on the barrows for removal to the scaffold, or be broken, which may not be an easy task, before it can be placed upon a barrow or charged into the cupola. All this requires labor and labor costs money. Besides this, the iron may be filled with loose sand, locked in pockets, and heavily coated with sand on the outside, that makes dirty iron and clogs up the cupola.

An over iron pig bed should always be located in a place where it will not be tramped over, and if the arrangement of the foundry is such that this cannot be done, then some means of protecting it should be devised.

This may be done by providing a sufficient number of pig mould patterns to fill the bed, and making up the bed before casting begins, and leaving the patterns in the sand during the time of casting. The bed may then be walked over without disturbing the moulds and when casting is over the patterns may be drawn and the pig moulds found intact. This places the over iron in a good shape for removal and also for charging to be remelted.

Another good plan for protecting an over iron pig bed, is to place the top of the bed just below the level of the floor, and place an iron frame around it, make the pig moulds in the sand inside the frame and cover them with iron plate, supported by the frame around the moulds.

These plates, being on a level with the floor, may then be walked over without disturbing the mould, and when ready for pigging out, the plates may be removed and the pig moulds filled with iron.

Weighing or Measuring Coke.

When coke was first placed upon the market as an article of commerce and cupola fuel, it was all sold by the bushel, and foundrymen when stating their melting ratio, gave the number of pounds of iron melted per bushel of coke, in place of the number of pounds of iron melted per pound of coke, as is now the custom.

Prior to the manufacture of coke as a commercial article, it was the practice of foundrymen to construct a small oven and make their own coke. The weight of a bushel of this coke was stated to be thirty-two pounds. The first coke to be placed upon the market in Pennsylvania was called Pittsburgh coke. This coke was coked in improved beehive ovens, and was claimed to be a superior and heavier coke than the home-made coke, and its weight was placed at thirty-six to forty pounds to the bushel.

At that time, the United Presbyterian Church was the leading church at Pittsburgh, and they permitted no work being done on the Sabbath, and coke ovens falling due to be drawn on the Sabbath day, had to be held over until Monday. This gave a seventy-two hour time of coking, in place of forty-eight hours, and produced a more dense and heavier coke, the weight of which was placed at forty pounds per bushel.

With the discoverey of the superior coking coal of Connellsville, Pa., nearly all the Pittsburgh commercial coke plants were moved to Connellsville, and the practice of not drawing ovens on Sunday continued for many years, if not to this day. The only seventy-two hour coke made, was that of ovens falling due to be drawn on Sunday and held over until Monday.

The Connellsville seventy-two hour coke proved to be a heavier coke than the Pittsburgh coke, and was given forty-six pounds as the weight of a bushel, and this became the standard weight for cupola coke as long as it was sold by the bushel.

Many of the by-product cokes are said to be more compact and heavier than the beehive oven cokes, and some of them are claimed to weigh as high as sixty to seventy pounds to the bushel. This being the case, the same number of pounds of the heavier coke would not fill a bushel basket to the same extent or occupy so great a space in the cupola as the lighter weight coke.

The cupola, being a space furnace, in which iron is only melted within a given space, and must be supported at this point by coke to be properly melted, the question of whether in cupola charging, coke should be charged by weight or measure, becomes a more important question than when there was not such a wide variation in the weight of a bushel of coke.

It has been my contention, in all my cupola writings, that coke should be charged by measure and not by weight, and the advantage of this method over the weighing method becomes more apparent as the variation in the density and weight of coke increases. For a light weight coke places the iron too high for melting, and the surplus of coke must be burned away before the iron can settle into the melting zone, and this coke is wasted, and there is not sufficient of the charge of coke remaining to melt the charge of iron, and dull iron results.

When a heavy weight coke is charged, the cupola is not filled to a proper height and the iron settles too low before the charge is melted and we again have dull iron.

It will thus readily be seen, that with one car of dense heavy coke, and the next car of light friable coke, we are all at sea in charging by the weight method, while with the measure method, the same space is filled in the cupola by either a light or heavy weight coke, and in case dull iron appears, we have only to change the weight of the charges of iron, increasing their weight for a heavy coke, and decreasing their weight for light coke, to insure hot even iron.

The measuring of coke may readily be done by providing a sufficient number of galvanized iron baskets or tubs, for taking up the coke for the heat, as fast as wanted for charging.

This system requires no weighing of coke, for the baskets may be made to hold a given weight, and the time and labor of shoveling the coke on and off the scales, when charging, saved, and more rapid charging of fast melting cupolas done.

It also dispenses with the use of large barrows for coke, as two or four of these baskets may be placed on the barrow and taken up on an elevator.

Fuel Required in Melting.

The wide variation in the quality of cupola coke, volume of blast, height of cupola and size of heat, renders it impossible to state any definite weight of iron that should be melted with a pound of coke. From five to six to one is about the average melting in the foundries of this country. Seven to one is considered good melting by practical foundrymen, and eight to one the limit that can be melted and a good hot even iron obtained. This figure is seldom exceeded under the most favorable circumstances in a cupola, but is frequently far surpassed in cupola reports, and by foundries at foundrymen's conventions. To mix the various grades of pig and scrap iron, and obtain an even grade of iron in castings, iron should be melted hot and evenly, upon the fuel, and permitted to filter drop by drop, through a good bed of coke, in its descent to the bottom of the cupola, to superheat it, and bring the drops in contact with each other, and a thorough mixture is effected, and an even grade of iron is obtained. With scanty fuel, iron is melted low in a cupola. Smelting is done to a large extent by the flame or heated blast. Iron is melted of an uneven temperature, and a thorough mixture of the different irons in the mixture is not effected, resulting in uneven or dirty iron in the casting. At one of our largest car wheel foundries, melting from 80 to 100 tons in one cupola at a heat, only seven to one is melted. With such large heats, they could no doubt do better, but their wheels have to stand a number of very severe tests, and they have found by long experience that this per cent of fuel gives a more even iron and less condemned wheels than a lesser per cent. of fuel. Foundrymen will do well to take this into consideration, when figuring upon melting iron with the least possible amount of fuel, for good castings are of more value than coke.

Melting 10, 12 and 15 to One.

Iron has been melted in a cupola at the rate of ten, twelve and fifteen pounds of iron to a pound of coke, and periodically an elaborate account of such melting appears in the foundry journal. An investigation of a number of these reports has shown that the iron was actually melted with this per cent of fuel, but in all cases it was done in experimental heats, and iron was not sufficiently hot for casting anything but chunks, and in one case, in which 15 to 1 was melted, the iron, after being poured into the pig bed, left an iron skull from one to two inches thick in the ladle. But the iron was melted 15 to 1. Such melting is not undertaken by practical foundrymen in actual foundry practice, for there is always more or less uncertainty as to the quality of coke and cupola management, frequently resulting in dull iron and loss of castings and perhaps loss of a heat, as the bottom may have to be dropped. Coke is cheaper than foundry labor, and they prefer to use the amount necessary to melt the iron properly than to losing castings from bad iron.

Men who claim to do such melting are either deceived by their cupola report or are fakers, who know nothing of the theory of melting in a cupola, and when they fail to give this result, blame it on the quality of coke, height of cupola, volume of blast, size of heat, etc.

Does It Pay To Slag a Cupola.

Does it pay, or is it necessary, to slag a cupola, are questions that are frequently asked by foundrymen.

To slag a cupola, a substance that in itself produces or is converted into a slag by the heat of the cupola is required. The most satisfactory substance to produce this results is limestone and shells. These materials cost very little in some sections, and are quite expensive in others.

Neither limestone nor shells contain any heat producing units, and heat is required to heat them to an extent that they are converted into a slag, and an increase in consumption of fuel is required for slagging, so that there is some considerable expense entailed in the production of a slag for slagging a cupola.

Beside this expense, there is an increase in the per cent. of iron lost in melting, which has been found by analysis to vary from a trace, to as high as seven per cent. in the slag, depending upon the working of the cupola, as an oxidizing flame produces a heavier loss. Beside this there is a labor expense for caring for the slag as it flows from the cupola, and removing it from the foundry, when either hot or cold.

If there is not a gain to offset this expense, then it does not pay to slag a cupola, and there are many cupolas being slagged every heat, in which the slagging of them is entirely unnecessary and a direct loss.

Before the slagging system of melting is adopted for a cupola, conditions should be carefully analyzed to determine whether it is necessary to slag it, and to what exent it should be slagged.

The object in slagging the cupola is the same as that in the slagging of a blast furnace, from which the cupola slagging practice is taken, namely, the removal of the ash of the fuel, and the non-metallic residue of the ore from the furnace, to prevent the furnace becoming clogged up with this material, and the smelting of the ore being retarded or stopped.

The object in slagging the cupola is practically the same, the only difference being the removal of the ash of the fuel and sand, rust, and dirt adhering to the iron in place of being in combination with the iron, as in the ore of an iron.

Blast furnaces are kept in blast for days, weeks and months, and its is absolutely necessary that they should be slagged to keep them in blast for this length of time, and by the same practice, cupolas have been kept in blast, night and day for weeks, or as long as the cupola lining lasted, in the melting of iron and also in the smelting of iron ores.

Neither a blast furnace nor a cupola could be kept in blast for so great a length of time, were it not for the use of a fluxing material that produced a fluid slag, capable of absorbing and liquefying ash, and non-metallic substances of the iron, and carrying them out of the furnace or cupola when slag is permitted to run out.

When a cupola is put in blast, there is no ash of the fuel or dirt from the iron in the cupola, such substances are the result of combustion of the fuel and melting of the iron, and it is not necessary or desirable that slag producing material should be charged until such substances have been formed in the cupola by melting the iron.

It is the practice not to charge slagging material or flux until at least two and sometimes four or five charges of iron have been placed in the cupola. When limestone or shells are charged in this way, they are generally placed upon the top of the charge of iron, and when the iron settles into the melting zone and is melted, the limestone or shells are also melted, and form a fluid slag that settles to the bottom of the cupola, and in its descent comes in contact with and absorbs the ash of the fuel used in melting the previous charges, and carries it to the bottom of the cupola in a liquid form, where it may be drawn off at a slagging tap hole, and the cupola left clear for further melting.

After the first charge of flux is made, flux is then placed upon each charge of iron, but may be omitted on the last charge, and is generally omitted on the last two and sometimes three charges of iron. This is a matter to be determined by the working of the cupola near the end of a heat, and also the free or stiff dumping of the cupola, after the heat has been melted.

Small, slow melting cupolas, such as those used in bedstead foundries, require slagging earlier in the heat than large cupolas, and in these cupolas it may be found advisable to place limestone or shells on the first charge of iron, to keep the cupola working open and free. This is another matter to be determined by the melting of the cupola.

Cupolas that do not require the charging of flux in long heats, until on the second to fifth charge of iron, do not require slagging at all, when only this number of changes are melted, and it is not the practice to slag when only a short heat is melted for the size of cupola.

The carbonate of lime in the shape of limestone and shells is the only substance that has yet been found that produces a satisfactory slag for either a blast furnace or a cupola. Many other slag producing substances have been tried, but they have either produced too sluggish a slag, or too fluid a slag, and were found to be too destructive to the lining of furnaces and cupolas, and had to be abandoned.

Some of the limestones have also been found to be destructive to cupola linings and also to tap holes, which cannot be kept of a proper size for the stream of iron when such limestone is used. The remedy when this occurs, is to change the limestone or change the front and tap hole material, and get a quality of fire brick, that is not fluxed by the stone.

The quantity of limestone that should be used varies with the quality of the stone. A stone rich in lime requires less to be used than a stone lean in lime. A milled remelt and sandless cast pig requires less than an unmilled remelt and sand cast pig. No definite amount that should be used could be stated, but the average amount used is about 20 to 25 lbs. to each ton of iron melted.

The placing of a charge of limestone or shells upon the last one or two charges only, for the purpose of making a clean dump and brittle slag and cinder for chipping out, is a very old practice the utility of which is very doubtful. I have tried this many times and never found that it made any cleaner dump or easier chipping out, although at times it appeared to do so, but at other times it appeared to make it worse and I think it does not make any difference whether this practice is followed or not.

There are two objects to be attained in slagging a cupola. These are first the keeping of a cupola in good condition for melting a long heat, and second, the melting in short heats of gates, sprues, runners, sink heads, over iron, etc., without milling or otherwise cleaning to save cost of cleaning.

These two objects may readily be obtained by the liberal use of limestone or shells, and a cupola kept in blast as long as desired, or the lining will last with clean or uncleaned remelt. While the same cupola if a small one, might clog up in an hour, and a large one in two to three hours, in many foundries, the system of molding and casting makes the tapping of slag well worth the cost.

At many of the light casting foundries such as stove and bench work foundries, the remelt gates and other scrap is equal to 50 per cent. of the heat. The milling of this iron entails a considerable expense for labor and power, and it will be found much less expensive to slag the cupola than to mill or otherwise clean this iron.

As for cleaning or improving the quality of iron in the cupola by slagging, there is nothing to be gained, for all cast iron has passed through a larger bath of slag and brought more in contact with it in the blast furnace than can possibly be done in a cupola, and the only improvement that is effected in iron by slagging is in keeping the cupola open and melting freely, and preventing the deterioration of the iron when cast.

When slag does not flow freely from a cupola when slag is tapped, look at instructions for making a slag hole, and if this has been followed, and the tap hole is right, increase the amount of limestone or shells used until a fluid slag is produced. If this increase does not produce a fluid slag, the lime stone is a lean one, and a richer one must be procured.

Foundry Miscellany

CHAPTER XIII

Cleaning Iron.

In the days of poor coke, slow melting, and dull iron for pouring, it was difficult to get clean, sound castings, and all kind of plans were devised and tried for cleaning molten iron just before pouring a casting.

One of the favorite methods for doing this, was to agitate the iron in the ladle by causing it to boil. This was done by placing a small potato or apple on the end of a tapping bar or iron rod, and forcing it down through the molten iron to the bottom of the ladle and holding it there.

The potato or apple contained sufficient moisture to cause the molten iron to boil, similar to the boiling of iron in a newly-lined ladle not fully dried, and a scum of dross and dirt soon formed on the surface of the iron. This was skimmed off and the iron supposed to be clean.

When an apple or potato was not at hand for boiling the iron for some special castings, a ball of fire clay was used, but this was not considered as good as the potato or apple, for if a little too wet, it boiled the metal too violently and sometimes caused the iron to explode if suddenly thrust into it.

Another method of cleaning iron was by poling it. This was done by the use of a stick or pole of green wood, which was thrust into the molten iron and moved around or the iron stirred with it. This method was used principally in large ladles, that every part of the iron might be agitated and dirt or dross set free.

The poling of iron was also done in the bath of molten iron in reverberatory furnaces. For this purpose a green hickory or other hardwood pole, three to four inches in diameter, was used, the end of this pole was thrust into the iron and the iron thoroughly stirred with it, or poled as it was called. The moisture in the wood caused the iron to boil around the pole, and thoroughly agitate the iron and throw out all dirt and dross that tended to make dirty castings.

This method of cleaning iron caused dirt and dross to collect on the surface of the molten metal freely, and had the appearance of cleaning the iron, but this appearance was deceptive, for the boiling of the iron produced the dirt by throwing graphite carbon out of the iron, and produced a harder iron. The same as is done when iron is boiled in a green, fresh daubed ladle, and the iron is really dirtier and also harder after boiling than before.

This practice has probably been entirely abandoned, as I have not seen or heard of it being practiced for many years, and I would not advise foundrymen to adopt it as a means of making clean castings, for they would find the reverse to be the case.

The boiling method of cleaning iron was replaced a few years ago by the ferro-alloy method. This consisted of adding various ferro-alloys to molten iron in the ladles, by placing the alloy in the bottom of the ladle and tapping the iron upon it, or by placing the alloy on the surface of the molten iron, and stirring it into the iron with a skimmer. Another method was to sprinkle it upon the stream of iron in the spout, as it flowed from the cupola.

These ferro-alloys were claimed to not only clean the iron, but also to give to the iron various desirable characteristics desired in iron for various lines of castings.

But owing to the high melting point of the ferro-alloys, for which the heat to melt them had to be extracted from the molten iron, the temperature of the iron was reduced to an extent that the alloy was not fully melted and absorbed before the iron was too dull for pouring, and the result was a dirtier iron instead of a cleaner iron. The cleaning and improving the quality of foundry irons by the use of ferro-alloys had but a short run, although they are still used to a limited extent for this purpose.

To clean iron, melt it hot, and to make clean castings, pour it hot.

Cupola Blowers.

Probably the first design of a blower used to furnish blast for foundry cupolas was the piston cylinder blower, used for blowing blast furnaces in early days.

This was a positive pressure blower with an uneven blast, but a good cupola blower, and I have seen many of them in use in old, long-established foundries, in the eastern section of the country. I have not seen any of them in use for many years, and they have probably all gone out of use with many of the old foundries. The last one I remember seeing in use, was at the foundry of The Perry Stove Works, Albany, N. Y. This foundry was closed out some years ago.

This blower although a very good one, was too expensive to install, and occupied too much room for small cupolas, or in fact any cupola, and a cheaper blower was sought for, which led to the designing and construction of a variety of types of blowers.

Among the new types was the water pressure blower, which was an excellent cupola blower, but required a stream of water and milldam to operate it. The bellows blower, constructed and operated upon the same principle as the blacksmith forge bellows, the fan rotary blower, and the rotary positive pressure blower.

The last two proved the most economical and practical blowers, and have replaced all the other blowers, except perhaps in the few old foundry plants in isolated districts.

The fan blower, as first manufactured, delivered a very uncertain volume of blast, and when the escape of blast from the blast pipe was shut off, by clogging up of the cupola, or the blast gate closed, revolved in its own wind, and delivered no blast at all.

To overcome this objectionable feature, various changes were made in the shape and size of the air paddles and in the shape of the fan shell. Double and quadruple blowers were constructed, placed side by side, from which the blast is forced from one into the other, to give the blast greater force for entering the cupola, and make it a positive pressure blower. All these attempts to make it a pressure blower failed and the fan blower still remains a non-positive blower.

The improvements made in the design and construction of the fan blower has made it an excellent blower, that delivers an even, steady volume of blast, and I very much prefer it for short heats, where the cupola can be kept working open and free, but for long heats, in which there is a greater tendency of the cupola to clog and bung up, the positive pressure blower is to be preferred.

The first positive pressure blower was the cylinder blower, with a steam cylinder at one end of the piston rod, and an air chamber at the other end. Every revolution of the engine pushed the blast out of either end of the air cylinder, and gave a positive blast. This was an excellent cupola blower, but was expensive to install and required considerable room, but many of them were placed in foundries.

After this came the Mackenzie rotary positive pressure blower, which was a very good blower, and it was said it was only necessary to keep it floating in oil to keep it in good running order.

Next came the Baker rotary pressure blower, which was an improvement on the Mackenzie. Then came the Root rotary pressure blower, which was said to have been originally designed for a water wheel, but blew the water out so fast that it was made a pressure blower. Many of each of these blowers were installed in foundries and gave very satisfactory results, but all had their defects, and many of them have been replaced by more modern pressure blowers, a variety of which are now manufactured and on the market and may be had for cupola blowers.

Of the original three pressure blowers, only one remains. This is the Root blower, which has been modernized and brought up-to-date. The Mackenzie blower, I believe, is no longer manufactured, and the Baker blower has been replaced by the Wilbraham-Green blower.

The rotary pressure blower is so constructed that each revolution delivers a definite number of cubic feet of air every revolution. Install a blower suited to the size of the cupola and a proper volume of blast is insured for the cupola. It is only necessary to see that the blower is in good working order and belts do not slip, to insure this result.

The most pronounced objection to the rotary pressure blowers, when first introduced, was the unsteadiness of the blast, but this has been found not to be detrimental to the melting, and about the only objection to it now is the increased cost over that of fan blowers.

Hot Blast.

That a hot blast produces more rapid smelting of ores in blast furnaces and a softer and more desirable foundry iron than a cold blast, was fully established many years ago, and attempts were at once made to produce a hot blast for a cupola, to produce more rapid melting, and still further improvement in the quality of the iron.

To heat the blast for a furnace an oven was constructed and filled with hundreds of feet of cast iron pipe through which the blast was forced before entering the furnace. These pipes were heated to almost the melting point by fire pots or furnaces placed in the oven, and when the blast emerged from them it was at a temperature of many hundred degrees.

The furnaces were kept in blast for months and ovens and pipes constantly heated for the same length of time, and a comparatively small amount of fuel was required to heat the blast. The saving in fuel in the furnace was more than sufficient to supply the oven.

This plan could not be adopted by foundrymen owing to the cupola not being constantly in blast, and the expense of fuel in heating the pipes for each heat was a great deal more than the saving effected in melting fuel, and a new plan had to be devised for heating the pipe.

This was done by dispensing with the cupola stack and placing an arch over the cupola, to divert heat escaping from the cupola and passing it through the oven.

With the low cupolas then in use sufficient heat escaped to heat the pipe and the blast to a temperature high enough to melt lead. But time was required to heat the pipes before the blast could be heated, and in short heats the heat would be melted before the blast became hot, and even in heats requiring several hours to melt, and a large part of the heat was melted before the blast became sufficiently hot to reduce the melting fuel. Another objectionable feature was the breaking of the pipes in the oven. The repeated heating and cooling caused them to break, and the break usually occurred in heating them when it could not be repaired for the heat, and these objectionable and expensive features caused this system to be abandoned.

The heating of blast was then tried by placing coils of pipe in the cupola stack, but the slow heating of the blast for the early part of the heat and the breaking of pipe caused this plan to be abandoned.

The blast for furnaces is now heated without the use of extra fuel by gas taken from near the top of the furnace. But this plan is not at all likely to be applied to cupolas, owing to the cupola not being continuously in blast.

The next plan tried was to draw the heated air from the cupola stack and pass it through the blower and return it to the cupola. This furnished a good hot blast, but proved a complete failure, owing to the heat of the blast heating the blower to an extent that completely destroyed it.

This plan, in a modified way, was exhibited at a meeting of the American Foundrymen's Association, Toronto, Canada, 1908, by the Beloit Cupola Company and was a complete failure owing to heating of the blower.

Heating the blast has many times been tried by extending the outside belt air-chamber up to the charging door and putting the blast into it at the top, to be heated by heat of the cupola casing, before entering the tuyeres. This in every case proved a complete failure, as the blast was not at all heated.

Dry Air Blast.

Many foundries have claimed that they obtain hotter iron in winter months than in the summer months, with the same per cent. of fuel, and attribute this to a drier blast, due to cold weather reducing the amount of moisture in the air.

But I have never heard of any of them reducing their cupola fuel to prove this theory and I believe it to be an optical illusion, due to foundries being darker in the winter months than in the summer, and the molten iron appearing hotter in the darker foundry. As the same phenomenon may be observed on a dark rainy day when the air is full of moisture in midsummer.

Not many years ago extensive experimental work was done along this line by blast furnace men in which freezing plants were constructed for freezing all moisture out of their blast, and it was claimed at that time that a considerable saving in fuel was effected in smelting their ores. I have never learned of this system having been generally adopted by furnace men and do not think it went any further than the experimental work.

The only way to remove moisture from the air appears to be by the freezing or cooling process, and to extract all the moisture requires a thorough freezing of the air.

To do this an expensive freezing plant would be required to freeze the moisture out of a sufficient volume of blast for a cupola of medium or large capacity, and it is not at all likely that a sufficient quantity of melting fuel could be saved by installing such a plant to supply a dry blast for a cupola of any size.

In the making of matches a dry atmosphere is a very important matter, for matches dipped when the humidity is high and air loaded with moisture crack and the heads frequently fly off when the match is scratched in lighting.

The freezing process of drying the air cannot be used in the dipping process of match making, and many other plans for obtaining a dry atmosphere in the dipping room have been tried, but all have proven a failure, and it is the practice in match factories to stop work in such weather, or sell matches made in moist atmosphere as seconds at a reduced price.

Foundrymen desiring a dry blast for their cupolas had better wait for the match factories to find a cheaper process of drying the atmosphere.

Moist Blast.

While men favoring a hot blast and a dry blast for cupolas have been active to prove the correctness of their theories, the advocates of a moist or wet blast have not been idle and considerable experimental work has been done along this line.

One of the most exhaustive experiments of this kind that has come to my notice was one made by the Lobdel Car Wheel Co., Wilmington, Del. The foundry management of this firm had noticed that their iron was hotter on wet, rainy days than on dry days, and attributed this to moisture in the blast, and it was decided to give moisture to the blast in dry weather the same as in wet weather.

To do this a blast air chamber fifty feet long and three feet square was constructed under ground, in the top of which pipes were arranged for spraying the blast with water on its way to the cupola.

This did not produce any hotter iron or save any fuel and the number of spraying pipes were increased with no better results.

The air before entering this chamber was then analyzed and again analyzed after passing through the spraying chamber and it was found to not have taken up an atom of moisture in passing through the spraying chamber.

Steam jets were then thrown into the chamber through the spraying pipes in place of water with no better results, and analysis showed that no moisture had been taken up by the blast from the steam.

Various other methods were then tried in this chamber, such as partly filling it with water, and throwing down thin sheets of water from the top, through which the blast was forced. Neither of these plans induced the blast to take up moisture and the experiment was given up as a pronounced failure.

Various other schemes have been tested to place moisture in a blast or cupola, such as spraying water into the tuyeres, and throwing a jet of steam into each tuyere, with no satisfactory results, either in saving fuel or in improving the quality of iron.

The following extract is taken from an article prepared by Mr. M. H. Bancroft, and published in "Castings" some years ago, entitled "Weather and Output of Cupola."

Weather and the Output of the Cupola.

"Why does a cupola melt better on a cold day in the winter than on a hot summer day? Why does a cupola melt better on a rainy day in the summer than a dry day at the same season ot the year? These are questions that are constantly being asked, and have puzzled many a foundryman. Both are easy of answer if we consider the underlying principles.

"Air Capacity for Moisture—As a given volume of air is heated at constant pressure it expands and at the same time its capacity for moisture is very greatly increased. In locations near the sea or where there are considerable bodies of water to draw from, air is usually fairly saturated with moisture. The table below gives the weight of a cubic foot of air at several temperatures and also the amount of water contained in the air at these temperatures.

"The figures given in this table correspond to a barometer reading at 29.921 inches of mercury, the ordinary reading at the sea level. If air at a relatively high temperature and saturated with moisture is suddenly cooled, the moisture will be percipitated as rain or dew if the temperature is above 32 degrees Fahr. and as snow or frost if the temperature is below 32 degrees. Air that is almost saturated seems dry to us, while that which is supersaturated seems moist and in the lower temperatures colder than it actually is. In temperatures that approach blood heat very moist air seems hotter than is really the case.

Effect of Heat on Air.

Temperature in degrees Fahrenheit	Weight of air 1 cubic foot in pounds	Pounds of water in 1 cubic foot	Total No. pounds of air and moisture
0	.0863	.000079	.086379
32	.0802	.000304	.080504
62	.0747	.000887	.075581
82	.0706	.001667	.072267
92	.0684	.002250	.070650

Weight of air and amount of entrained water at various temperatures.

"Let us now investigate the effect of the varying degree of moisture and also the effect of changes in the density of air due to variations in the temperature. Between zero and 92 degrees Fahr. the expansion of air as shown in the table has reduced the weight of a cubic foot 26 per cent in terms of the higher temperature. At the same time the amount of moisture which air carries has been increased 27½ times.

"Air is always supplied to a fan or blower, which under given conditions and in a stated length of time delivers a definite volume of air. Any change in the density of air will therefore affect the amount of oxygen entering the cupola and any alteration in the amount of water the air carries will also have its effect on the combustion. Whatever enters the tuyeres must pass through the fire. Water that goes in as an invisible vapor will dampen the fire just as effectively as an equal amount introduced from a hose."

Mr. Bancroft goes on to give scientific details of his theory and tests, but as these are of more interest to the scientist than to the practical foundryman they will be omitted, but may be found in my work "The Cupola Furnace."

From his article as above given it would appear that The Lobdel Car Wheel Co. experiments were on the wrong tack and had the blast been kept in this underground air chamber for a sufficient length of time to cool it the moisture in it would have been decreased rather than increased by cooling it below the temperature of the atmosphere. But owing to the rapidity with which it passed through the chamber it was not changed and the per cent of moisture remained the same.

We have here before us the three principal cupola blasts, namely, hot, dry and moist blast, and the experiments or efforts their advocates, or some few of them, for they are many, have made to obtain their ideal blast for a cupola. All these efforts have proven a complete failure in practical application to a cupola blast.

These experiments and tests would seem to indicate that with our present scientific knowledge further attempts to change the composition of air for a cupola blast are useless, and foundrymen must take their cupola blast for the present, at least, as they find it in the air, whether hot, dry or moist, when casting time comes around, and wait for further scientific developments to get a blast to their liking.

The advocates of the dry blast can have their desire for a dry blast satisfied to some extent by the use of dry coke, and the advocate of a moist blast have his satisfied to some extent by the use of a wet coke, while the advocate of a hot blast can only have his satisfied during the hot months of summer.

I, myself, am a firm believer in coke being exposed to the weather, and wetting it before charging. I have obtained excellent results from this practice in the days of poor coke, and in one case was able to use a lot of high sulphur coke after it had laid out in the weather all winter.

Number of Men Required to Man a Cupola.

The number of men required to man a cupola depends upon the size of cupola and heats melted.

One man is sufficient to man a very small cupola, melting light heats, including making up the cupola for a heat, and getting up the stock for melting and casting every day.

This is the practice in many of the bedstead foundries, where the melting is slow and taps far apart, which gives him time to do his charging between taps.

In many of the small jobbing foundries, casting every other day, it is the practice to have the melter clean castings one day and make up the cupola and get up his stock the next day, or divide up the work as he sees fit to do so.

In these two types of foundries the melter generally does the ladle daubing and drying.

With a thirty to forty inch cupola, casting every day, a melter shovels out the dump and may be required to remove it to the tumbling barrels. He then makes up his cupola for the heat, mixes his daubing, and does everything about the cupola, and may be required to daub and dry ladles, and is only given a helper to raise the bottom doors, shovel in sand for the bottom, get up cupola stock, and help do the charging.

Large cupolas require a melter and a helper all or part of the time, depending upon the nearness of the daubing trough, tumbling barrels, etc., to the cupola.

Very large cupolas require a melter and two helpers to do the work of removing the dump, making up the cupola, daubing ladles, cutting the wood for cupola and ladles, and lighting up.

These are all the men that are required to man a cupola if the men are strong and able bodied. If the men are light weight, delicate men, more of them will be required.

The number of men required to get up cupola stock and do the charging depends entirely upon the layout of the foundry plant. Distance the iron and coke have to be carried in the yard, means of carrying it and elevating it to the scaffold, etc., and no number of men can be stated for this work.

The late J. W. Keep placed the number of men required to completely man a cupola at five, basing his estimate upon the work done at the Michigan Stove Works, in which the heats melted were twenty or more tons and the gates and small scrap had to be collected from the foundry by these men.

Melting Capacity of Cupolas.

In estimating the melting capacity of a cupola, the number of square inches of melting surface in the melting zone is learned and this is multiplied by ten, which is the number of pounds of iron a cupola in good melting condition and supplied with the proper volume of blast will melt per hour with a good coke fuel. With a good anthracite fuel, seven pounds to each square inch. With a light or high ash coke, between five and seven pounds have been found to be the best that can be done per square inch of melting surface.

The following table gives the melting capacity of cupolas per hour, estimated at ten pounds to the square inch of melting surface:

Diameter of Cupola In Inches	Pounds Per Hour	Diameter of Cupola In Inches	Pounds Per Hour
20	3,141	50	19.635
24	4.523	55	23.758
30	7.068	60	28.274
36	10.178	65	33.183
40	13.566	72	40.715
45	15.904	80	50.365

Cost of Melting Iron.

When melting iron as an expert, in visiting many foundries, I estimated the average cost of melting iron in a cupola to be $2 per ton of iron melted.

This cost included cupola lining and repairs, daubing, wood, melting fuel, flux, and all labor employed in getting up stock, and doing cupola work.

This estimate did not include power, tools, etc., which belong to the overhead cost, and is to be estimated.

In investigating this matter I found that it cost more for fuel and labor to melt one ton of iron than a number of tons in the same heat, and that the cost decreased as the number of tons melted increased, and the above estimate was made on a fair-sized heat for the diameter of cupola.

At the time this estimate was made the cost for fuel, labor and all cupola supplies was much lower than at present with our war-time prices, and it is doubtful if a fair sized heat, for diameter of cupola, could be melted for double the stated price per ton.

To learn this cost at any time it is only necessary to learn the cost of fuel consumed in melting a heat, cost of all labor employed in making up the cupola for a heat, daubing ladles, getting up cupola stock, charging, and all labor in any way employed at the cupola in melting a heat. This gives the cost of fuel and labor.

It is not practical to estimate the cost of lining, daubing and lining repairs for each heat. This must be done by taking the cost of the new lining when layed up, and cost for fire clay, sand and firebrick for repairs, during the life of the lining, and dividing this cost by the number of tons melted during this time.

These two items give the actual cost for labor and maintenance of the cupola. To this is to be added cost of maintenance of barrows, cars or trucks in removing cupola dump, getting up cupola stock, etc., and cost of small tools, such as shovels, cupola picks and other small tools. Cost of maintenance of blower may also be added or charged to overhead cost, with power, etc.

The keeping of the cupola account in this way not only gives the actual cost of melting iron, but also enables the founder to determine if his cupola is being managed in an economical way.

The elaborate cupola report blanks, supplied at many foundries, to be filled out by the foreman or melter, give a great deal of valuable information when accurately filled out, but I have never seen one of them that covered the maintenance of the cupola, labor cost, and actual cost of melting.

Even the elaborate cupola reports of each heat required by the U. S. Government from foundries making semi-steel projectiles do not cover this cost.

The result of this is that one cupola lining only lasts from three to six months, while another lasts from one to two years, melting the same number of tons per heat. This is due to improper charging and maintenance of the lining that throws the heat against the lining, as illustrated under the heading of Small Charges, in which a five-inch brick lining was burned out in melting seven short heats, and in the two Southern foundries in which the lining in one cupola only lasted a few months, and in the other had been in use for eighteen months without having a new brick put in, and each melting about the same number of tons per heat.

Another matter that I have noticed is the excessive number of men employed in many foundries in making up the cupola and getting up cupola stock. At many foundries double the number of men are employed at this work that are employed at others for the same sized heat and under the same conditions.

These are matters that should be included in cupola reports and tabulated for reference.

Cupola Reports.

In the days of rule of thumb foundry practice, melters were instructed to use about a certain amount of pig and scrap, which was seldom weighed and no account kept of it, and the pig and scrap pile was looked at to determine when more would be needed. Coke was charged by the shovelful, or measured in baskets, and no account kept of the amount used.

Later on the slate was provided upon which was placed the amount of coke to be placed in the bed, and in charges, and the weight and kind of pig and scrap to be charged.

This slate was designed only as a guide to the melter, and the mixture of iron was only changed when a brand or grade number run out, or the iron obtained from the mixture was not satisfactory for the work to be cast, and at many foundries no record of the melting was kept, but at some foundries the slate was returned to the office after each heat and a record of the mixture in each heat, weight of pig and scrap melted, fuel used in bed and charges, recorded in a book for future reference.

This was a very good system, and in some respects more satisfactory than the present system of cupola blank reports to be filled out by the melter and returned to the office, in many cases so dirty they are not readable, and in others not properly filled out, to be filed for reference.

A charging slate is made by taking a common school slate and scratching permanent lines on it similar to those placed on cupola blank reports, or they may be made with lines for names of iron, scrap, coke, etc., and square spaces for figures of weight of each.

The instructions on this slate may be copied into a cupola report book after each heat, and the book kept clean and the report in much more convenient form for reference than when kept in separate sheets.

Many of the cupola report blanks that I have seen are entirely too elaborate to be of practical value, and cannot be filled out by the melter or foreman each heat, and many of the spaces to be filled are left blank, while other important matters are omitted.

A cupola report, to be of value, should not only give information for reference, but also information for present use, such as clean dump, or hang-up, condition of lining when chipped out after each heat. A hang-up dump indicates poor melting and heavy destruction of lining, and when this occurs there is something wrong with the making up of the cupola, or charging, which should be remedied at once. Variation in the temperature of iron also should be reported, for this indicates poor melting, and such information is of value at once. The number of cupola men should also be reported each day, and a number of other matters that may be made of value each day should be placed on the cupola reports.

Spark Arresters.

A few days ago I visited the plant of the Philadelphia Sash Weight Works, the foundry referred to on page 48, to learn what success they had met with in their new device for arresting sparks from their cupola stack.

I learned that they had reduced the height of their cupola stack to fifty feet, closed up all the openings in it and placed a drum on top of it extending out over the cupola casing two feet, and four feet high. A round cone-shaped cupola hood was placed over the cupola, a three-inch pipe arranged to throw a three-inch stream of water on the center of this hood and flow down over the hood, giving a sheet of water all around the top of the stack through which the sparks had to pass before reaching the open air.

To supply the water a pump was installed and a tank constructed for the water, which was returned to the tank through a drain or overflow pipe, and pumped up again. Twelve horsepower was required for the pump to raise this column of water.

This arrangement effectually prevented the escape of sparks from the cupola stack, but it was soon found that the strong cupola blast threw out a spray of water which was saturated with iron and floated off in the air staining window glass, wash drying on the line in the near neighborhood, and was a greater nuisance than the sparks, although less dangerous.

To overcome this trouble two more rings were added to the height of the drum, and a shelf placed around the inside of it to check the escape of spray and throw it down inside of the drum. Only one heat had been melted with this construction, and it had not been determined whether it was a success or not.

In making necessary alterations for this construction and installing it $3000 had been expended, which was estimated to be equal to cost of the entire plant when constructed.

Treatment of Burns.

In these days of first aid requirements by the laws of many states in manufacturing plants of all kinds, it is very important that such aid should be prompt and efficient, and probably in no manufacturing plant is first aid more frequently called for than in the foundry.

In these plants men are not only liable to cuts, bruises and injuries similar to those of other manufacturing plants, but are also liable to burns from molten iron as it flows from the cupola in pouring moulds, spilling of iron in carrying, runouts from moulds, and explosions of iron and slag.

The first treatment of a burn is a more important matter than that of many other injuries for, if the fire is not drawn out promptly and completely, the burn is often very painful, and frequently slow to heal.

For the drawing of fire from a burn I have found Antiphlogistine to be the most prompt and efficient remedy that I have ever used.

One time I received a large and very severe burn on my forearm, and at once applied a thick layer of Antiphlogistine, spread on a cloth. This drew out the fire in a very short time, and it felt so comfortable that I did not remove it for two days.

I then removed the dressing and put on another application of the same which I kept on for three days, the arm feeling so comfortable that I thought it had healed up and was all well.

But to my surprise, when the dressing was removed, found that it had not healed and showed no indications of healing.

Having no other dressing at hand I spread a very thin layer of Antiphlogistine on a cloth to prevent the cloth sticking to the large, open sore, until I could get another dressing.

This felt so comfortable, and being too busy to look up another dressing, I let it remain on for a couple of days, I then removed it and, to my surprise, I found it was healing very rapidly. I at once applied another thin spreading of the Antiphlogistine and permitted it to remain on until the burn was entirely healed, which was only a few days.

I never suffered any pain from this burn from shortly after the Antiphlogistine was applied until it was healed up, leaving no scar. The mistake made in the second application of this remedy was in applying it too thick, and drawing the sore, in place of healing it. This is a mistake commonly made in the application of ointments, salves, and other remedies to burns, all of which, if used, should be applied very sparingly, after the fire has been drawn, so as to avoid drawing the sore and keeping it in an open running condition.

Another mistake commonly made in the treatment of burns is in the removing and renewing of the dressing too frequently. The exposure of a burn or other sore to the air, washing and dressing it, frequently does the sore more harm than good. A burn, when the fire has been drawn, should be dressed with a thin application of the healing remedy and not removed for at least twenty-four hours, and if it feels comfortable, should be permitted to remain for two or three days before removal.

The application of a dressing to a burn is another matter that should be given careful attention. This should be applied in a manner that will exclude air, sand and dirt from the burn, and remain in place until removed, and not permitted to slip off and be pushed on again, as is frequently done.

In case a burn is slow in healing it may be treated with an antiseptic solution of bichloride of mercury. This is a remedy used in surgical operations and is applied by wetting absorbent cotton or lint with it and bandaging it upon the burn. This is a rapid-healing remedy that does not require frequent removal, and has been permitted to remain on amputated limbs after amputation for ten days, with only the temperature of the patient being taken to indicate the progress of healing. In case of a burn, pain would be the indicator for necessity of removing the bandage. This is an excellent remedy for cuts and bruises, also.

Antiphlogistine may be obtained in small cans at drug stores, and its first application to a burn should be from an eighth to three-sixteenths of an inch in thickness. Bichloride of mercury may be obtained in drug stores put up in bottles in tablet form. One of these tablets is to be dissolved in a quart of water and to be used for external application only, as it is very poisonous when taken internally.

Another excellent remedy for drawing fire from burns, and one always at hand in a foundry, is loom clay, or new moulding sand. This material, when moistened and a thick wad of it applied to a burn, excludes the air and gives prompt relief.

Fuel and Blast in Melting

CHAPTER XIV

Combustion and Utilization of Heat

In all forms of combustion and utilization of heat certain conditions are necessary, and this is in no case more marked than in the management of a cupola. For if the fuel is not in a sufficient body and so distributed as to produce the even, high and prolonged temperature necessary to melt the iron sufficiently to pour the work to be cast, then there is a waste of fuel, for the fuel has not served the purpose for which it was consumed. If the iron is not so placed in the cupola as to utilize all the heat of the fuel in melting, then there is a waste of fuel, due to escape of heat produced but not utilized.

In either case, there is uneven melting, and hot and dull iron, and in prolonged heats, a bunging up and bridging over of slag and cinder in the cupola, and perhaps a stoppage of melting altogether. To prevent this occurring, the fuel and iron must be properly placed in charging.

When fuel is being consumed it gradually decreases in bulk and settles down, and this settling down is more marked in a furnace of the cupola type than any other, for the charges of iron and fuel, or load, as it is sometimes called, is supported by the bed of fuel, and as the bed is consumed the load upon it settles down, and if the full melting capacity of the cupola, with the least amount of fuel, is to be realized, the top of the bed must be at or near the top of the melting zone when charging of iron begins, and the charge of iron on the bed, the heaviest the bed will melt, before the fuel settles to the lower edge of the melting zone, which will be indicated by the iron becoming dull near the end of the charge.

In melting the charge of iron placed upon the bed the fuel in the melting zone is consumed and the top of the bed settles to near the bottom of the melting zone, and is replenished by the next charge of fuel, which must be sufficient to bring the top of the bed to the top of the melting zone for melting the next charge of iron, which should be the heaviest the charge of fuel will melt. The indications of it being too heavy will be dull iron near the end of the charge, and if too light a slacking off of the rapidity of melting with waste of fuel, which indicates that the fuel for this charge has not all been consumed to an extent that admits of the charge of iron settling into the melting zone.

This process of renewing the bed goes on throughout the entire heat, whether a long or short one, and if the top of the bed is of a proper height, and each charge of fuel and iron are of proper proportions, level and even, then melting of iron of an even temperature goes on throughout a heat with no loss of heat or waste of fuel. This kind of charging requires the least possible amount of fuel with which iron can be melted in a cupola.

If the charges of iron are not level and even on top the charges of fuel cannot be properly distributed even if made level on top, for it sinks into holes and hollow places in the top of the charge of iron, with the result that there is an excess of fuel in one place and a deficiency in another. If the fuel is not evenly distributed there is an excess of iron in one place and a deficiency in another, with the result, hot iron in one part of the heat and dull iron in another.

One of the causes of uneven charging and melting is the melting of heavy pieces of scrap that cannot be thrown in and have to be dumped from the charging door directly in front of it and against the lining. Such pieces generally stand up higher than the other iron, and receive a lighter covering of coke. Such pieces should not be melted in the following charge in the same place, for more time and heat is required to melt them than pig and light scrap, and if one heavy piece follows another that side of the cupola gets to working cold, and the dull iron mixes with the hot iron, which also becomes dull. When only a limited number of such pieces are to be melted, spread them throughout the heat, and if a large number are to be melted put in some extra fuel and spread them out over the charge. Only in this way can they be melted hot and the cupola kept in good melting condition throughout a heat.

Another and more common cause of uneven melting is the placing of the iron and fuel to be charged in such a position on the scaffold that a man can pick it up and throw it into the cupola without moving from his standing position. This I have noticed invariably results in the greater part of the iron being thrown on one side of the cupola and the coke on the other. The iron and coke, of course, should be placed in the most convenient place on the scaffold for rapid charging, but each man should be required to stand squarely in front of the door and throw his iron in the place that will distribute the heavy and light iron evenly and have the iron perfectly level on top when the charge is all in. The charge of coke should be placed in the cupola in the same way, care being taken to have it level and of an even thickness, that it may not become exhausted in one place while there is an abundance in another. For this causes uneven settling of the stock and uneven melting.

This uneven charging is the cause of more waste of fuel than any other, for the remedy for dull iron is invariably more fuel. This is put in from time to time until it becomes a regular practice to use more fuel. I have found many foundries melting from four or five-to-one that should be melting seven-to-one in their size heat for a cupola.

Coke should never be placed in a cupola in such light charges that it scarcely covers the iron, for this is not a sufficient body of coke to produce a high temperature or a prolonged heat, and with a strong blast is liable to ignite the coke up to the charging door and cause a heavy destruction of lining with dull and dirty iron.

The depth of the charge of coke should be varied with the volume of blast, and should not be less than four inches, and this only for cupolas of very small diameter. For large cupolas, from six to eight inches, and the weight of iron placed upon it should be the heaviest, the depth of coke will melt before coming down dull. The depth of coke charges that will give the best results is a matter that should be standardized for every cupola. The reason for poor charging is that foremen are generally moulders taken from the floor who have had no training whatever in cupola management, either as apprentice or moulder, and are not competent to instruct either the melter or his helpers as to how the work should be done.

Melters as a rule are not highly educated men, and many of them know nothing about the theory of combustion and utilization of heat in a cupola, and work entirely upon the theory that if fuel and iron are placed in a cupola the iron must melt if there is sufficient fuel to melt it, and if the iron is too dull for the work to be cast more fuel is thrown in for the next heat, and this is repeated until slow melting and dull iron is really due to an excess of fuel rather than a deficiency.

A heating stove does not radiate heat to so great an extent when choked with fuel as when only a proper amount is placed in the stove at a time. This is a condition that can readily be remedied by a competent foreman giving the melter and his helpers instructions as to how the cupola should be made up for a heat, and fuel and iron charged, and seeing that his instructions are carried out.

A foreman that understands cupola practice can frequently make a better melter in a few days out of one of his helpers or a new man than from a melter who has his set ways of doing things, which, like the laws of the Medes and Persians, altereth not.

A competent foreman is never wholly dependent upon his melter.

Indications in Melting

When melting iron in a cupola the first charge of iron is placed upon the bed of coke in the cupola. On this iron is placed the charge of coke, and on this coke a second charge of iron, and on this charge of iron the next charge of coke, and so on until the cupola is filled to the charging door.

As soon as the blast is put on the fuel begins to burn away rapidly and the iron to melt, and the entire stock of fuel and iron in the cupola begins to settle down with its own weight, and more charges of fuel and iron are put in until the entire amount of iron to be melted has been placed in the cupola.

In case the top of the bed is too low the latter end of the first one or two charges will come down dull, and continue to grow duller as the melting progresses, unless there is an excess of fuel in the first two charges sufficient to bring the top of the bed up to a proper height for melting the charge of iron.

In a case where iron on the bed comes down hot and fast and gradually grows dull and slow in melting as the charges settle into the melting zone, this indicates insufficient fuel in the charge to melt the iron placed upon it. The top of the bed becomes lower after melting each charge, and the iron gets duller until melting stops.

In case there is uneven charging of fuel and iron the cupola gets to melting in spots or on one side, and there is uneven melting and the iron comes down hot or dull at times until the stock rights itself or gets into such a shape in settling that the melting is very slow or stops altogether.

If there is a deficiency of slag producing flux the cupola soon after the blast is put on begins to clog up with a tough, dry cinder formed from the ash of the fuel, sand and dirt on the pig and scrap, together with the oxide of iron formed in melting, and causes slow and uneven melting and difficulty in dumping.

These conditions more frequently occur and are more noticeable in long heats than in short ones, and in cupolas of large diameter rather than small ones, where there is not room for the fuel to be unevenly distributed to so great an extent, and the heat is a short one.

When a cupola is getting into either of these conditions something must be done to restore it to a normal melting condition before it becomes a dead one and melting stops, and what is done while the cupola is in blast is termed nursing a cupola, to restore it to a healthy melting condition.

In determining these different conditions the only guide the melter or foreman has is the stream of iron as it flows from the cupola, and slag as it flows from the slagging hole.

If the iron is more than seven or eight minutes in appearing at the tap hole after the blast is put on, then the bed has not been properly burned up or is too high. Iron should be charged as soon as the fire begins to show through the top of the bed.

If the iron comes down in five to eight minutes and is hot on the start and becomes dull as the melting of the bed charge progresses, then the bed is too low, which may be due to it having been burned to too great an extent before charging began or to a deficiency of bed fuel. To determine which of these it is, the bed should be carefully watched for the next heat and iron charged at the proper time. If the iron again becomes dull as melting progresses, then the bed is too low and the fuel should be increased for the next heat to an extent that will bring the top of the bed several inches higher when all in.

If the iron comes down hot, but there is a slacking off in the speed of melting as the charges of iron are melted, then there is too great a body of coke in the charge of fuel and the slacking up is due to this being burned away before the iron can settle into the melting zone, and the coke in the charge should be decreased or the charge of iron increased.

If the iron comes dull at the end of melting each charge then the coke in the charges should be increased to an extent that will bring the iron down hot.

The bed and charges of iron and coke should all be systematized to an extent that will give hot, even melting and hot iron by varying the charges of coke and iron until this result is obtained and these charges made the standard. If this is done and each charge of iron and coke made level on top, there will be no trouble in melting and a change will only be necessary when the coke comes in very soft and light. The weight of iron in the charges should then be reduced or coke increased.

This is the system of charging followed in stove plate and benchwork foundries, where the iron is required to be very hot; the remelt is so heavy they use very little old scrap, and their remelt is of a size and shape that admits of an even distribution of the fuel, and they seldom have uneven iron or a poor heat.

Nursing a Cupola

In cupolas in which a large per cent of the iron is old scrap, the size or shape of the scrap may make it impossible to evenly distribute the fuel, and carelessness in charging sometimes places the fuel nearly all on one side of the cupola and iron on the other. The cupola then gets to working cold on one side or in spots and causes uneven settling of the stock, with uneven melting and a strong tendency to clog up and bridge over, and something must be done while the blast is on to prevent this occurring if a long heat is to be run off. This is termed nursing a cupola while in blast.

This condition will be indicated by dull iron or slow, uneven melting, which indicates a deficiency of fuel in the charges or in spots, and a full charge of fuel should at once be put in with a double charge of limestone on it to form a fluid slag, and on this another charge of fuel with the regular charge of iron, with a liberal charge of limestone put in until the double charge of coke has settled into the melting zone.

This will generally right things in a cupola. If it does not fully restore it to a normal melting condition, but shows some improvement a full charge of fuel may be put in with only a half charge of iron upon it.

This may be repeated from time to time until the cupola regains its normal condition. Limestone should be charged freely on each charge to produce a free-flowing slag, to cut away any clogging up of the cupola that may have occurred.

Even with the standard charges and even charging, a condition may arise in long heats, owing to a poor quality of coke, that requires this kind of nursing, and it must be resorted to if the heat is to be run off. A full charge or a split charge of coke may be all that is necessary, but if it occurs more than one day the weight of the charges of coke should be increased to an extent that will prevent it.

A proper slagging is also an important matter in nursing a cupola for a long heat. A thick, tough slag that requires poking the slag hole with a tapping bar to keep it open indicates the cupola is not working open and free or there is not sufficient limestone or shell being charged. In either case the limestone and shell should be increased until there is a hot, free-flowing slag.

These are the methods that have to be resorted to very frequently, more especially in cupolas of a large diameter, to keep it up to a full melting capacity and run off the heat. It is the method resorted to in blast furnace practice where blank charges of coke are sometimes put in for half a day at a time with a liberal charge of limestone to get the furnace working hot, as it is termed, which is indicated by a very fluid, free-flowing slag.

Slagging a Cupola

Limestone and shells are the only substance or material that has been found to produce a satisfactory slag in a cupola that may be drawn out to keep the cupola open and melting freely. When either of these materials are properly used and the cupola properly charged a cupola of any size may be kept continuously in blast as long as the lining will last.

The object in using these materials is to form a fluid slag capable of absorbing the ash of the fuel and dirt and dross of the iron and prevent them forming a cinder that adheres to the cupola lining and builds out from the lining until it greatly reduces the melting value of the cupola or stops melting altogether.

This slag absorbs the refuse, and when drawn off carries it out of the cupola. This system has long been the blast furnace practice of removing ash and refuse of melting from the furnace, and it was first introduced into cupola practice in this country by

Mr. Colliau about forty years ago. Prior to that time limestone or shells were only used in a limited quantity to make a brittle slag for chipping out.

The quantity of limestone required to slag a cupola varies with the quality of the limestone. With a lean stone more is required than with one rich in carbonate of lime. A high ash coke requires more than a low ash coke, and dirty and heavily rusted scrap more than clean, new scrap or pig. Unmilled gates, if a high per cent of them is melted, require more limestone than milled gates, and no definite amount can be stated that will suit all conditions. But 20 pounds of stone or shell to the ton of iron in the charge is a good amount to start with and then vary it to suit conditions, the fluidity of the slag being taken as a guide. A thick, mucky slag requires more stone or shell and an over-thin flowing slag less stone or shell.

The stone is broken into very small pieces and is generally put in on top of the charge of iron. In the very small cupolas of bedstead foundries it is placed on the first charge of iron and each subsequent charge, and the slag hole is only occasionally opened. In the larger cupolas the first flux charged is generally put in on the third to fifth charge of iron, but this is a matter that should be tested to see which charge gives the best results in melting and a clean drop.

The slag may be drawn from the cupola through a separate tap or slag hole, placed in the back or side of the cupola, or be permitted to flow out of the iron tap hole with the stream of iron.

When the tuyeres and tap hole are placed low and the flow of iron is continuous or almost continuous the slag hole is opened after the second charge of iron upon which flux was placed is melted and permitted to remain open during the remainder of the heat.

When the tuyeres or slag hole are placed high for holding iron for a large tap slag only can be drawn when the cupola fills up with molten iron and floats the slag up to the hole. The hole is opened when the slag is up and closed when the iron is drawn out, and the slag drops down below the hole.

When the slag is permitted to flow out with the iron a long spout is used with a pocket in it and a cross bar to catch the slag and throw it out through a lip on the side of the spout. In this case an inch and a quarter tap hole is put in for the iron and slag together and the cupola is not stopped in during the entire heat.

This size of tap hole admits of sparks of iron and slag being thrown out freely during the entire heat. This system is best suited to a cupola placed outside the foundry wall with a spout extending through an opening in the wall into the foundry, and this opening closed with an adjustable apron that may be raised for clearing the tap hole. This arrests the sparks and prevents them burning the moulders when catching in.

If the cupola is already in the foundry a brick wall may be constructed in front of it and the spout arranged as above. The wall should be about three feet from the cupola to give room for making up the spout and removing the slag.

Limiting Fuel in Melting

By careful reading of combustion and utilization of heat in melting by a practical or theoretical foundryman it will readily be seen that the limiting of a foreman or melter to the use of a small amount of coke in melting or requiring them to melt nine or ten pounds of iron to a pound of coke consumed in melting is the height of folly, for the quality of coke varies and sometimes widely with every car, and more of it is required to produce a hot iron with one car than with another.

The bed may be burned to a greater extent for one heat than another before iron is charged and a certain amount of heat has escaped without being utilized in melting and has to be made up. Lack of instructions as to the proper way of charging heavy pieces of scrap iron or carelessness in charging may cause uneven settling of the stock and escape of heat with the result dull iron and dirty casting if the iron is being melted on a close margin of a least amount of coke with which the iron can be melted.

The foreman and melter know that if they melt one bad heat after another with a heavy loss of castings they will lose their job, and the result is that coke is forked into the cupola and no record of it is made on the cupola report, and the cupola report is perfectly worthless as a cost-keeping record of the cost of melting. The founder may be under the impression he is melting nine to one when he may not be melting six to one.

A cupola will not melt up to its melting capacity per hour with a heavy excess of fuel nor will it melt hot or clean iron. Nor will it do good melting with a deficiency of fuel, and the founder's best guide for the use of only a proper amount of fuel in melting is to require fast melting and hot iron.

This requirement will save time in melting, save coke, and reduce scrap castings to a minimum. By dividing the weight of iron melted by the number of pounds of coke purchased and consumed in a given time he can learn the number of pounds actually melted to the pound of coke and the cost of coke in the production of a pound or ton of casting.

During the past few years, when coke was costing anywhere from eight to twenty-five dollars per ton in the yard, every possible means was tried to save coke in melting, and I was called upon more frequently than ever before to locate the cause of dirty castings and trouble in melting. In almost every case I found the trouble to be due to a deficiency of coke in the cupola and oxidation of iron in melting, and I overcame the trouble by an increase of coke in melting, and even with the extremely high price of coke made more money for the founder than when he was saving coke. For he was not only losing the cost of coke consumed in melting but also the cost of labor in moulding the scrap castings, which was no small matter with the high wages being paid moulders at that time.

Iron should be melted fast and be white hot as it flows from the spout. It should be the aim of every foundryman to get his melting up to or near the estimated melting capacity of a cupola per hour as possible. He will then be using only a proper amount of fuel.

Taking Off the Blast During the Noon Hour

I have been asked many times by foundrymen who are melting or contemplating melting all-day heats with continuous pouring if the blast can be taken off during the noon hour and put on again, and satisfactory melting done after the blast has been off for from a half hour to an hour. This is a problem that many founders have tried to solve with varying results.

This kind of melting is generally desired in a cupola of a diameter of from 18 to 40 inches, and it is difficult to keep a cupola of these diameters in good melting condition in an all-day heat, even when the blast is kept on continuously, and far more so when the blast is taken off for a time and put on again.

To keep a cupola of any diameter in blast all day it must be freely slagged and the slag kept in a fluid condition in the cupola that the blast may pass through it as it emerges from the crevices between the pieces of coke through which it has passed. When the blast is taken off these openings are at once closed by the slag, and if the blast is off for a sufficient length of time to admit of the slag becoming stiff and tough the blast cannot penetrate it and melting cannot be renewed.

If the blast finds openings around the lining or in spots where the slag has remained fluid, or if there has only been a thin body of it when this occurs the openings may enlarge to an extent that restores the cupola to a normal melting condition and admits of the heat being run off, but the chilled slag is more likely to act as a shelf upon which slag and iron lodges, and the cupola is soon bridged over and melting stopped.

To prevent chilling of the slag when the blast is off the tuyeres have been packed with sand to exclude all air. This plan has proven a success and also a failure.

Still another plan that has been tried was to have little or no slag in the cupola at the time of taking off the blast, but it was found that this put the cupola in a poor condition for melting before the blast was taken off, and a worse condition when it was put on again.

The slowing down of the blast during the noon hour has also been tried, and when the moulders work piece work one-half of them are kept at work while the others eat. This plan has given good results in some cases and very poor in others.

Another plan that has been tried is to put in a double charge of coke and on this a double charge of limestone at a time that will admit of it having settled into the melting zone at the time the blast is taken off. The object of this is to produce a high temperature at this point as soon as the blast is put on and melt the limestone into a very fluid slag that will cut away any chilling of the slag and clogging of the cupola that may have occurred.

I have found this to be good practice in small cupolas in long heats, even when the blast is not taken off for the noon hour, but like the other plans it sometimes fails to restore the cupola to a normal melting condition.

Foundries in which this kind of melting is desired are generally small foundries making small castings of which only a limited amount of iron is desired and in the melting of which only small cupolas can be used, and although some success has been met with by the various systems described it has generally been found to be more practical to install two cupolas and melt in one up to the noon hour and put the other one in blast for the afternoon melt.

This was the system adopted by the Westinghouse Air Brake Co., Wilmerding, Pa., one of the first companies to install the continuous melting system.

In continuous melting for heavy castings, such as water pipe and car wheels, the iron is caught in a ladle holding from two to five tons and carried to the moulds on a track or by traveling crane, and is poured direct or into pouring ladles, and the pouring gangs arranged to eat their dinner while the large ladle is filling or iron melting.

In large foundries making light castings the moulders generally work piece work and take so little time to eat their dinner that no stoppage in melting is necessary, or they may have some heavy work which they arrange to cast at the noon hour.

Continuous Melting and Pouring in England

In many of the small foundries in England it is the practice to put the cupola in blast in the morning and melt all day and cast the mould as soon as they are closed and clamped.

The moulds are shaken out as soon as the castings are cooled to an extent that will admit of them being taken out and the flask and sand are then used over for another mould. This is done to save floor space in moulding flasks and sand and get a large output of castings from the very small plants.

The cupolas used in melting are small ones of the stationary bottom, draw front type, to which a tank or reservoir is attached for catching or holding the molten iron. This tank is placed in front of the cupola and connected with it by a closed spout, and the cupola is not stopped in during the heat, and the iron as it is wanted for pouring is drawn from the tank.

The cupolas used are small, slow-melting cupolas that are only required to melt iron for two or three moulders on small work in the day's melt, and the iron when drawn from the tank is always too dull to run castings of light section.

This system can be used with large cupolas and by emptying the tank just before the noon hour and permitting it to fill up during the time the moulders are eating their dinner, provided they are not too long in doing so, and no taking off of the blast will be necessary. But I would not recommend it for castings of light sections.

The cupola tank system has been tried out many times in this country, but always abandoned, due to failure to get hot iron from the tank.

The latest try-out of this kind that has come to my notice was in a large agricultural foundry at Springfield, Ohio, where a Baillot hot blast cupola was installed with a tank attachment and proved a complete failure both as hot blast and tank cupola. For the hot blast attachment did not heat the blast to any perceptible extent, and no saving in fuel was attained. Iron sufficiently hot to run agricultural castings could not be drawn from the tank.

For running a continuous stream from the cupola a wide mouth catching ladle from which iron may be poured into the carrying ladle while the stream is running from the cupola into the catching ladle is very much to be preferred to the closed tank system.

Saving Coke in Melting

At no time in the history of foundry practice in this country has the coke-saving fakers had a greater opportunity to work off their coke-saving systems of cupola practice than in the past few years, when coke was selling at as high as twenty-five dollars per ton and every founder was desirous of reducing his consumption of coke to a minimum.

Widely advertised coke-saving systems have been bought and high prices paid for them; high-waged foremen have been employed who claimed they had a system by which they could melt 9, 10 or 12 to 1, with the result, no coke saved, the bottom dropped in the middle of a heat, with loss in output of castings, short moulding floors for the next heat, and full pay for the moulders, with the scrapping of many castings and waste of high-priced coke in remelting scrap casting.

This I have found to be the case in many foundries to which I was called to investigate trouble in melting with a heavy loss of casting. Some few founders have been deceived by false cupola reports and actually believe they were melting 9 or 10 to 1, and give glowing reports of the new system, only to find later on that a car of coke did not melt any more iron than with their old system or foreman.

The cupola is the most economical and rapid-melting furnace in use for the reason that the metal is melted in direct contact with the fuel, and a larger per cent of the heat developed by the fuel is utilized in heating and melting the metal than in any other furnace; and it is only necessary to have a proper distribution of fuel and iron and a proper volume of blast to obtain the best of results in melting from a cupola.

The utilization of heat in a cupola is a matter that I investigated more than forty-five years ago, and found that iron could only be melted within a given space in a cupola and all fuel consumed outside of that space was a waste of fuel; and I introduced at that time and placed in my work, "The Founding of Metals," published in 1877, the present system of placing iron and fuel in a cupola in charges, or layers of fuel and iron, that would admit of the charges of fuel settling into the melting one at a time to melt the charge of iron placed upon it.

This system was at once adopted in place of the system of mixing the iron and fuel as in blast furnace practice, and no man has been able to develop a better system, although many have claimed to do so, but all have failed; and until an entirely new system of placing fuel and iron in a cupola that will utilize a higher per cent of heat in melting is found there is no possible way of saving the carloads and trainloads of coke claimed to be saved by so-called systems.

There have been some important changes made in construction of cupolas and some improvements in blowers since I first began melting. The suggestion I made in my first work of increasing the height of cupola and enlargement of tuyeres has been generally adopted, and cupolas are now made by standard manufacturers of a height and with a tuyere area that utilizes the heat escaping from the melting zone in heating iron in a cupola and preparing it for melting, and admits of a proper volume of blast being supplied for the diameter of cupola, and both fan blowers and the rotary pressure blower have been perfected to an extent that there is no longer any trouble in procuring a blower that will deliver an ample volume of blast for a cupola of any diameter.

Cupolas and blowers having been perfected, it is now up to the foreman and melter to obtain the best of results in melting, and this can only be done by a thorough knowledge of the theory of combustion and heat and its application in cupola melting. To apply this theory in a practical way it is necessary that a foreman or melter should have a practical knowledge of cupola management in every detail, for the shaping of a lining, improper application of daubing, excessive burning of the bed, improper charging, etc., may be the cause of uneven melting, dull iron or a bad heat.

Choking Down the Blast

In my expert work I was called to a foundry to investigate the cause of slow-melting dull iron and the heavy destruction of lining in the melting zone. This destruction was so heavy that from two to three inches of mica-schist, a very refractory lining material, were burned out every heat clear around the lining in the melting zone, and there was very little destruction of lining above this point. The cupola was a No. 3 Whiting of a good height and a proper tuyere area, and a positive pressure blower of a proper size for the cupola was used to supply the blast. I was at a loss to determine the cause of the heavy destruction of lining and poor melting.

I first tried raising and lowering the bed, then varying the weight of coke and iron in the charges, with no better results. I then tried increasing the speed of the plower to give a stronger blast. This made matters worse, and the bottom had to be dropped before the heat was melted. For the next heat I reduced the speed of the blower below that of which it had been running before speeding it up, and got hot iron throughout the heat, with less destruction of lining in the melting zone, but the rapidity of melting was below the estimating capacity of the cupola per hour.

On further investigation I found that the cupola was designed for a five-inch lining, and an eight-inch lining had been put in for safety and to reduce the coke required for the bed for short heats. This reduced the diameter of the cupola six inches, which accounted for the cupola melting below its melting capacity per hour and giving hot iron when the blast was reduced to the proper volume for the diameter of cupola.

In making these tests the iron came down very hot, while the charge on the bed was melting; after this charge was melted, iron began to come down dull and of an uneven temperature. The first charge of coke was increased for the next heat; this melted the charge of iron placed upon it, hotter than in the preceding heat, but the iron gradually grew dull and melted slowly.

The weight of the charges of coke were then increased through the entire heat, but this only caused slow and uneven melting, with an increased destruction of lining in the zone. Blank charges and split charges in the various parts of the heat were then tried, with no better results, and left no doubt that the cause of the heavy destruction of lining in the zone and unsatisfactory melting were due to an excess of blast.

The blast forced into a cupola is composed of about 21% oxygen and 79% nitrogen; the oxygen is a supporter of combustion, and the nitrogen is not. In passing through a cupola the oxygen separates from the nitrogen and is consumed, and the nitrogen passes up through the stock unchanged.

In this case the blast was so heavy that it was choked down by the close-packed stock in the small cupola until the oxygen was burned out of it in the melting zone to an extent that caused a rapid combustion of the coke in the bed and an intense heat that destroyed the lining very rapidly in the zone. This brought the first part of the iron charged down hot, but the coke was consumed so rapidly by the excess of oxygen that the latter part of the charge came down dull, and this was repeated with each charge until the melted iron all became dull.

This is a condition that could only have occurred with a positive pressure blower, for with a fan blower the excess of blast would have been thrown back on the blower, which would have revolved in its own wind.

After reaching this conclusion I advised placing a five-inch lining in the cupola and restoring the blower to its speed before the changes to increase and decrease the blast were made. This was done, and there was no further trouble with uneven melting or dull iron when the cupola was properly charged.

Since this experience I have been called to a number of foundries in which I found a similar condition, and would advise that in all cases where the diameter of cupola is decreased by an increased thickness of lining that the speed of the positive blower be decreased to correspond to the diameter of cupola.

INDEX

THE CUPOLA

CHAPTER I

CUPOLA TUYERES

CHAPTER II

CONSTRUCTING A CUPOLA

CHAPTER III

CONSTRUCTING A CUPOLA—CHAPTER III—(*Continued*)

CUPOLA MANAGEMENT

CHAPTER IV

MELTING

CHAPTER V

CUPOLA LININGS

CHAPTER VI

CHARGING A CUPOLA

CHAPTER VII

CUPOLA FUELS

CHAPTER VIII

CUPOLA AND LADLE FLUXES

CHAPTER IX

CUPOLA BLAST

CHAPTER X

FOUNDRY DEVICES

CHAPTER XI

WHAT CAN BE MELTED IN A CUPOLA

CHAPTER XII

FOUNDRY MISCELLANY

CHAPTER XIII