furnace, and ferrosilicon, etc., must either be charged with the other stock, or in the ladle if one is used.

In both oil and gas furnace melting, the remarks already made on the dangers of too rapid firing at the first apply with even greater force than for coal hole melting, as it is easier to obtain extreme temperatures soon after the pots are charged. With bad handling, too hot a flame at first, and too much air admitted with the gas or oil, new pots are sometimes completely used up in one heat; properly handled, pots should average in a gas furnace three or four heats in steel foundry practice. When high carbon steel is melted, they will last much longer.

THE RAW MATERIAL

The raw materials used in crucible steel foundries are:

Puddled iron.
Charcoal iron.
(Basic) open-hearth scrap, especially boiler plate punchings.
Washed metal.
Charcoal.
Ferrosilicon, generally 50 per cent.
Ferromanganese, generally 80 per cent.
Nickel, ferrochrome, metallic chrome, tungsten, molybdenum, etc.
(Heads, gates and scrap castings.)

Specifications for the first four on the list should be carefully drawn so that the phosphorus and sulphur of the steel shall be within the limits desired. If castings are made to recognized specifications, a top limit of .08 per cent. of phosphorus and sulphur will be demanded for those on which no tensile tests and bend tests are made, and .05 per cent. where these tests are called for. In any case the phosphorus and sulphur for good castings should never be allowed to exceed the upper limit of .08 per cent.

In order to keep within these limits, the phosphorus and sulphur in the raw material have to be somewhat lower than this, since there is some loss of iron in melting, and the impurities therefore increase; some phosphorus comes from the ferromanganese, etc., used; and a little sulphur is picked up from the flame; and as it is necessary for good economy to remelt the scrap made in the shop the increase works up to a limit.[1]

Assuming that we melt in each pot 30 lb. of our own scrap, 69½ lb. of iron (or boiler plate punchings) and washed metal together, and ½ lb. of ferromanganese; that the loss in melting is 2 per cent.; that the ferromanganese contains .3 per cent. of phosphorus; and that the maximum percentage of phosphorus we can allow in our steel is .05 per cent.; we can figure the maximum allowable percentage of phosphorus in our iron and washed metal as follows:

Let x equal this allowable percentage; then,

$$.05=\frac{69.5(x)+30(.05)+.5(.3)}{98}$$

whence, x equals .046 per cent.

Practically, it is better to keep below this figure. Swedish (charcoal) iron and puddled iron can be bought at .012 per cent. or .02 per cent. in both phosphorus and sulphur, though .03 per cent. is a safe limit, and cheaper material can be bought at this figure. Washed metal can easily be purchased below .02 per cent. or .025 per cent. in these impurities, and had better be kept to this figure, since the expense is generally not greater than for material analyzing .03 per cent. Open-hearth scrap can be bought below .03 per cent., and .035 per cent. is the highest that can safely be allowed, since the determination of the exact analysis of an entire lot is impossible, and some of each shipment may run higher than the average. Ferro-silicon and the other alloys, except ferromanganese, are commonly low enough in phosphorus and sulphur not to need attention. Ferromanganese frequently runs high in phosphorus, and the German product especially should be taken only on guarantee of its phosphorus content, as it runs higher in that impurity than English ferro. The average contents in other constituents can be taken about as follows: those to be specified are in parentheses.

Material	C, %	Si, %	Mn, %	S, %	P, %	Ni, %	Cr, %	W, %	Mo, %	Slag %
Puddled and Swedish iron	.10	.10	.10	(.012)	(.012)	......	......	......	......	1–3
Basic open-hearth scrap	.10 to .30	.08 to .20	.40 to .80	(.03)	(.03)	......	......	......	......	......
Washed metal.	about 3	.10	.10	(.025)	(.025)	......	......	......	......	......
Ferrosilicon.	2.00	(10)	3–4	.03	.1	......	......	......	......	......
Ferrosilicon.	.08 to 2	(50)	......	.03	.03	......	......	......	......	......
Ferromanganese	6.00 to 7.00	.20 to .50	(80)	.03	.30	......	......	......	......	......
Ferrochrome	(1 to 8)	.1 to 1.0	......	.08	.04	......	(70)	......	......	......
Tungsten...	(.03 to .5)	.05 to .5	......	(.01 to .3)	(.008 to .02)	......	......	(90–98)	......	......
Molybdenum	(up to .5)	.2 to .4	......	(.03 to .3)	(.003 to .02)	......	......	......	(90–98)	......
Nickel......	.5	.1	......	.02	.02	(98)	......	......	......	......

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[1] See Chapter 12.

THE CONTROL OF ANALYSIS

In figuring the analysis of crucible steel, nearly everything is fairly easy to estimate, except the carbon. While part of the carbon is contained in the alloys added and the iron and washed metal (or charcoal) melted, a considerable amount is absorbed from the graphite of the pots. This amount will vary from .15 or .20 per cent. to .40 per cent. according to the following factors:

1. Scrap and iron high in manganese absorb more than those low in manganese.
2. Heats hard to melt (puddled iron or steel scrap and a little washed metal) absorb more than heats easy to melt (all our own scrap for instance).
3. New pots contribute more than old.
4. Heats held long after melting pick up carbon rapidly.

Just how much will be gained can only be learned by experience and experiment, and mixtures frequently have to be changed to keep analysis correct. As a gas furnace grows old it melts more slowly, and commonly the steel then absorbs more carbon. Pots melted in gas and oil furnaces do not pick up as much carbon as those melted in coal holes.

For melting soft steels, below about .25 per cent. carbon (or even higher in the case of alloy steels), a clay or clay-lined pot must be used, to prevent the absorption of carbon. In fact, there is a loss of from .15 per cent. to .40 per cent. carbon in clay pot melting, which varies as follows:

1. Heats hard to melt lose more than those easy to melt.
2. Heats held long after melting lose more.

The clay lining of these pots is sometimes cut through to the graphite by the slag, especially if the slag formed is high in MnO, and then the steel absorbs carbon and the analysis obtained is not what was expected. This seldom happens on a new pot, or a pot used the second time on steel easy to melt. After the second heat there is not often enough of the lining left to use the pot again for making low carbon steel, unless the steel that has been made was very easy to melt. When the lining is cut through, the pot can be used for high carbon steel, allowing for a smaller absorption of carbon than for a regular graphite pot as long as any considerable amount of lining remains.

Silicon and manganese, when added in the form of 50 per cent. ferrosilicon and 80 per cent. ferromanganese, frequently come out lower than expected, if the alloys are charged in the pots with the iron and scrap. They are best added cracked fine and weighed into manilla envelopes, which are tied up with twine and tossed into the pots about five minutes before drawing. This procedure greatly shortens the time formerly allowed for "killing" or "dead melting" (allowing the steel to absorb silicon from the clay of the pot), which was once from $\frac{1}{2}$ to $1\frac{3}{4}$ hours. Dead melting is now seldom practised, and the steel is not held long in the pots after it has become quiet.

The alloys used, such as chrome, tungsten, molybdenum and nickel, are charged with the iron or scrap. The metallic nickel on the market is nearly pure, and should generally be figured as containing 98 per cent. nickel. Molybdenum and tungsten are best used in the metallic (powdered) form and can be figured, if of about 98 per cent. purity, as containing 95 per cent. metal. Ferrochromes generally contain 70 per cent. chrome, and can be figured as containing 65 per cent. Carbon, silicon and manganese in all materials charged, if of sufficient quantity to affect the results, should be carefully figured in, not omitting to figure the carbon in the ferrosilicon and ferromanganese used as final additions.

If charcoal is used as the source of carbon, the amount it will contribute is variable, according to the difficulty of melting the steel. Easily melted charges absorb most carbon from charcoal. It is a safe rule to figure the charcoal as containing 85 per cent. carbon on heats of all high carbon scrap, and as low as 70 per cent. or even 65 per cent. in all puddled iron (or plate scrap) heats of low carbon content.

Without close co-operation between steel maker (figure man), and melter, the control of analysis, especially of carbon, is impossible. The pots never melt at a uniform rate, and, as already stated, the rate of melting affects the amount of carbon absorbed from the graphite very greatly. The pots nearest the ports in a Krupp furnace will melt first; in regenerative hole furnaces, generally the hole nearest the gas valves leads; in coal holes, the fires draw better in one hole than in another; and in any hole the middle pots generally lead the end pots. Hence some pots will melt more slowly than others, and since it is commonly not practicable to draw the pots as they melt, some will be held fluid after melting longer than others. In hole furnaces it is, of course, possible to draw all the pots in one hole as soon as they are melted, and even in Krupp furnaces this can be done to some extent. The furnace crews, however, naturally do not relish being kept about in their wet rags very long, and it is seldom good policy to start drawing until all pots are far enough along so that they can all be pulled without much delay. Another reason why intermittent drawing is bad practice is that in drawing the furnace cools off considerably, which retards the melting of the laggards; and that the melter being busy bossing the job of drawing cannot give his attention as he should to the steel being melted.

In hole furnaces, the melter has an opportunity to slow down the holes that are melting too fast, either by shutting off the forced draught on coal holes, or by opening the covers on gas holes. On oil furnaces, the flame can be cut down for the same purpose. The good melter watches his steel carefully, and by noting the rapidity of melting, the boiling of the steel, the depth of cutting at the slag line, etc., can gauge with surprising accuracy the progress of absorption of carbon, and draw his heat at such a point that the majority of the pots will give steel close to the desired composition. But inevitably there will be variations, frequently quite wide, between the analyses of individual pots.

The same is true, with a reverse sign, of melting in clay pots or clay-lined pots; indeed, it is seldom possible in clay-lined pot practice to obtain the same nicety of control that is characteristic of higher carbon steel making in graphite pots.

THE USE OF LADLES TO PROMOTE UNIFORMITY

Here we see in greater detail one of the disadvantages already mentioned of crucible steel making, the auto flexibility, so to speak, of the process, which often causes wide variations in the analysis, and hence the physical properties, of the castings produced. In tool steel practice, mixing the steel in large ingots by pouring a number of pots through a common funnel, one after the other, or pouring three pots into two and then into the ingot mould, has proved but a partial corrective of this evil. The large ingots, say of eight or ten pots, so poured, have proved very far from uniform along their length and cross-section, as there is not time in the moulds for thorough mixing of the steel from the different pots; and the same will commonly be true of steel castings poured by dumping pots successively into a casting. The corrective for this trouble is mixing the steel in a ladle. Necessarily, in ladle pouring, all the pots have to be melted before any are drawn, but a good melter will often draw some pretty cold ones, balancing them with hot steel from other pots, when he feels that the average of the heat has reached the analysis desired, and will turn out steel of surprising uniformity from heat after heat. It is never, however, possible to guarantee the same exactness of composition that is possible for instance in acid open-hearth practice, and a leeway of 10 "points" at the least, as .30 per cent. to .40 per cent. when .35 per cent. is desired, is the closest control of carbon that can be expected for a number of heats.

There is one disadvantage in ladle pouring, however, in that it sacrifices some of the heat of the metal. Thus, although the steel can be got quickly into the ladle and is protected from cooling by the blanket of slag (which is purposely made abundant for ladle work by putting about a cupful of brick dust in each pot), yet it naturally does not keep as hot as if left in the furnace till needed. Hence, in pouring very small work, even if the steel after mixing in the ladle is promptly distributed about the shop in shank ladles, more difficulty will be experienced than in pouring directly from the pots. It is, therefore, a question of judgment how far to go toward securing uniformity of composition by ladle mixing at the sacrifice of the high temperature so necessary for running small and intricate work. We are more or less between the devil and the deep sea: to leave pots too long in the furnace because the pouring gang is small and few pots can be handled at a time, increases heterogeneity; to draw them all and mix the steel in a ladle often means lost castings or metal poured into scrap because it has grown too cold to run thin sections. Again, a large pouring gang can handle the pots rapidly from the furnace, if they are poured direct, or can handle a number of small shanks at once if the steel is mixed in the ladle, but a large gang costs money. Moreover, to pour small castings over the lip of a large ladle, or through a nozzle, is out of the question, as the stream is too large and there is no chance to pour the casting at the rather gentle rate often necessary. Perhaps the ideal condition would be to have enough heavy work on hand to take the cooler metal from the ladle after about half the heat had been poured into light castings by means of small shanks filled from the ladle. The whole subject is a nice question of judgment, and is discussed at some length here, because though similar conditions exist in pouing steel in the other steel-making processes, they do not to any extent involve the non-uniformity of composition so hard to deal with in crucible steel making.

As the troubles of the melter in securing steel of proper composition from a whole heat are many and various, it is clear that to require him to produce more than three or four different kinds of steel in one heat so multiplies the chances of error as to practically insure a good deal of steel of faulty composition.

Packing Pots.—In packing pots, a little iron (or plate scrap) is first laid on the bottom, then the charcoal, nickel, ferrochrome, etc. (brought in weigh pans from the "physic" room), then the rest of the iron and scrap. Washed metal is frequently charged in good-sized lumps on the very top, leaving the cover raised some inches—in the opinion of the author this is poor practice, as some of this metal is apt to run down the outside of the pot and cut it badly. Pots should never be charged more than level full, and though putting the washed metal on the top facilitates melting because the high carbon washed metal melts first and in running over the iron and scrap helps carburize and melt them, yet in the process some carbon is inevitably oxidized which would not be lost if the washed metal were covered with a good layer of iron or scrap.

Examples of Charges.—In figuring crucible steel charges, the author has found the most convenient method is to work entirely in ounces, a 90-lb. pot containing, of course, 1440 oz. This is a comparatively easy number to divide by, especially since one soon learns its multiples; and the larger figures so involved will be found easier to handle than fractions or decimals of a pound, which must afterward be reduced to the nearest ounces in weighing out the charges. For the benefit of the steel maker who may be interested in this method of figuring, and for the elucidation of some of the remarks already made on gains and losses in melting, the following typical cases are appended.

The lime in these examples is to help form a slag, by uniting with the iron oxide of the rust and scale on the iron and some silica from the clay of the pot. The black oxide of manganese is added with the idea that manganese will be reduced from it by the carbon of the steel, resulting in the better deoxidation of the metal. Its use in conjunction with ferromanganese is of doubtful value.

The "Base" is the estimated weight of the steel, from which the percentages of carbon, silicon, etc., are calculated.

(1) HIGH-SPEED TOOL STEEL—GRAPHITE POTS—COAL HOLES

CHARGE

Lime		½ oz.	
80 per cent. ferromanganese		1 oz.	= 1 oz.
70 per cent. ferrochrome	4 lb.	8 oz.	= 72 oz.
Tungsten	8 lb.	12 oz.	= 140 oz.
Molybdenum	2 lb.	14 oz.	= 46 oz.
Wrought iron	75 lb.		= 1200 oz.
Ferromanganese in package,			= 1 oz.
			1460 oz.
Base			= 1440 oz.

CARBON

Ferromanganese	2 oz. at	.06	= .12 oz.
Ferrochrome	72 oz. at	.07	= 5.04 oz.
Tungsten	140 oz. at	.01	= 1.40 oz.
Molybdenum	46 oz. at	.015	= .69 oz.
Iron	1200 oz. at	.001	= 1.20 oz.
			8.45 oz. = 59 per cent.

CHROME

Ferrochrome	72 oz. at .65	= 46.8 oz.	= 3.25 per cent.

TUNGSTEN

Tungsten	140 oz. at .95	= 133 oz.	= 9.24 per cent.

MOLYBDENUM

Molybdenum	46 oz. at .95	= 43.7 oz.	= 3.03 per cent.

MANGANESE

Ferromanganese	2 oz. at	.75	= 1.50 oz.
Iron	1,200 oz. at	.001	= 1.20 oz.
			2.70 oz. = .19 per cent.

ANALYSIS OF STEEL

C	Cr	W	Mo	Mn	P	S	Si
.87	3.39	9.31	2.92	.19	.02	.014	.12

(2) HIGH-SPEED STEEL—CLAY-LINED POTS—COAL HOLES

CHARGE

Lime		½ oz.	
80 per cent. ferromanganese		3½ oz.	= 3.5 oz.
70 per cent. ferrochrome	4 lb.	8 oz.	= 72.0 oz.
Tungsten	8 lb.	12 oz.	= 140.0 oz.
Molybdenum	2 lb.	14 oz.	= 46.0 oz.
Wrought iron	74 lb.		= 1184.0 oz.
Ferromanganese in package,			= 2.5 oz.
			1448.0 oz.
Base			= 1440.0 oz.

CARBON

Ferromanganese	6 oz. at .06	= .36 oz.
Ferrochrome	72 oz. at .07	=5.04 oz.
Tungsten	140 oz. at .01	=1.40 oz.
Molybdenum	46 oz. at .015	= .69 oz.
Iron	1184 oz. at .001	=1.184 oz.
		8.674 oz. = .60 per cent.

Chrome, tungsten and molybdenum same as (1).

MANGANESE

Ferromanganese	6 oz. at .75	=4.50 oz.
Iron	1184 oz. at .001	=1.184 oz.
		5.684 oz. = .39 per cent.

ANALYSIS OF STEEL

C	Cr	W	Mo	Mn	P	S	Si
.40	3.21	9.01	3.25	.10	.013	.014	.09

(3) High Per Cent. Nickel Steel—New Clay-lined Pot—Coal Holes

Melting Time 4 hr. 51 m.

CHARGE

Lime	½ oz.	
Black oxide of manganese	2 oz.	
Charcoal	4.5 oz. =	4.5 oz.
Nickel	17 lb. 4 oz. =	276.0 oz.
80 per cent. ferromanganese	1.5 oz. =	1.5 oz.
Iron	73 lb.	=1168.0 oz.
Ferromanganese in package		= 5.0 oz.
		1455.0 oz.
Base		=1440.0 oz.

CARBON

Charcoal	4.5 oz. at .70	=3.15 oz.
Nickel	276 oz. at .005	=1.38 oz.
Ferromanganese	6.5 oz. at .06	= .39 oz.
Iron	1168 oz. at .001	=1.168 oz.
		6.088 oz. = .42 per cent.

NICKEL

Nickel	276 oz. at .98	=270.48 oz.	=18.78 per cent.

MANGANESE

Ferromanganese	6.5 oz. at .75	= 4.875 oz.
Iron	1168 oz. at .001	= 1.168 oz.
		6.043 oz. = .42 per cent.

ANALYSIS OF STEEL

C	Mn	P	S	Si	Ni
.15	.30	.01	.018	.044	19.17

(4) Hard Chrome Steel—Graphite Pot—Coal Holes

Melting Time 4 hr.

CHARGE

Lime		½ oz.	
Black oxide of manganese		2 oz.	
80 per cent. ferromanganese		1 ½ oz. =	1.5 oz.
70 per cent. ferrochrome	2 lb.	2 oz. =	34.0 oz.
Charcoal		3 ½ oz. =	3.5 oz.
Ferrosilicon		3 ½ oz. =	3.5 oz.
Iron	88 lb.		=1408.0 oz.
Ferromanganese in package			7.5 oz.
			1458.0 oz.
Base			=1440 oz.

CARBON

Ferromanganese	9 oz. at .06	= .54 oz.
Ferrochrome	34 oz. at .07	=2.38 oz.
Charcoal	3.5 oz. at .70	=2.45 oz.
Iron	1408 oz. at .001	=1.408 oz.
		6.778 oz. = .47 per cent.

CHROME

Ferrochrome	34 oz. at .65	=22.1 oz.	=1.53 per cent.

MANGANESE

Ferromanganese	9 oz. at .75	= 6.75 oz.
Iron	1408 oz. at .001	= 1.408 oz.
		8.158 oz. = .57 per cent.

SILICON

Ferrosilicon	3.5 oz. at .50	=1.75 oz.
Iron	1408 oz. at .001	=1.408 oz.
		3.158 oz. = .22 per cent.

ANALYSIS OF STEEL

C	Mn	P	S	Si	Cr
.79	.39	.01	.02	.175	1.47

(5) HARD NICKEL STEEL—GRAPHITE POTS—COAL HOLES

Melting Time 4 hr.

CHARGE

Lime	½ oz.	
Black oxide of manganese	2 oz.	
80 per cent. ferromanganese	3 oz. =	3.0 oz.
Charcoal	11.5 oz. =	11.5 oz.
Nickel	2 lb. 15.5 oz. =	47.5 oz.
Iron	87 lb.	=1392.0 oz.
		1454.0 oz.
Base		=1440. oz.

CARBON

Ferromanganese	3 oz. at .06	= .18 oz.
Charcoal	11.5 oz. at .70	=8.05 oz.
Nickel	47.5 oz. at .005	=0.238 oz.
Iron	1392 oz. at .001	=1.392 oz.
		9.86 oz. = .69 per cent.

MANGANESE

Ferromanganese	3 oz. at .75	=2.25 oz.
Iron	1392 oz. at .001	=1.392 oz.
		3.642 oz. = .25 per cent.

NICKEL

Nickel	47.5 oz. at .98	=46.55 oz. = 3.23 per cent.

ANALYSIS OF STEEL

C	Mn	Ni
.87	.24	3.42

(6) SOFT NICKEL STEEL—CLAY-LINED POTS—COAL HOLES

Melting Time 5 hr. 20 m.

CHARGE

Lime	½ oz.	
Black oxide of manganese	2 oz.	
80 per cent. ferromanganese	1 oz. =	1.0 oz.
Charcoal	5.5 oz. =	5.5 oz.
Nickel	2 lb. 10.5 oz. =	42.5 oz.
Iron	72 lb.	=1152.0 oz.
Ferromanganese in package		4.5 oz.
Ferrosilicon in package		9.0 oz.
		1214.5 oz.
Base		=1200 oz.

CARBON

Ferromanganese	5.5 oz. at .06	=0.33 oz.
Charcoal	5.5 oz. at .70	=3.85 oz.
Nickel	42.5 oz. at .005	=0.213 oz.
Iron	1152 oz. at .001	=1.152 oz.
		5.545 oz. = .46 per cent.

MANGANESE

Ferromanganese	5.5 oz. at .75	=4.125 oz.
Iron	1152 oz. at .001	=1.152 oz.
		5.277 oz. = .44 per cent.

SILICON

Ferrosilicon	9 oz. at .50	=4.50 oz.
Iron	1152 oz. at .001	=1.152 oz.
		5.652 oz. = .47 per cent.

NICKEL

Nickel	42.5 oz. at .98	=41.65 = 3.47 per cent.

ANALYSIS OF STEEL

C	Mn	Si	P	S	Ni
.19	.31	.367	.015	.023	3.84

(7) STEEL CASTINGS—GRAPHITE POTS—KRUPP FURNACE

CHARGE

Black oxide of manganese	3 oz.	
Boiler punchings	75 lb. =	1200.0 oz.
Heads and gates	25 lb. =	400.0 oz.
Washed metal	10 lb. =	160.0 oz.
80 per cent. ferromanganese		1.5 oz.
60 per cent. ferrosilicon		10.0 oz.
		1771.5 oz.
Base		=1760. oz.

CARBON

Punchings	1200 oz. at .002	=2.40 oz.
Gates	400 oz. at .0075	=3.00 oz.
Washed metal	160 oz. at .03	=4.80 oz.
Ferromanganese	1.5 oz. at .06	= .09 oz.
		10.29 oz. = .58 per cent.

SILICON

Ferrosilicon	10 oz. at .55	=5.5 oz.
Gates	400 oz. at .002	= .8 oz.
Punchings	1200 oz. at .001	=1.2 oz.

7.5 oz.=.43 per cent.

MANGANESE

Ferromanganese	1.5 oz. at .75	=1.125 oz.
Punchings	1200 oz. at .002	=2.400 oz.
Gates	400 oz. at .003	=1.200 oz.

4.725 oz.=.27 per cent.

MELTING TIMES AND ANALYSES OF HEATS

Time	C	Si	Mn
5 hr. 45 m.	.71	.26	.34
5 hr. 45 m.	.61	.25	.27
5 hr. 30 m.	.75	.28	.29
5 hr. 55 m.	.62	.29	.29
4 hr. 45 m.	.67	.30	.28
6 hr. 15 m.	.68	.34	.30
5 hr. 35 m.	.80	.33	.38
5 hr. 35 m.	.80	.27	.36
Average	.71	.29	.36

(8) Same as (7), Except that Ferromanganese=3 oz.

FIGURED ANALYSIS

C	Si	Mn
.59	.43	.33

MELTING TIMES AND ANALYSIS OF HEATS

Time	C	Si	Mn
	.84	.28	.31
6 hr. 40 m.	.66	.29	.32
5 hr. 40 m.	.77	.31	.35
4 hr. 50 m.	71	.31	.34
Average	.75	.30	.33

(9) The Analyses of 25 Heats of Charges (7) and (8) Gave Results as Follows:

	P	S
Lowest	.019	.016
Highest	.062	.088
Average	.033	.063

Three points of crucible steel foundry practice are illustrated in these figures—the use of washed metal and open-hearth scrap as raw materials, the high carbon carried to make the charge melt easily, and the high sulphur and phosphorus content of some of the steel made.

ALLOY STEELS

The crucible process is well suited to the manufacture of ordinary carbon steels, except those very low in carbon; and of nickel, chrome, nickel-chrome, tungsten and molybdenum steels. Examples of most of these are shown in the tables above.

Manganese steel can be produced in crucibles, by charging a mild steel mixture that will melt at about .20 to .25 per cent. carbon in clay-lined pots, and mixing this steel with proper amounts of ferromanganese, melted separately in graphite pots. It is not possible to melt the whole charge together, because, as already noted, mixtures high in manganese cut deeply into crucibles and absorb a great deal of carbon. When an attempt is made to melt wrought iron, or soft steel scrap, and ferromanganese together in a graphite pot, the absorption of carbon is so great as to result in a steel containing 2 or 3 per cent. of carbon, quite useless for the purposes for which manganese steel is made. Even in clay-lined pots, the cutting action is so severe as to eat through the clay lining and cut deeply into the graphite, so that the carbon of the steel will be far too high.

For the same reason manganese steel sink heads, gates and other scrap cannot be remelted in graphite or clay-lined crucibles, so that the scrap has to be sold or used up in open-hearth furnaces. Clay crucibles could be used for making the steel and remelting the scrap, but clay crucibles as already noted are awkward to handle, and the cutting action of the scrap is so severe as to wear out pots very rapidly.

The cost of manganese steel made by the crucible process is so high that it is not practicable to produce the steel in this way, except for certain special products of small size—and even for these castings other processes are more suitable.