HISTORY OF HEAT

Time	No. test	Item	Carbon
6.00 to 6.50 p. m		Charged	....
1.00 a. m		Melted	....
1.05 a. m	(1)	Quiet	Test too hard to drill.
1.30 a. m		700 lb. ore	
2.00 a. m		300 lb. ore	
2.40 a. m		200 lb. ore	
3.15 a. m		200 lb. ore	
4.00 a. m	(2)	R 4"	.62
4.30 a. m	(3)	R 3"	.50
4.35 a. m		300 lb. ore	
5.00 a. m	(4)	R 3"	.35
5.30 a. m	(5)	R 2"	.27
6.00 a. m	(6)	R 2"	.21
6.30 a. m	BR		.15
6.37 a. m		350 lb. ferrosilicon (12%). 75 lb. pig.	....
6.50 a. m		Tapped	....
		195 lb. ferromangenese (80%) in ladle.	

Slag thin, dark green.

The Basic Process—Melting.—The charge in the basic furnace generally contains more pig iron (and cast iron scrap) than is used in the acid process, and up to 50 per cent. of pig is often charged in regular pig and scrap practice. It is not at all necessary to use such heavy percentages of pig, more especially when soft steel is being melted, since such heats frequently melt very high in carbon, and consequently require considerable amounts of ore. As in the acid process, it is best if possible to charge such a mixture that the bath when melted shall contain 1 per cent. of carbon or less, and very little silicon or manganese. The latter, however, seldom goes below .20 per cent. in basic practice. In order to secure this analysis in the molten bath, the carbon in the charge should be about 1.50 per cent., manganese about 1 per cent., and silicon .50 to .60 per cent. The examples of basic heats shown a little further on illustrate several typical charges, and it will be noted that in some cases a very high carbon charge will melt quite low in carbon.

The limestone charged commonly amounts to from 10 to 15 per cent. of the weight of the metal. As in acid practice, the ore con-

sumption should not exceed 6 per cent. of the weight of the steel.

In basic practice it is essential, in order to effect the elimination of phosphorus and sulphur, that a highly basic slag be formed from the start. The limestone is, therefore, charged first. On top of the stone is placed the scrap, and the pig is put in last. Because the bottom is basic, neither the limestone nor the cinder from the melting scrap can attack it and form slag, so that this method of charging is quite safe and enables us to secure a basic slag as soon as melting starts. Moreover, the scrap is protected from excessive oxidation by means of the carbon, silicon and manganese of the pig iron, which melts first and soon partially buries the scrap. There is only one drawback to this order of charging, which is that when much light scrap, especially turnings, is melted, it sticks to the bottom and makes a good deal of work for the men, who are obliged to poke it loose with bars.

Iron ore, or mill scale, is sometimes charged with the limestone, especially when a high percentage of pig iron is melted, in order that as much silicon and manganese as possible may be eliminated during the melting. They, of course, cannot attack the bottom, for the same reason that the cinder cannot do so.

A basic heat, when melted, unless very hot, is commonly covered with a blanket of sluggish slag, in which many lumps of limestone float about. As the temperature rises, the stone melts, because the slag is able to absorb more and more lime (CaO) as it grows hotter, since the melting point of these slags is the higher the greater the proportion of bases to acid; and therefore the hotter the slag, the more lime it can absorb. When the heat is "down," the first helper rabbles up all scrap that sticks to the bottom, and when his metal is all melted takes the first test, as in acid practice.

If the slag formed on the melted bath is very basic and sluggish, as described above, the phosphorus in the steel generally will be largely eliminated when the bath is melted, and the efforts of the men must be devoted to bringing down the carbon of the bath by additions of ore without making the slag too irretentive of phosphorus. The fracture of the test piece and, in shops where very close control of analysis is desired, a quick analysis of the test, show the amount of carbon and of phosphorus that have to be eliminated, and the additions of iron ore and lime are proportioned accordingly.

Before any ore is added, the slag should be nearly all melted.

Though the ore assists in promoting the fluidity of the slag, additions of fluorspar may be needed to reduce its melting point, and enable the last of the limestone to melt. In case the slag is very thin, watery and black, indicating an excess of silica and iron oxide, and a deficiency of CaO, burned lime (or occasionally limestone) is shoveled in, to bring the composition and consistency to the desired point. Such a watery slag indicates that dephosphorizing during melting has been less complete than is desired, and extra pains must be taken to secure a limey slag.

Ore is added in sufficient amounts to oxidize the carbon and produces a vigorous boil, as in acid practice. When its effect begins to wear off, and the carbon approaches the desired point, additions of lime are made to keep the slag as basic (and sticky) as possible, in order to promote the elimination of phosphorus. The progress of this elimination is watched closely, and in many cases it is sufficiently advanced by the time the carbon is low enough, and the heat hot enough, to tap. If very low phosphorus content is desired, however, especially if the charge is very high in that impurity, the bath may have to be brought down to .10 per cent. in carbon or lower, and heavy additions of lime and fluorspar made. Meanwhile the carbon of the bath may, if desired, be kept up by additions of pig iron. This is the more to be recommended, as by the boiling produced it aids in keeping the bath hot and in bringing all the steel in contact with the dephosphorizing slag.

The elimination of sulphur is very erratic in the basic furnace, as the examples shown later well illustrate, and though in a general way it follows that of phosphorus, yet in some cases the sulphur can be eliminated to the desired degree only by bringing the bath to very low percentages of carbon and making heavy additions of lime. It will be noticed in these typical heats that the total amount of sulphur eliminated is much less than that of phosphorus.

The same precautions that have been described in the case of the acid furnace should be observed in basic practice. The ore should be got in early, and allowed to work until its iron oxide has been used up as far as possible in eliminating silicon, manganese, and carbon from the bath. By working heats for some time after the effect of the ore has worn off, the iron oxide is as far as possible eliminated from both slag and steel, resulting in the best possible metal. No heat should be tapped that is highly oxidized and "wild," but the process continued until the tests pour quite clean from the spoon. It is possible, and even in some cases common

practice, to rush a heat, running the carbon down rapidly with ore, and stopping its elimination at the desired point with pig iron or ferrosilicon, but steel so made is of inferior quality. This is the more true because the basic slag is at the best rather high in iron oxide, and hence oxidizing, to the last.

In basic practice, the recarburizers, especially the manganese, are added largely in the ladle. One reason for this is that manganese, coming in contact with the slag, reduces more or less of the calcium phosphate and causes rephosphorizing of the steel; another is that much more of the manganese added to a basic furnace is lost by oxidation than in acid practice. However, in the manufacture of basic steel for very high-grade forging work, in one of the leading American shops, it is customary to add a part at least of the manganese, in the furnace. The alloy is charged in heavy chunks which sink through the slag and as it is largely immersed in the steel while melting it does not cause marked rephosphorizing, while its effect in eliminating the oxides from the bath and improving the quality of the steel is very marked.

The pig iron, if used solid, must be added in the furnace; coal or coke is often used in the ladle, though as a rule the best practice demands that as much of the carbon as possible be added in the metallic recarburizers. Ferrosilicon is generally added in the ladle.

In figuring recarburizers for basic heats, allowance has to be made for the considerable proportion of manganese, generally from .20 to .40 per cent., retained by the steel. The examples here given illustrate this point very well.

Typical Heats.—These typical heats were made in large furnaces for high-grade forging work, but serve very well to illustrate basic practice for the production of steel very low in phosphorus and sulphur. In all of them rather low phosphorus charges were melted, to make sure of attaining the great purity desired, and for the same reason the working of the heat was carried further than usual foundry practice requires. A special basic pig, containing only .3 per cent. of phosphorus, was used. Ordinarily, basic pigs contain from .6 to 1 per cent., and the charge from .3 to .5 per cent. of phosphorus.

Heat (1) was originally charged for making .48 per cent. carbon steel, and afterward changed over to .30 per cent. carbon. As it melted very high in carbon, 3000 lb. of ore were needed to run the carbon down, and great deal of lime and fluorspar to reduce the phosphorus, which also melted rather high, considering the require-

ments and the fact that the limestone charged amounted to 14 per cent. of the weight of the heat. The fluorspar is added to make the very limey slag fluid.

Heat (2) melted much lower in carbon, and pig had to be thrown in to keep the carbon up. The phosphorus was very obstinate after it had reached .03 per cent., and as will be seen, it would not go down to .012 per cent. until the carbon had reached very low figures.

Heat (3) melted very low in phosphorus, and staid down. While waiting for the carbon to reach low enough figures, lime was added to keep the slag basic.

Heat (4) is included to show a heat which melted very high in carbon, but low in phosphorus. The phosphorus content of this charge was purposely made lower than usual because very low phosphorus steel was to be made, with high carbon. Had the charge contained the usual amount of phosphorus, the heat would probably have melted too high in that element, and refused to go down to very low figures until the carbon had been largely eliminated. The objection to this was that a great amount of pig iron or spiegel would have been necessary as recarburizer to obtain the carbon needed, and this shop had no cupolas at its command for melting recarburizer. The large plants making basic rail steel commonly use hot metal in large amounts as recarburizer, and in this way are able to work high phosphorus charges down low in both carbon and phosphorus and recarburize to high carbon content without trouble.

Heat (5) is included to show a heat that dropped to very low phosphorus content without much working of the slag with lime. Evidently this slag was already very limey and thick, as fluorspar was added after the ore had done much of its work. The amount of limestone charged with this heat was practically the same as that in heat 1, but in this case its effect was pronounced.

Heat (6) melted a good deal like heat (2), though the carbon of the charge was much lower, but the phosphorus, probably because less had to be eliminated, proved much less obstinate, and went down to low figures while the carbon was still comparatively high. Evidently the slag was limey and thick early in this heat, though the amount of limestone used was but 9.4 per cent. of the weight of the charge, as fluorspar was added heavily soon after the bath was melted.

(1) 35-ton Basic Furnace—Producer Gas—Forging Ingots
CHARGE

Basic pig	38,000 lb.
High phosphorus scrap	26,600 lb.
Low phosphorus skull	11,400 lb.
	76,000 lb.
Limestone	10,500 lb.
Base	74,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge	2.25	1.05	.60	.199	.06
Aimed for	.26/.30	.50/.65	.14/.18	.015	.025
Obtained	.28	.73	.13	.029	.021

Carbon estimated	.25
Carbon added	.039
Manganese added	.37
Silicon added	.21

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si lb.
Ferrosilicon	300	6.36		151.62
Ferromanganese	350	22.51	280.0	1.75
		28.87	280.0	153.39
		.039%	.37%	.21%

HISTORY OF HEAT

Time	No. test	Item	C	P	Mn
8.10 to 9.15 a. m		Charged			
5.15 p. m		Melted hot			
5.20 p. m	(1)	Quiet	1.92	.071	.37
5.30 p. m		600 lb. ore			
6.30 p. m		600 lb. ore			
7.00 p. m	(2)	R 1″		.065	.35
7.15 p. m		600 lb. ore			
7.30 p. m	(3)	R 1″		.065	.34
7.45 p. m		600 lb. ore			
8.15 p. m	(4)	R 1″		.06	.30
8.30 p. m		600 lb. ore			
8.55 p. m	(5)	R 1″	.90	.05	.25
9.00 p. m		400 lb. fluorspar			
9.25 p. m	(6)	R 1″	.78	.05	.31
9.50 p. m		400 lb. lime			
9.55 p. m	(7)	R 1″	.61	.035	.34
10.00 p. m		1200 lb. lime			

HISTORY OF HEAT (Continued)

Time	No. test	Item	C	P	Mn
10.25 p. m.....	(8)	R 1″	.53	.035	.33
10.35 p. m.....		600 lb. lime; 400 lb. fluorspar.	.....	.....	.....
10.55 p. m.....	(9)	R 1″	.45	.03	.37
11.10 p. m.....		400 lb. lime	.....	.....	.....
11.25 p. m.....	(10)		.38	.02	.36
11.45 p. m.....		400 lb. lime	.....	.....	.....
11.55 p. m.....	(11)		.33	.018	.36
12.05 p. m.....		700 lb. lime	.....	.....	.....
12.25 p. m.....	B R		.25		
12.35 p. m.....		Tapped { 300 lb. ferrosilicon (50%). 350 lb.ferromanganese (80%). } in ladle.			

(2) 35-TON BASIC FURNACE—PRODUCER GAS—FORGING INGOTS
CHARGE

Basic pig.............................. 34,200 lb.
High phosphorus scrap .... 30,400 lb.
Low phosphorus skull .... 11,400 lb.

                                         76,000 lb.
Limestone............................ 10,600 lb.
Base................................. 74,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge............	2.08	1.01	.56	.189	.064
Aimed for..........	.26/.30	.60/.65	.14/.18	.015	.025
Obtained..........	.29	.61	.16	.014	.035

Carbon estimated....................... .10
Carbon added.......................... .22
Manganese added....................... .58
Silicon added......................... .21

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si lb.
Ferrosilicon................	300	6.36		151.62
Ferromanganese.............	490	30.67	432.0	2.45
Coal.......................	250	125.00		
		162.03	432.0	154.07
		.22%	.58%	.21%

HISTORY OF HEAT

Time	No. test	Item	C	P	Mn
5.45 to 6.45 a. m..........		Charged Melted	.....	.....	.....
....					
3.10 p. m........	(1)		.40	.03	.18
3.20 p. m........		300 lb. fluorspar	.....	.....	.....
3.40 p. m........	(2)		.28	.035	.21
3.50 p. m........		1000 lb. pig	.....	.....	.....
4.10 p. m........	(3)		.28	.035	.24
4.20 p. m........		{ 400 lb. lime 200 lb. fluorspar	.....	.....	.....
4.40 p. m........	(4)		.24	.03	.28
4.50 p. m........		300 lb. lime	.....	.....	.....
5.10 p. m........	(5)		.15	.028	.28
5.20 p. m........		300 lb. lime	.....	.....	.....
5.40 p. m........	(6)		.09	.013	.26
5.50 p. m........		{ 250 lb. lime 1000 lb. pig	.....	.....	.....
6.20 p. m........	(7)		.11	.012	.22
6.30 p. m........		450 lb. pig	.....	.....	.....
6.50 p. m........	B R	R 2″	.09		
7.05 p. m........		Tapped			

300 lb. ferrosilicon (50%)
490 lb. ferromanganese (80%)   } in ladle.
250 lb. coal

(3) 35-TON BASIC FURNACE—PRODUCER GAS—FORGING INGOTS
CHARGE

Basic pig.............................. 34,200 lb.
High phosphorus scrap .... 30,400 lb.
Low phosphorus skull.................. 11,400 lb.

                                         76,000 lb.
Limestone............................ 7,600 lb.
Base................................. 74,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge............	2.08	1.01	.56	.189	.064
Aimed for..........	.26/.30	.60/.65	.14/.18	.015	.025
Obtained..........	.29	.71	.16	.022	.025

Carbon estimated..................... .22
Carbon added........................ .087
Manganese added..................... .50
Silicon added....................... .19

FIGURED AS FOLLOWS

Material	Pounds	C lb.	Mn lb.	Si Lb.
Ferrosilicon..................	280	5.93	....	141.51
Ferromanganese.............	455	28.48	364.0	2.28
Coal........................	60	30.00	....	....
		64.41	364.0	143.79
		.087%	.50%	.19%

HISTORY OF HEAT

Time	No. test	Item	C	P	Mn	S
3.20 to 4.20 p. m......	.....	Charged	.....	.....	.....	.....
....	.....	Melted	.....	.....	.....	.....
12.15 a. m.......	(1)		.82	.01	.25	.032
12.20 a. m.......		500 lb. ore				
1.00 a. m.......	(2)		.53	.01	.26	
1.10 a. m.......		{ 300 lb. ore				
		{ 200 lb. fluorspar				
1.45 a. m.......	(3)		.47	.01	.26	
2.15 a. m.......	(4)		.41			
2.20 a. m.......		600 lb. lime				
2.45 a. m.......	(5)		.34			
2.55 a. m.......		350 lb. lime				
3.15 a. m.......	(6)		.28			
3.20 a. m.......		300 lb. lime				
3.55 a. m.......	B R		.23			
4.10 a. m.......		Tapped				
		280 lb. ferrosilicon (50%)				
		455 lb. ferromanganese (80%) } in ladle				
		60 lb. coal				

(4) 35-TON BASIC FURNACE—PRODUCER GAS—SPECIAL FORGING INGOTS

CHARGE

Basic pig.......................... 44,400 lb.
Low phosphorus scrap .... 29,600 lb.

74,000 lb.

Limestone.......................... 7,400 lb.
Base.............................. 72,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge............	2.60	1.14	.83	.147	.053
Aimed for.........	.80/.95	.35/.50	.12/.16	.015	.03
Obtained..........	.95	.38	.13	.012	.021

Carbon estimated.............. .87
Carbon added.............. .017
Manganese added.............. .085
Silicon added.............. .163

FIGURED AS FOLLOWS

Material	Lb	C lb	Mn lb	Si Lb
Ferrosilicon..................	175	3.71	....	88.45
Ferrosilicon..................	245	4.31	5.15	28.42
Ferromanganese.............	70	4.38	56.00	.35
		12.40	61.15	117.22
		.017%	.085%	.163%

HISTORY OF HEAT

Time	No. test	Item	C	P	Mn	S
10.25 to 11.30 p. m....	.....	Charged	.....	.....	.....	.....
....		Melted				
6.30 a. m.......		400 lb. fluorspar				
7.00 a. m.......	(1)		2.12	.012	.31	.029
7.10 a. m.......		500 lb. ore				
7.30 a. m.......		500 lb. ore				
8.00 a. m.......	(2)		1.62	.012	.22	
8.15 a. m.......		300 lb. lime				
8.30 a. m.......	(3)		1.15	.012	.25	.023
8.45 a. m.......		200 lb. lime				
9.00 a. m.......	(4)		1.03			
9.15 a. m.......		{ 750 lb. lime				
		{ 300 lb. fluorspar				
9.35 a. m.......		{ 350 lb. lime				
		{ 100 lb. fluorspar				
9.50 a. m.......	B R	R 1″	.85			
10.00 a. m.......		Tapped				
		175 lb. ferrosilicon (50%)				
		245 lb. ferrosilicon (11%) } in ladle				
		70 lb. ferromanganese (80%)				

(5) 35-TON BASIC FURNACE—PRODUCER GAS—FORGING INGOTS

CHARGE

Basic pig.......................... 38,000 lb.
High phosphorus scrap........... 26,600 lb.
Low phosphorus scrap........... 11,400 lb.

76,000 lb.

Limestone.......................... 10,600 lb.
Base.............................. 74,000 lb.

ANALYSES

	C	Mn	Si	P	S
Charge............	2.25	1.05	.60	.199	.06
Aimed for.........	.46/.49	.50/.55	.15	.04	.04
Obtained..........	.52	.60	.115	.022	.027

Carbon estimated......................................44
Carbon added..063
Manganese added.....................................30
Silicon added......................................15

FIGURED AS FOLLOWS

Material	Pounds	C lb	Mn lb	Si lb
Ferrosilicon................	220	4.66	....	111.19
Ferromanganese............	275	17.22	220	1.38
Coal......................	50	25.00	oo	oo
		46.88	220	112.57
		.063%	.30%	.15%

HISTORY OF HEAT

Time	No. test	Item	C	P	Mn
7.35 to 8.40 a. m......	......	Charged	......	......	......
4.10 p. m......	......	400 lb. fluorspar	......	......	......
4.15 p. m......	(1)	....	1.70	.054	.49
4.15 p. m......	......	3000 lb. ore (in 1000-lb. lots)	......	......	......
6.35 p. m......	......	200 lb. fluorspar	......	......	......
6.40 p. m......	(2)	....	.75	.012	.30
7.10 p. m......	(3)	....	.58	.012	.30
7.50 p. m......	(4)	....	.50	.012	.28
8.15 p. m......	B R	R 1″	.42	......	......
8.20 p. m......	......	Tapped	......	......	......
		220 lb. ferrosilicon (50%)			
		275 lb. ferromanganese (80%) } in ladle			
		50 lb. coal			

(6) 35-TON BASIC FURNACE—PRODUCER GAS—NICKEL FORGING INGOTS
CHARGE

Basic pig...21,600 lb.
Cast-iron scrap....................................5,000 lb.
Nickel-steel scrap................................53,200 lb.
Nickel plaquettes..................................655 lb.

           80,455 lb.

Limestone..7,600 lb.
Base...76,000 lb.

ANALYSES

	C	Mn	Si	P	S	Ni
Charge............	1.60	.98	.54	.134	.043	......
Aimed for.........	.27/.30	.60/.70	.14/.18	.035		3.50
Obtained..........	.31	.67	.15	.014	.025	3.45

Carbon estimated......................................27
Carbon added..053
Manganese added.....................................49
Silicon added......................................21
Nickel added..80

FIGURED AS FOLLOWS

Material	Pounds	C lb	Mn lb	Si lb
Ferrosilicon................	175	3.71	....	88.45
Ferrosilicon................	580	8.47	12.18	67.28
Ferromanganese............	450	28.17	360.00	2.25
		40.35	372.18	157.98
		.053%	.49%	.21%

HISTORY OF HEAT

Time	No. test	Item	C	P	Mn	Ni
9.20 to 10.20 p. m.....	......	Charged.	......	......	......	......
6.30 a. m.....	(1)	....	.50	.029	.30	2.70
6.40 a. m.....	......	400 lb. fluorspar	......	......	......	......
6.50 a. m.....	......	200 lb. fluorspar	......	......	......	......
7.00 a, m.....	(2)	....	.44	.014	.29	......
7.30 a. m.....	(3)	....	.36	.012	.31	......
7.40 a. m.....	......	300 lb. lime	......	......	......	......
8.00 a. m.....	(4)	....	.31	......	......	......
8.10 a. m.....	......	400 lb. lime	......	......	......	......
8.35 a. m.....	B R	R 1″	.27	......	......	......
8.40 a. m.....	......	150 lb. lime; 621 lb. nickel plaquettes.	......	......	......	......
8.50 a. m.....	......	Tapped	......	......	......	......
		175 lb. ferrosilicon, 50%				
		580 lb. ferrosilicon, 11% } in ladle.				
		450 lb. ferromanganese, 80%				

USE OF SMALL FURNACES

Among others, Mr. W. M. Carr has shown what can be done with very small open-hearth furnaces for pouring light castings, and with his portable furnace claims to be able to handle any work that can be made by the Bessemer or crucible process. His furnace is of very small capacity, some 2 tons, and is built with a barrel-shaped removable body or hearth, which is taken directly to the moulds and poured through a nozzle in one side, which takes the place of the tap hole. The slide for raising and lowering the stopper rod is fastened to the side of the furnace. When the metal is ready to pour, a stopper rod is inserted through the charging door, the fur-

nace body is picked up with the crane, the end openings are closed by means of special doors provided for the purpose, and the steel is teemed directly from the furnace into the moulds.

Oil is used for fuel, though natural gas would probably serve as well. It is doubtful if producer gas would work well in such a short furnace.

The advantages of this design are easily seen. The first is the result of the removable feature; that the steel is kept hot longer in the hot furnace than it would be in a ladle. The second is the small size of the heats and the high temperature of the steel, which make it possible to pour very small castings. Third, in that its output is small, the furnace is quite well suited to the ordinary small foundry, which cannot command a large tonnage especially when first started up. Moreover, the installation cost is low, so that the loss by "overhead" in idle time is not great; and the furnace can readily be shut down and started up again at small expense. Oil-burning open-hearth furnaces in general can be shut down, with all doors and valves closed, on Saturday afternoon and left till the next day without growing too cold. The men can come out on Sunday morning, and have the furnace ready to charge by midnight. Though the small furnace will grow much colder in the same time, yet it will heat up more rapidly.

There are several disadvantages to this method of working. First, all recarburizing must be done in the furnace, and if the basic process is used this may involve rephosphorizing. Second, the castings all have to be poured through a nozzle, as it is not possible to fill shanks through a nozzle, and then pour from the shanks—the steel would be chilled too much. Nozzle pouring, even with a 2-ton heat, is not good practice for light work, as the stream has too much velocity which renders it impossible to fill the moulds at the nicely regulated rate so essential to fine work. This could of course be provided for by using a furnace with a spout instead of a nozzle, and shanking direct from the furnace; if this were done, recarburizing in the ladle would be feasible.

Third, the small furnace, though it enables us to pour small castings of open-hearth steel, which can be made considerably better than Bessemer metal, sacrifices some of the advantage of cost of metal that the open-hearth has over other processes, because labor, and some other charges, are distributed over so small an output.

Continuous Melting to Supply an Electric Furnace.—In the use of an open-hearth furnace to supply metal for a small electric fur-

nace pouring light castings, metal must be available at short intervals. In order to use but one open-hearth and one electric furnace for this purpose, it is possible to use a tilting open-hearth furnace and run it on the continuous melting principle, tapping out a part of the heat every two or three hours, and adding more cold stock.

It is even conceivable that this method might be followed in an open-hearth foundry making rather light work, in order to distribute the pouring over the day instead of doing it all in two heats. Recarburizing in the ladle would be necessary in such work, since it would be very expensive to add silicon and manganese to the whole bath, tap but a fraction of the steel, and then lose the silicon and manganese in bringing down the carbon of the bath again after the next lot of pig and scrap had been melted. Moreover, it would slow down the process to follow this practice, as carbon cannot be eliminated readily from the bath in the presence of silicon and manganese, and hence after each ladle full was drawn and more metal melted to take its place, time and ore would have to be wasted in oxidizing the silicon and manganese added to the bath as recarburizer.

To use this method successfully for the production of steel at frequent intervals, but a small part of the heat should be tapped each time, unlike the usual continuous processes, in which a large part of the bath is taken off. Moreover, as hot metal from the blast furnace would not be available for operations on such a small scale, and the heats probably could not be drawn rapidly enough to justify the use of a cupola to melt the successive additions, cold pig and scrap would have to be charged, and it is not probable that the furnace would melt quite as fast under these conditions as when melting a whole heat at a time. We can, however, assume safely that the furnace would melt, and at least partially refine steel, at the rate of a heat in 15 hours, or one-fifteenth of its capacity per hour. With a 10-ton furnace, we should be able to tap off a 2-ton heat, which is about the handiest size for use in a small casting foundry, every 3 hours, or 8 heats a day.

With producer gas fuel, the acid furnace run in this manner cannot be used for the production of castings direct, because, as is shown in the section on raw materials, the increase of sulphur is too great. Either an acid or a basic furnace can be so run in conjunction with an electric furnace, since the latter can be provided with a basic lining, and made to do all the dephosphorizing. It will be more economical, however, to do the bulk of this work in the open-hearth furnace, since on account of the heavy expense for current, the elec-

tric furnace cannot compete with the open-hearth in dephosphorizing, and should whenever possible be used only for the final purification of steel.

It would be possible, even, to use a basic open-hearth and an acid electric furnace—but the latter has some important disadvantages that make such an arrangement a poor one.

This method of working involves getting the full capacity of the furnace ready as usual, taking off 2 tons for the electric furnace, charging and melting 2 tons of pig and scrap, adding ore to oxidize the carbon, silicon and manganese (and in the basic furnace lime and fluorspar to eliminate phosphorus and sulphur), and again taking out 2 tons. The slag should be held back in pouring, only enough being removed to make it possible to work the heat, and in the basic furnace, enough to keep the phosphorus content of the slag sufficiently low.

In a 10-ton basic furnace, if 2 tons of steel of .10 per cent. carbon, .05 per cent. silicon, and .20 per cent. manganese, are tapped out, and 1 ton of pig (carbon 3.5 per cent., silicon 1 per cent., manganese 1.60 per cent.), and 1 ton of scrap (carbon .15 per cent., silicon .20 per cent., manganese .60 per cent.), are added, the composition of the bath will be raised to carbon .45 per cent., silicon .16 per cent., manganese .38 per cent. To oxidize these impurities will not require much ore or time, as probably quite a part of the oxidation will be done by the gases of the furnace in melting. As the pig and scrap will be protected by the fluid bath, however, the work of the gases in eliminating the metalloids will be less than the 40 per cent. usually assumed as the basis for calculations in regular practice.

One problem presented by this method of working is the maintenance of the bottom and banks in good condition. The bottom itself is cut very little when the furnace is kept full of steel; but the banks at the slag line will require patching every two or three heats, and if only 2 tons out of 10 are drawn off, there will not be a good chance to do this work well. The front and back can of course be repaired by tipping the furnace, but the end banks will not be exposed by this method. In order to prevent break outs, therefore, it will probably be necessary at intervals to take off several heats successively without recharging. If the steel is being poured directly into castings this will not be a serious matter, as it is not necessary to pour at regular intervals. When the steel is being used to supply an electric furnace, however, the delay will cause the latter to lie idle while the open-hearth furnace is melting the larger charge put

in to make up for the two or three heats tapped out. This idle time can be made up for in part by melting a heat of cold scrap in the electric furnace.

THE RAW MATERIALS

The raw materials for the open-hearth furnace may be summarized as follows:

ACID PROCESS

Specified Analysis

Material	P	S	Si	Mn
Low phosphorus pig	.03 to .035	.03 to .035	as desired.	as desired.
Low phosphorus scrap	.03 to .035	.03 to .035	....	....
Washed metal	.03 to .035	.03 to .035	....	....
Wrought iron	.03 to .035	.03 to .035	....	....
Iron ore	.03 to .035	.03 to .035	....	....

BASIC PROCESS

Basic pig	.60 to 1.00	.03 to .1	1 to 1.25	....

Scrap—miscellaneous unclassified cast iron, wrought iron and steel scrap—if the sulphur is too high, production of low sulphur steel will be difficult. Iron ore and limestone low in silica.

The basic furnace of course does not need material low in phosphorus and sulphur, as these are eliminated in the process. The silicon, however, must be low, since limestone must be provided to flux the SiO_2 resulting from its oxidation, and therefore the more silicon there is in the bath the more lime is used up in fluxing it. For this reason, machine cast pig is preferable to sand cast, as it is free from adhering SiO_2 (sand), which consumes a good deal of lime. For the same reason, both ore and limestone should be low in silica.

The slight loss of metal in the acid process does not raise the phosphorus and sulphur in the steel enough to need figuring. An oil-fired or natural-gas-fired furnace will not pick up sulphur; but a producer gas-fired furnace will pick up at least .01 per cent. of sulphur per heat. For this reason, the stock melted must be lower in sulphur than the steel desired, and also the gas coal used in the producers must generally be bought to specifications, coal over .1 per cent. in sulphur being unsuited for many acid furnaces making fine steels. The amount of sulphur so picked up varies greatly in different furnaces, depending evidently somewhat upon the distance

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from producers to furnace; the greater this distance, the less the "pick up."

Using the equations with which we worked before on this head, and assuming that we melt 40 per cent. of our own scrap per heat, and that the pick up amounts to .01 per cent. per heat, we can figure the percentage of sulphur that we can allow in our raw materials as follows;

Let X equal the allowable percentage in raw material, including ore:

.05 per cent. equal the maximum percentage in our steel;

6000 lb. of pig
8400 lb. of purchased scrap } be the weight of a charge;
9600 lb. of our own scrap

2300 lb. be the weight of metal obtained per heat;

The additions to the furnace be those of acid heat No. 5 in the list of typical heats already given;

then,

$$.05 = \frac{\overset{\text{Pig}}{6000X} + \overset{\text{Scrap}}{8400X} + \overset{\text{Ore}}{1100X} + \overset{\text{Own scrap}}{9600(.05)} + \overset{\text{Ferrosilicon}}{350(.02)} + \overset{\text{Whole heat}}{24000(.01)}}{23000}$$

whence $X = .027$ per cent.

If the pick up be .02 per cent., and purchased pig and scrap each contain .03 per cent. we shall get, for the maximum sulphur in the steel,

$$X = \frac{14400(.03) + 1100(.03) + 9600X + 350(.02) + 24000.(02)}{23000} = .071\%.$$

If it be found, then, that our furnace picks up .02 per cent. let us see what must be the composition, X, of purchased pig, scrap and ore, in order that our steel shall not exceed .05 per cent.

$$.05 = \frac{14400X + 1100X + 9600(.05) + 350(.02) + 24000(.02)}{23000}$$

whence $X = .012$ per cent.

We cannot afford to buy material of this analysis, even if we can get it, so that we must buy coal of lower sulphur content, in order to reduce the "pick up"; use some other fuel, such as oil or natural gas; dispose of all our scrap; or change over to a basic furnace. If we do not remelt our scrap, we calculate as follows:

$$.05 = \frac{\overset{\text{Pig}}{6000X} + \overset{\text{Scrap}}{18000X} + \overset{\text{Ferrosilicon}}{350(.02)} + \overset{\text{Ore}}{1100X} + \overset{\text{Whole heat}}{24000(.02)}}{23000}$$

whence $X = .026$ per cent., the content of sulphur that we must have in our raw material in order to keep the sulphur in our steel below .05 per cent.

We can, of course, buy scrap, pig and ore of this analysis; but to be obliged to sell all our own scrap is out of the question.

If part of the capacity of a small tilting furnace is taken out every two or three hours and used for the production of castings direct, the furnace must be basic, if producer gas be the fuel; because, on account of the prolonged sojourn of part of the metal in the furnace in using this method, an acid furnace fired with producer gas will produce a much higher sulphur steel than the same furnace run on straight heats. This can be calculated by the method of figuring which we have used for regular practice.

Assuming that we use a 10-ton furnace and the furnace melts at the rate of a heat every 15 hours, then if

a equals original sulphur of stock charged,

b equals "pick up" of normal heat in 15 hours,

X equals sulphur of bath after an infinite number of heats.

Further assuming that 2 tons are tapped every three hours, and 2.10 tons more metal (allowing for loss), are charged; this metal to be 40 per cent. our own scrap, or .84 tons, and 1.26 tons pig iron and scrap of sulphur equals (a).

We can work this out on two assumptions, as follows:

A. That the "pick up" (b) is at a uniform rate over the 15 hours of a normal heat. Then the rate of "pick up" per hour is $\frac{b}{15}$, and for the three hours, $\frac{b}{5}$. On this assumption we have,

$$X = \frac{8\left(X + \frac{b}{5}\right) + .84\left(X + \frac{b}{5}\right) + 1.26\left(a + \frac{b}{5}\right)}{10}$$

That is, we have in our furnace after a tap and recharge, 8 tons of metal at sulphur X, and after three hours, at $X + \frac{b}{5}$, .84 tons of our own scrap at sulphur X, and after three hours at $X + \frac{b}{5}$, and 1.26 tons of new pig and scrap at sulphur (a), and after three hours at $a + \frac{b}{5}$, and this 10.1 tons will give us 10 tons of metal.

From this equation we get $X = \left(\frac{6.3}{5.8}\right)a + \left(\frac{10.1}{5.8}\right)b$