the banks, at or near the surface of the bath, are fought by shoveling sand and bricks (in the basic furnace, dolomite, bricks, etc.) into the opening with the sand spoon, and turning the hose on the plates on the outside to chill the metal. With all hands from several furnaces on the job, a very mean looking break out can be stopped, but it is hard work and men play out left and right.

A break out, of course, is caused by an improperly closed tap hole or a badly repaired bottom. To guard against break outs in the bottom, large holes should be splashed clear of metal after the heat is tapped, and filled up with sand (in the basic furnace, magnesite), well set in, a layer at a time. Break outs through the front banks are more easily guarded against when the furnace has doors in the tap hole side, through which the front is repaired properly and its condition examined.

Tapping.—In order to get the heat out in a lively stream from the first, the tapping of an open-hearth furnace should be done carefully. Two men are required at the hole, one armed with a narrow shovel and one with a tapping bar. The banked-up sand should be removed cleanly and the filling of the hole dug out over the whole cross-section, until a large red-hot patch is exposed. A vigorous punch of the bar into the center of the filling will then bring the steel quickly, and the stream will almost at once cut out the whole hole. In some cases the bar may have to be driven through with a sledge. At times the steel comes almost of itself, and the men have to work fast and be nimble in getting out of the way as the stream breaks out. The men tapping should have a clear floor left and right to give them space to get away at once in case of too lively a tap. Of late several ingenious tap hole guards have been devised and described in the technical press, for the protection of the men tapping a furnace from the showers of sparks when a heat "taps itself," and their use is strongly to be recommended.

If the tap hole does not at once cut itself out, the melter or man in charge gives the word to "punch her out," whereupon the men on the charging side, who have a heavy bar ready for the purpose, slide this bar in through the peep hole of the door and punch out the hole with a few vigorous strokes.

A hole that cannot be punched through by hand must be opened with the heavy tapping bar, sometimes called the "snot bar." This tool is made of about $1\frac{1}{2}$-in. round steel, and is provided with a handle which can be slipped over it and secured with a wedge. It is driven through the tap hole with sledges, the handle attached

and wedged fast, and is then backed out of the hole by sledging on the handle. When the steel comes, quick work is necessary to save the bar.

If this procedure will not open the tap hole, it is because steel has run into the filling and frozen, and the chances of getting the heat out in time to use it are poor. Two methods of opening such a hole are possible, of which one is to bank charcoal against the filling, if the latter is red hot, cover it with sand, and blow up the fire with a gentle blast of air introduced through an iron pipe. This method is slow and uncertain, as it depends upon heating up the steel plug in the tap hole enough to melt it. This is facilitated by the absorption of charcoal by the steel, resulting in the lowering of the melting point of the steel by the increase in its carbon content.

A far better way is to go at the plugged hole at once with an oil or gas burner, and heat the steel up until it starts to melt and run. Then the oil can be shut off and a strong blast of air alone directed upon the melting metal. The air oxidizes enough of the iron to FeO to keep the steel at melting point by the heat of combustion of the metal itself, and with air alone a hole can be melted through the plug and back to the fluid bath behind. It is a lively job for the operator, as he is exposed to a shower of slag and scintillating particles of steel that pour from the hole and keep him dodging, and without his glasses he is in danger of having an eye badly burned.

Meanwhile, the charge in the furnace is, if possible, kept at the proper composition by additions of pig iron, ferrosilicon, etc., and sometimes the steel is saved as a heat; but, as already stated, a badly plugged hole frequently means a heat poured into ingots for scrap, and a furnace bottom deeply cut into; indeed, if the hole is not opened in an hour or so, the proceedings may be enlivened by a break out. Such a badly plugged hole means that it was not scraped clean and carefully closed after the preceding heat was tapped.

The Acid Process—Melting.—For the usual pig and scrap method in the acid furnace, the charge consists of from 20 to 35 per cent. pig and the rest scrap. Much less pig than this can be charged, but in order to get a bath composed largely of scrap, which necessarily melts very low in carbon, hot enough to tap, a good deal of pig iron has to be thrown in to make the steel boil.

As this is a discussion of the steel foundry, the all pig-iron process (either acid or basic) is automatically excluded from consideration,

since we shall have to remelt in every heat from 20 to 40 per cent. of our own scrap, the proportion largely depending upon the size of our castings and the number and size of the heads used on them.

The high silicon content of the foundry scrap which we have to remelt greatly affects the calculation of the charge. It is in general the best practice to so proportion the silicon and manganese of the charge that these elements will be practically eliminated when the bath is melted. In a producer gas-fired furnace, we can assume a good composition for the charge as carbon 1.20 per cent., manganese 1.00 per cent., silicon .50 per cent. In an oil furnace, the silicon, manganese, and sometimes carbon, must be higher. Assuming that we have 30,000-lb. charges, one-third our own scrap (carbon .25 per cent., silicon .30 per cent., manganese .60 per cent.), pig iron at carbon 4 per cent., silicon 1.5 per cent., manganese 2.0 per cent., and low phosphorus scrap at carbon .15 per cent., silicon .10 per cent., manganese .40 per cent., let us see the proportions of pig we shall have to use.

Material	Weight	Weight, lb.		
		C	Si	Mn
Our own scrap.................	10,000	25	30	60
Purchased scrap..............	12,000	18.0	12	48
Pig iron.....................	8,000	320.0	120	160
	30,000			
		363.0	162	268
		1.21%	.54%	.89%

Such a mixture will melt quite free from silicon and manganese, and probably at from .70 to 1.00 per cent. carbon. The consumption of ore should not exceed 6 per cent. of the weight of the charge, and on such heats will be found to average well below this figure. It is possible for quicker running to reduce the pig iron so that the carbon shall be about 1.00 per cent. as in the next example.

Material	Weight	Weight, lb.		
		C	Si	Mn
Our own scrap.................	10,000	25	30	60
Pur. scrap...................	13,500	20.25	13.5	54
Pig.........................	6,500	260.00	97.5	130
	30,000	305.25	141.0	244
		1.01%	.47%	.81%

Pig iron very high in silicon and low in manganese may frequently cause embarrassment, as may be seen from the following calculation, based on pig of 3.0 per cent. silicon, .30 per cent. manganese.

Material	Weight	Weight, lb.		
		C	Si	Mn
Our own scrap.................	10,000	25	30	60
Pur. scrap...................	13,500	20.25	13.5	54
Pig.........................	6,500	260.00	195.0	19.5
	30,000	305.25	238.5	133.5
		1.01%	.79%	.44%

This condition may easily become complicated by the availability of purchased scrap consisting largely of cast steel averaging .30 per cent. silicon. The use of high proportions of this scrap, or of high silicon pig, will result in heats that melt high in silicon, with the result that much time is spent in the elimination of the silicon by means of ore. Confronted with such conditions we must cut down the proportion of pig iron so that the charge will be low in carbon, yet contain enough silicon, when melted, to protect the carbon from oxidation. Our bath will then melt at about the carbon content of the charge, and we can run it down with little or no ore; or if it melts too low in carbon and is hard to get hot because it will not boil, we can "pig" it to assist operations.

Many of the low phosphorus pigs that are available in the East to-day are very low in manganese also, averaging about .30 per cent. When these pigs are used, the proportion of manganese in the bath will be low, with the result that the amount of manganese oxide available for the slag will be small. Consequently the proportion of iron oxide in the slag will be high, and the loss of iron correspondingly increased. (Campbell[1] has shown that the figure $FeO+MnO$ in acid open-hearth slags is approximately a constant.) This may be offset by the use, when available, of manganese steel scrap as a part of the charge.

Charging ore with the pig and scrap is a possible method of hastening the elimination of silicon and manganese from the bath while melting, but is not often resorted to because of the effect on the bottom. The FeO of the ore takes up SiO_2 whenever it can get at the hearth, cuts the bottom severely and forms volumes of slag.

[1] "The Manufacture and Properties of Steel," 2d Ed., p. 272.

In charging the acid furnace all the pig iron is placed upon the bottom, and the scrap on top of the pig. This method is followed to prevent the severe cutting of the bottom caused by the iron oxide formed on the melting scrap coming immediately in contact with the silica bottom and absorbing SiO_2, with consequent formation of slag and the loss of iron. By interposing a layer of pig, which melts first, a pool of molten metal is formed into which the melting scrap drops, and the slag floats on this bath from the first. By floating on molten pig, much of the FeO is reduced by the carbon, silicon and manganese of the pig, and the iron saved.

In some shops the scrap is charged first, with the idea that if the pig is on top it will melt first and flow over the scrap, whereby the iron of the latter will be protected from excessive oxidation by the carbon, silicon and manganese of the pig. This protection, however, is only partial at the best, and probably the advantage gained is more than offset by the increased loss of iron oxide formed on the scrap, which comes at once in contact with the bottom and unites with the SiO_2 of the sand to form slag, before the pig iron can melt and run down to head it off from the bottom.

Charging should if possible be completed at one operation. Sometimes when a great deal of light scrap has to be melted, it is impossible to get it all in at once, though much can be done by charging scrap into say the right-hand end of the furnace, with the flame entering from the left, then reversing the valves and filling up the left-hand end, reversing again and charging more scrap at the right. During the charging of the left side, the metal on the right is heated up and sinks down, making room for more. Too much light scrap is a great nuisance, as it not only increases the loss of metal but also delays charging and melting. Turnings are especially hard to melt, as they stick to the bottom in lumps and have to be poked off with a bar.

In handling the open-hearth furnace, heated with producer gas, it is desirable to use an even flow of gas, and as little of it as possible. When the charge is cold, the flame will be dark at the best, and a good supply of air will be needed to burn the gas. The gas valve should be opened to about the point at which it will be kept; the stack damper raised just enough to carry away the waste products, but not enough to draw the gases so strongly that the flame will "race" through the furnace; and air enough admitted to make the flame look as white as possible. If the gas is being fed so fast that a steady flame pours out of the peep holes in the doors, especially

if raising the stack damper will not keep the flame in the furnace, too much gas is being fed and the furnace being "crowded." By keeping an eye on the top of the stack, waste of gas can be guarded against. The furnace operator and the gas man have to get used to each other; if the former keeps his supply of gas regular by using a constant opening of the valve, his gas man soon learns how often he has to dump coal in the producers to maintain even pressure, and things will go smoothly. A furnace man who constantly makes large shifts in the position of his gas valve, alternately draining the producers of gas and nearly blowing the tops off them by shutting down his valve, does not know his business and his gas man will hate him.

The flame should be regulated chiefly by shifting the stack damper and air-supply valve. As soon as the charge begins to get hot (and looks red through the blue glasses), the furnace man should begin to shut off the air supply a bit at a time, and try to make the flame roll through the furnace, hanging well down into the stock, and moving slowly. The flame should look as white as possible, free from dark spots and flickering; and neither a short flame reaching only part way into the furnace, nor a flame so long as to be still burning at the far end, should be carried. The former means either too little gas or too much air, and results in heating the charge mostly at one end and oxidizing it severely; the latter means too much gas, which will continue to burn quite uselessly in the checkers and waste fuel scandalously. Above all, the flame should roll slowly along, hugging the stock and playing through it, should be white, and long enough to heat the whole length of the hearth.

With such a flame, the melting stock will "honeycomb," and melt down rapidly and evenly; it will be clear at a glance that the metal is hot throughout, a thick section being nearly as hot in the middle as at the surface. A swift, short flame, dragged along by the draught of a wide open stack damper and fed with too much air, "glazes" the stock so that it melts chiefly in a thin layer at the surface, and largely at the top of the pile. Such melting oxidizes the metal badly, wasting iron and making the steel "wild" from excess of dissolved oxide.

At all times, the furnace man watches his roof, walls, and outgoing port closely, keeps the flame down to the bath (and so away from the roof), and slacks the temperature when he sees his brickwork giving signs of starting to melt. By shutting off the air, and lowering the stack damper, the temperature is kept down.

Natural gas or oil firing should be handled along the same lines, though changes in the fuel supply are not so undesirable.

When the charge is "down," and nearly all the floating pieces have melted, the first helper gets busy with his bar and pokes all scrap free from the bottom. It may take him some time to do this, especially if much light scrap and turnings have been charged, as these stick to the bottom like limpets.

When all is melted, the bath should be well stirred with the bar, and the "raise" noted. By this is meant the height to which the slag boils over the bar as it is moved about. The colder and "wilder" the metal, the higher this boil will be. The boiling produced by this rabbling has the effect of freeing the steel from oxides by bringing it into contact with the slag.

A test of the metal is then taken by means of the small test spoon, which should be first warmed in the furnace a moment, then well coated with slag, then dipped deep in the bath and rapidly withdrawn. A small test mould is filled, and the metal left over poured slowly from the spoon to judge its temperature. If it pours clean from the spoon to the last drop, it is very hot. The more of it freezes in the spoon, the colder and wilder the metal. A little of the slag adhering to the handle of the spoon is saved from each test; by its color the progress of the elimination of iron oxide is watched. When the steel is cold and wild, it scintillates and "rises" strongly in the test mould. Another means of judging the temperature of the bath is the manner in which it melts away the bar used for stirring it up; a hot heat cuts a bar off quite square, a cold one leaves the end "rat-tailed." The heat should be hot before oreing is started.

By the fracture of the test piece or by color carbon analysis, the melter estimates the carbon of the bath and the amount of ore needed to eliminate the carbon to the desired extent. The helpers throw in ore while the first helper swings doors and watches the behavior of the bath, which, unless still high in silicon, begins to boil violently as the ore is thrown in. If much ore is needed, it cannot be added all at once, or the bath will "boil over." The boiling increases in violence only slowly up to a certain point, when the addition of one or two more chunks of ore will bring the whole bath boiling up, and slag and metal will run out the door and all over the floor. At the same time, the great amount of CO suddenly evolved (and burning to CO_2) so fills the furnace with gas that the flame pours from all openings in volumes and the neighborhood becomes decidedly unpleasant. Should a "boil over" occur, the reversing valves should be thrown "on center" at once, to shut gas from the furnace, and if the boil does not subside, the gas should be shut off, the reversing valves thrown over again, and no more gas admitted till things quiet down. It does not do to leave the reversing valves on center long, as it generally heats them badly, but a "boil over" comes so quickly that to throw the valves on center is the only way to shut off the gas in time to do any good.

The boiling produced by the ore should be maintained by further additions, until in the opinion of the melter enough has been added to eliminate the carbon to the desired degree. When the first effect of the ore begins to wear off, the bath should be stirred with the bar and a second test taken. If enough ore has been charged, this second test should show greatly reduced carbon content; and a third taken half an hour after the second should show still lower. Should the second test show too little reduction of carbon, more ore must be added; the same is true after two or more tests if the carbon ceases to "slide down" fast enough, and frequently more ore will have to be added to keep up a proper rate of elimination. For the production of really fine steel, however, the effect of the ore should be pretty well worn off an hour or two before tapping, and ideal practice is to get it all into the furnace as soon as possible after melting, and have the carbon "slide down" rapidly at first, then less rapidly and then very slowly, taking an hour to make the last 8 or 10 "points." By this practice the FeO in the slag available for oxidizing silicon, manganese and carbon is practically all exhausted before the heat is tapped, and the FeO is largely eliminated from the steel and taken into the slag. As the effect of the ore wears off the "raise" becomes less, the slag grows less black and watery, and the metal pours more cleanly from the test spoon.

Should too much ore have been added, so that the carbon is "racing" down, the bath will be practically carbonless before it has had time to get hot, may even freeze up, if the melting has been done with a very short, oxidizing flame. To prevent this, pig iron or ferrosilicon must be thrown in until the carbon content is held stationary. Ferrosilicon is used when the bath is hot, but losing carbon too rapidly. The silicon uses up the oxygen of the ore without making the bath boil, and generally will prevent the carbon from dropping further. Pig iron is used when the bath has to be much heated up without further elimination of carbon. The boiling produced by the oxidation of the carbon of the pig greatly assists

in getting the bath hot; and, of course, if enough pig is added the carbon of the bath will be kept up.

Should a heat freeze, which happens only if such a "sharp" flame has been used in melting as to oxidize most of the carbon, silicon and manganese before the furnace is hot enough to maintain the resulting low carbon metal fluid, pig iron and spiegel or ferromanganese, are thrown in and melted, and more added as necessary until the fluid bath of metal high in carbon, silicon and manganese has taken up the solid or semi-solid metal beneath. This is a long, tiresome job, eats into the bottom of the furnace tremendously, and results in a heat poured into scrap, as the cutting of the bottom compels the tapping of the metal as soon as it is liquid enough to run out.

The temperature of the steel is followed by the indications already described. When the carbon is low enough to tap the heat, the metal should be so hot that it will pour out clean or nearly clean from the test spoon. If it will not, the temperature should be increased, holding the carbon up if necessary by throwing in pig iron or ferrosilicon, until the steel will pour reasonably clean. If the ferrosilicon, pig, or ferromanganese used as recarburizers are added in the furnace, a last test after they are melted does not come amiss. This last test, if the silicon (or both silicon and manganese) have been added, should pour perfectly clean from the spoon, and the test should lie flat in the mould.

Some furnace men add ore till the carbon is racing down and the steel full of oxides, the tests skulling the spoon and scintillating and rising strongly in the mould, throw in ferrosilicon and pig iron to check the elimination of carbon, tap the heat as soon as these are melted, add their ferromanganese in the ladle and pour their steel. They melt their metal hot and keep it hot, so that it at least pours. But it is full of oxides, "raw" and "wild" in the moulds, and of poor quality. By heavy doses of manganese and silicon, and frequently of aluminum, the steel is quieted (freed of oxide and gases) enough to make fairly sound castings; but it is not good steel. These are the shops where the makers of "final deoxidizers" make a great hit, and they do it partly by the use of "final deoxidizers," but largely by so improving the practice that when the heat is tapped, the oxides are largely eliminated to start with.

The French metallurgists have worked out a method of deoxidizing the slag (and hence the steel), in acid open-hearth work, to an extent much greater than is possible by simply allowing ample time

for the effect of the ore to wear off. This consists in sprinkling the slag, after the bath is sufficiently hot and the available oxide pretty well boiled out, with crushed bauxite or loam (containing alumina in considerable quantity), and crushed coke. The adding of these materials has to be carried out with great judgment and skill, the loam, and especially the coke, being spread evenly over the surface of the slag so that none falls in a mass at one point. This involves much dexterity with the shovel, as, of course, if coke falls in a mass at one point it is very liable to sink through to the bath and add carbon to it.

The action of these additions is to eliminate the oxides of iron and manganese from the slag by the reducing action of the coke, according to the usual reactions,

$$FeO + C \text{ equals } Fe + CO$$
$$MnO + C \text{ equals } Mn + CO$$
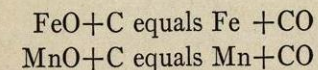
while the alumina replaces them in the complex silicate which is the slag. Carefully carried out, this procedure results in a slag nearly white, quite free from the brown color of FeO and nearly free from the green of MnO; though of course these oxides are not entirely eliminated. Yet skillful melters will make these additions until the slag (and hence the steel) is remarkably free from oxides; and the steel so made is of exceedingly high quality. Steel men in this country have, so far as the author is aware, never attempted (or at least never adopted) this procedure and many of them appear never to have heard of it. In these days of final deoxidizers, perhaps we shall see it used.

When the heat is tapped the furnace men scrape and close the tap hole, warm up the furnace a bit, and shovel sand all around the slag line of the hearth to repair the damage done by the slag. What can be reached by shoveling is so repaired, the out of the way spots in the corners are got at with the sand spoon. The furnace is made hot enough to "set" the sand and is then ready for the next heat.

Typical Heats.—In order to illustrate the procedure in handling an acid open-hearth furnace, the history of a few typical heats is shown in the tables that follow. In these, the charges weigh 30,000 lb., and a "Base" of 29,000 lb., is taken as the approximate weight of steel to be obtained. The analyses given are for the charge, the steel desired, and that obtained. The symbol .04 signifies that .04 per cent. is the highest percentage of an element that will be accepted. The phosphorus and sulphur content obtained are in some cases

lower than that given for the charge. This is explained by the fact that the latter is figured on known maximum contents of the pig iron and scrap used. The pig iron in this plant was kept in piles according to its phosphorus and sulphur, and each pile was known to be *below* such and such a figure. Similarly the different grades of scrap were known not to *exceed* certain figures.

The symbol R equals 1″, or R equals 2″, etc., signifies the height to which the bath boils when stirred, as already described. This shop was run for the production of steel upon which very close control of analysis was demanded, and a small laboratory for running "color carbons" on the tests was located in the open-hearth building. A color carbon analysis can be run in about 20 to 25 minutes, so that the men in charge are kept well posted on the analysis of the bath.

The symbol BR represents the last test taken before the recarburizer is added. The carbon of this test has to be estimated; "carbon estimated," in the tables, refers to it. Comparison with the analytical results, in the "history of heat," shows the very accurate judgment of the melters.

Heat (1) was chosen to illustrate a case in which not only was no ore added to decarburize the bath, but also, in order to get the steel hot without running the carbon down too far, a considerable amount of pig had to be added. The temporary rise in the carbon content after the addition of the pig, followed by renewed elimination of carbon, is well shown.

The slag of this heat was brown throughout. This refers to the color of the fracture of the cold slag, and is used as an indication of the degree of oxidation of the bath. When the bath is first melted the slag is nearly black, very thin and fluid, and consists largely of silicate of iron. The steel in contact with such a slag will be full of oxide. During the "working" of the heat, the black changes to a brown and this gradually to a greenish-brown or greenish-gray color. The green shades indicate the presence of MnO in the slag, and a much decreased oxidation of the bath.

The limestone added to this heat was for the purpose of thinning the slag. Frequently, especially on nickel-steel heats, the slag absorbs so much silica from the bottom of the furnace as to be almost infusible, and in these cases limestone is used to lower its melting point, and hence thin it. When, on the other hand, the slag is too thin and watery because it contains an excess of FeO, loam is added to thicken it.

Heat (2), made in the same furnace as (1), though quiet the first time it was rabbled (that is, there was no "raise" over the bar), became very wild, with a 3-in. raise, after the addition of the ore, and the slag was very thick and had a strong tendency to remain brown. These two conditions, pointing to a bath containing a great deal of oxide, grew less marked when the steel was ready to tap. The normal loss of manganese (and carbon and silicon) was to be expected, and was obtained. Thus .75 per cent. of manganese was added and dropped to .63 per cent., and the metal was raised to .32 per cent. carbon, which dropped to .27 per cent. Reference to heat (1), in which no ore was used, shows that there was a slight gain in manganese in that heat in spite of the 2-in. raise and the brown slag, which tend to show an oxidized heat.

Heat (3) went into the same casting as heat (2). The ore was evidently added before it was known that this heat was to wait for heat (2), and had the usual effect of sending the carbon down rapidly. In fact, too much ore was added for really good practice, as the carbon was already low and an accurate estimation of it would have dictated a much smaller addition, or none at all. Had it been known at the first that this heat was to wait for heat (2), it would have been run like heat (1), no ore at all added, and the heat allowed to run down slowly. As it was, a heroic addition of pig was needed to keep the carbon up, and it was considered advisable to use 12 per cent. ferrosilicon and charge it in the furnace, in order to counteract the oxidation resulting from the elimination of the carbon to such a low point. That the silicon had the effect of quieting the bath thoroughly is evidenced by the fact that no manganese was lost in recarburizing.

Heat (4) is in every respect a normal one. All the recarburizer was added in the furnace so that a heavy addition of manganese (1.01 per cent.) was needed, in order to obtain .75 per cent.

Heat (5) illustrates the practice of charging a certain amount of scrap (billets in this case), near the end of the run, after the steel is hot. The object of this is to produce vigorous boiling in the bath, exactly as the rod makes the steel boil, in order to facilitate the removal of oxides from the metal. In other respects the heat is not unusual, though the amount of ore required to eliminate the carbon is higher than in the first four heats. This was due largely to the higher silicon and manganese of the charge.

In heat (6), a great deal of ore was necessary to eliminate the carbon. In this heat, the steel melted high in carbon and vigorous

measures were necessary to get things going. A heat made soon after this one, in the same furnace, contained a great deal of foundry scrap (high in silicon), lay flat and not boiling when melted (because the silicon was still present in considerable quantity and protected the carbon from oxidation), and though the steel melted at only 1.25 per cent. carbon, 2200 lb. of ore were required to bring the carbon to .19 per cent. Where much steel foundry scrap, with its comparatively high silicon, has to be melted, this condition will be faced daily unless provision is made for the high silicon in the scrap by using low silicon pig, or less pig than usual, as already described.

(1) 15-TON ACID FURNACE—PRODUCER GAS—CASTINGS
CHARGE

Low phosphorus pig . . . . 6,000 lb.
Billets. . . . . 12,700 lb.
Scrap. . . . . 11,300 lb.

30,000 lb.
Base. . . . . 29,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge............	1.12	.90	.39	.035	.034
Aimed for........	.40	.65/.70	.28/.32	.04	.04
Obtained.........	.40	.75	.33	.026	.033

Carbon estimated. 35
Carbon added. 085
Manganese added. 73
Silicon added. 352

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si lb.
Ferrosilicon.	200	4.24	. . . .	100.00
Ferromanganese.	265	16.59	212.0	1.33
Pig.	100	4.00	.4	.80
		24.83	212.4	102.13
		.085%	.73%	.352%

HISTORY OF HEAT

Time	No. test	Item	Carbon
5.30 to 6.50 p. m.		Charged.	
2.00 a. m.		Melted	
2.05 a. m.	(1)	R 1″.	.75
2.20 a. m.		100 lb. limestone.	
2.40 a. m.	(2)	R 2″.	.55
3.10 a. m.	(3)	R 2″.	.44
3.40 a. m.	(4)	R 2″.	.37
3.55 a. m.		700 lb. pig.	
4.15 a. m.	(5)	R 2″.	.38
4.45 a. m.	BR	R 2″.	.34
4.50 a. m.		100 lb. pig.	
5.00 a. m.		Tapped.	
		200 lb. ferrosilicon, 50% } in ladle	
		265 lb. ferromanganese, 80% }	
		Slag light brown throughout.	

(2) 15-TON ACID FURNACE—PRODUCER GAS—CASTINGS
CHARGE

Low phosphorus pig. . . . . 6,000 lb.
Billets. . . . . 24,000 lb.

30,000 lb.
Base. . . . . 29,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge............	1.22	.86	.46	.042	.036
Aimed for........	.25	.65/.70	.28/.32	.05	.05
Obtained..........	.27	.63	.32	.033	.039

Carbon estimated. 24
Carbon added. 073
Manganese added. 744
Silicon added. 37

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si lb.
Ferrosilicon.	210	4.45	. . . .	105.0
Ferromanganese.	270	16.90	216	1.35
		21.35	216	106.35
		.073%	.744%	.37%

HISTORY OF HEAT

Time	No. test	Item	Slag	Carbon
1.30 to 2.50 a. m..........	......	Charged.........		
12.00 Noon...........	......	Melted.........		
12.05 p. m........	(1)	Quiet...........	Brown........	.72
12.10 p. m........	......	600 lb. ore.......		
12.45 p. m........	......	200 lb. ore.......		
1.05 p. m......	(2)	R 3″	Greenish brown thick }	.55
1.10 p. m......	......	5 shovels loam...		
1.35 p. m......	(3)	R 3″	Yellowish brown.	.47
2.05 p. m......	(4)	R 2″	Yellowish green..	.36
2.55 p. m......	BR	R 1″	Yellowish green..	.25
3.00 p. m......		Tapped.........		
....		210 lb. ferrosilicon, 50% } in ladle		
....		270 lb. ferromanganese, 80% }		

(3) 40-ton Acid Furnace—Producer Gas—Castings
CHARGE

Low phosphorus pig.....................	17,200 lb.
Scrap billets.........................	13,300 lb.
Scrap.............................	19,700 lb.
Turnings...........................	7,900 lb.
Scrap ingots.........................	27,900 lb.
	86,000 lb.
Base.............................	84,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge............	1.22	.86	.46	.042	.036
Aimed for........	.25	.65/.70	.28/.32	.05	.05
Obtained.........	.26	.69	.32	.032	.038

Carbon estimated................................	.09
Carbon added..................................	.157
Manganese added...............................	.689
Silicon added..................................	.393

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si lb.
Ferromanganese..............	650	40.69	520	3.25
Coal.......................	100	50.00		
Ferrosilicon.................	2820	41.17	59.22	327.12
		131.86	579.22	330.37
		.157%	.689%	.393%

HISTORY OF HEAT

Time	No. test	Item	Carbon
9.55 to 10.25 p. m.........	....	Charged	
7.50 a. m..........	....	Melted	
7.55 a. m........	(1)	R 2″	.65
Several lots........	....	1000 lb. ore	....
9.10 a. m........	(2)	R 3″	.37
10.10 a. m........	(3)	R 2″	.26
12.10 p. m........	(4)	R 2″	.12
1.10 p. m........	(5)	R 2″	.09
1.45 p. m........	....	1000 lb. pig	
2.10 p. m........	(6)	R 2″	.11
2.45 p. m........	BR		.10
2.50 p. m........		2820 lb. 12% ferrosilicon (hot)	....
3.05 p. m........		Tapped	
....		650 lb. ferromanganese (80%) } in ladle	....
....		100 lb. hard coal }	

(4) 15-ton Acid Furnace—Producer Gas—Nickel Steel
CHARGE

Low phosphorus pig...................	4,800 lb.
Washed metal	3,600 lb.
Nickel-steel scrap...................	14,700 lb.
Scrap billets.......................	900 lb.
Nickel plaquettes...................	356 lb.
	24,356 lb.
Base...............................	24,000 lb.

ANALYSES

	C	Mn	Si	P	S	Ni
Charge............	1.60	.79	.33	.028	.027	
Aimed for........	.38/.42	.65/.75	.14/.18	.03	.03	3.50
Obtained...........	.38	.75	.11	.024	.04	3.29

Carbon estimated...............................	.28
Carbon added.................................	.159
Manganese added..............................	1.01
Silicon added.................................	.177
Nickel melted.................................	2.44
Nickel added.................................	1.06

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si lb.
Ferrosilicon.................	310	4.52	6.51	35.96
Ferromanganese.............	285	17.84	228.00	1.43
Pig.......................	350	16.00	7.00	5.25
		38.36	241.51	42.64
		.159%	1.01%	.177%

HISTORY OF HEAT

Time	No. test	Item	Ni	C
6.45 to 7.40 p. m..........		Charged	....	....
1.30 a. m..........		Melted	....	....
1.35 a. m..........	(1)	R 1″	2.44	1.12
1.50 a. m..........		200 lb. ore	....	....
2.15 a. m..........		200 lb. ore	....	....
2.45 a. m..........	(2)	R 1″	....	.55
3.00 a. m..........		100 lb. limestone	....	....
3.15 a. m..........	(3)	R 3″	....	.41
3.45 a. m..........	(4)	R 2″	....	.33
4.15 a. m..........	BR		....	.25
4.16 a. m..........		262 lb. Ni plaquettes	....	....
		⎧ 310 lb. ferrosilicon (12%)	....	....
		⎪ 350 lb. pig	....	....
4.27 a. m..........		⎨ 285 lb. ferromanganese	....	....
		⎩ (80%)	....	....
4.35 a. m..........		Tapped	....	....

Slag heavy—dark brown at first, then light greenish gray.

(5) 15-TON ACID FURNACE—PRODUCER GAS—FORGING INGOTS

CHARGE

Low phosphorus pig	6,000 lb.
Scrap....................................	17,500 lb.
	23,500 lb.
Billets on floor............................	500 lb.
	24,000 lb.
Base.....................................	23,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charged............	1.38	1.03	.53	.035	.047
Aimed for..........	.30/.35	.60/.70	.14/.18	.045	....
Obtained............	.34	.64	.14	.032	.047

Carbon estimated...................	.27
Carbon added.....................	.075
Manganese added..................	.71
Silicon added.....................	.18

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Si lb.	Mn lb.
Ferrosilicon.................	350	5.11	40.6	7.35
Ferromanganese..............	195	12.21	.98	156.00
		17.32	41.58	163.35
		.075%	.18%	.71%

HISTORY OF HEAT

Time	No. test	Item	Carbon
6.20 to 7.30 a. m..........		Charged....	....
1.15 p. m..........		Melted....	....
1.20 p. m..........	(1)	Quiet....	1.20
1.25 p. m..........		400 lb. ore....	....
1.55 p. m..........		200 lb. ore....	....
2.25 p. m..........		200 lb. ore....	....
2.45 p. m..........	(2)	R 3″	.93
2.50 p. m..........		200 lb. ore....	....
3.15 p. m..........	(3)	R 3″	.82
3.20 p. m..........		100 lb. ore....	....
3.45 p. m..........	(4)	R 2″	.59
4.15 p. m..........	(5)	R 2″	.47
4.45 p. m..........	(6)	R 2″	.35
4.50 p. m..........		500 lb. billets....	....
5.15 p. m..........	BR		.28
5.25 p. m..........		350 lb. ferrosilicon (11%)....	....
5.35 p. m..........		Tapped....	....
		195 lb. ferromanganese in ladle	....

Slag light brown, greenish at end.

(5) 15-TON ACID FURNACE—PRODUCER GAS—FORGING INGOTS

CHARGE

Low phosphorus pig	4,800 lb.
Washed metal..........................	3,600 lb.
Scrap.................................	15,100 lb.
	23,500 lb.
Base..................................	23,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge.............	1.60	.79	.33	.028	.027
Aimed for..........	.24/.28	.60/.65	.14/.18	.06	.035
Obtained............	.25	.61	.13	.029	.04

Carbon estimated...................	.17
Carbon added.....................	.088
Manganese added..................	.716
Silicon added.....................	.185

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si lb.
Ferrosilicon.................	350	5.11	7.35	40.6
Pig.......................	75	3.00	1.50	1.13
Ferromanganese.............	195	12.21	156.00	0.98
		20.32	164.85	42.71
		.088%	.716%	.185%

10