CHAPTER VII

SUMMARY—SPECIAL DEOXIDIZERS—LADLES

As a convenient reference, the changes that take place in the content of metalloids in the several steel-making processes are summarized as follows:

Process	Element									
	C	Si	Mn	S	P	Ni	Cr	W	Mo	Va
Crucible: graphite	gain	(gain)	loss	(gain)	(gain)	......	(loss)	(loss)	(loss)	loss
Crucible: clay	loss	(gain)	loss	(gain)	(gain)	......	(loss)	(loss)	(loss)	loss
Bessemer (acid)..	*loss*	*loss*	*loss*	gain	gain	(loss)	loss $\frac{2}{3}$	loss	loss	loss
Open hearth: acid	*loss*	*loss*	*loss*	gain	gain	(loss)	loss	loss	loss	loss
Open hearth: basic	*loss*	*loss*	*loss*	loss	loss	(loss)	loss	loss	loss	loss
Electric (Basic bottom): Melt	(loss)	(loss)	(loss)	(loss)	(loss)	......	......	......	......	....
Electric (Basic bottom): Melt and refine	*loss*	*loss*	*loss*	loss	loss	......	loss	loss	loss	loss
Electric (acid bottom)	(loss)	gain	(gain)	(gain)	(gain)	......	......	......	......	....

(gain) or (loss) indicates slight gain or loss.
gain or *loss* indicates practically complete gain or loss.
...... indicates neither gain nor loss.

Special Deoxidizers.—In addition to the regular recarburizers, it is frequently necessary, especially in making very low carbon steel by the Bessemer process, to use other materials to more thoroughly deoxidize the steel and make it fluid and clean running. Aluminum has been used for a number of years for this purpose and has greatly aided the steel foundryman in pouring sound castings. It is a more efficient deoxidizer than silicon or manganese, and the proportion of the oxides reduced is much increased by its use. There are, however, several objections to it, the most important of which is that the product of the reaction,

$$3FeO + 2Al = Al_2O_3 + 3Fe$$

is alumina (corundum), an almost absolutely infusible mineral, which does not coalesce and float out of the steel but remains in finely divided form in the metal, and renders it somewhat weak. In

rolled steel, especially plates, the effect of this alumina is well known to be a considerable reduction of the strength of the steel when tested in a direction transverse to the direction of rolling.

The first of the special alloys to be used as final deoxidizer or "wash" was "S-A-M metal," which contains generally about 10 per cent. of silicon, 5 per cent. of aluminum and 10 per cent. of manganese. The products of the reaction of this alloy with FeO are SiO_2, Al_2O_3 and MnO, which unite to form a double silicate of manganese and aluminum, of comparatively low melting point. Such a silicate will coalesce into globules of sufficient size to float out of the steel to a considerable extent. Moreover, as Mr. Hibbard[1] has shown in his suggestive article on this subject, globules of slag of considerable size are less harmful to the steel than very minute solid particles scattered broadcast throughout the metal.

Most of the other "washes" now on the market are designed to give reaction products of great fluidity. For instance, the alloy of calcium and silicon produces CaO and SiO_2, which are counted on to unite with the MnO resulting from the reduction of FeO by manganese, to form a fusible silicate of CaO and MnO.

A somewhat different object is aimed at in the use of ferrotitanium as a final addition to steel. Titanium has the property of burning in an atmosphere of nitrogen, that is, it readily forms a compound of titanium and nitrogen. The valuable property is claimed for the alloy of removing the last traces of FeO from steel, and also of removing a large part of the absorbed nitrogen. Many tests have been made that seem to demonstrate the ability of ferrotitanium to reduce the FeO and remove the nitrogen of steel very thoroughly, and the result of its use appears to be a clean, strong metal. In the manufacture of steel for rolled shapes, the segregation of carbon, sulphur and phosphorus in the ingots is considerably reduced by titanium, resulting in superior toughness in the steel from the upper parts of the ingots. Segregation, however, is seldom an evil in foundry practice, as it takes place chiefly in the sink heads.

Whatever "wash" be used to reinforce the action of ferromanganese, it should be added after the latter has had an opportunity to perform as much deoxidation as possible. The "wash" being a more active deoxidizer than manganese, if added before the latter, or at the same time with it, will be wasted in performing the work that manganese can do, and none will be left over for the desired final deoxidation. If the recarburizers are added in the ladle, the

[1] *Transactions A. I. M. E.*, 1910, p. 803.

"wash" should be added last, when the ladle is partly filled, and of course the same applies to recarburizing in the vessel or furnace.

The Ladles.—The ladles and large "shanks" used in pouring steel are made of steel plate appropriately bolted together and braced; small shanks are often cast in one piece, in the shop. Shanks may be carried by hand, or suspended by means of a "bail" from an overhead trolley or crane. They are poured over the lip by tipping. Small ladles are generally hung from a bail and provided with a hand wheel, rack and pinion, so that they can be revolved on their trunnions for pouring over the lip, or in order to turn them upside down and dump them. They may also be provided with a nozzle. Large ladles, holding over 5 tons or so, are generally poured through one or more nozzles and are not arranged to turn over. They may be picked up by heavy crane-hooks under the trunnions, or provided with a bail like the smaller ones. In any case, they should not be so hung as to be top-heavy when full, lest failure of the catch to engage allow them to dump themselves suddenly and disastrously.

The ladles are lined with refractory material to a thickness sufficient to protect the metal of the ladle from the heat of the steel. The thickness of the lining, therefore, varies with the capacity of the ladle. Small shanks, and ladles of a capacity up to some three tons, are commonly lined out by daubing a coating of ganister over the plating. The coating is made quite thick at the bottom and thinner toward the top. For a 3-ton ladle, the lining in the bottom should be about 6 in. thick, and may be reduced to 2 or 3 in. at the lip. Large ladles are lined with one or more courses of clay brick; those on the side are generally laid with the medium dimension of the brick in the line of the radius of the ladle. Over the bricks in the bottom is spread a layer of ganister, which is brought a little way up the sides. Smaller ladles also may be so lined, but the difficulty of removing a heavy "skull" from a small, brick-lined ladle is so great that the ganister lining is to be recommended. Small skulls in lip-poured ladles, especially in Bessemer work, are often left in the ladle to be cut out by subsequent heats; but a skull should not be left in a cold ladle.

The lining should be thoroughly dried out, either with an oil or gas burner, or with a wood fire. When dry, the lining is heated up before use, either with the burner, or by inverting the ladle over a coal fire provided with forced draught. Large ladles, of course, cannot very well be turned upside down for heating, and must be dried with a burner. Small ladles and shanks are generally made at least red hot before use; large ladles need not be made so hot, though it does no harm, especially in case of a rather "cold" heat of steel.

The only feasible method of pouring large ladles into comparatively small castings, is by means of a nozzle and stopper. To ensure satisfactory pouring, two nozzles are generally provided, so that if one gets plugged up the other can be used. Small ladles, of 1 to 3 tons capacity, generally have but one nozzle and are poured over the lip in case of trouble with the nozzle.

Nozzles may be of graphite and clay, or of clay alone. They should be put in place with care, and the lining rammed in around them thoroughly. The nose of the nozzle should project well beyond the plate used to hold it in position, so that the steel from a dribbling nozzle shall not freeze on the plate.

The stopper head is generally made of graphite and clay. Sometimes it is threaded to screw on the end of the stopper rod; but this design is a poor one, because the expansion of the rod in heating up is very apt to crack the stopper head. A far better design is the head with a hole clean through it for the reception of a bolt, which enters a hole in the lower end of the rod and is keyed in place. The hole in the stopper over the head of this bolt is filled with ganister after the stopper has been fastened to the rod.

Nozzles with a deep seat for the stopper head, and in particular a steep-sided seat, should be avoided like the plague. Especially in large ladles, the stopper often gets slightly out of line with the nozzle, and with this steep-sided seat, the stopper then cannot "find" the opening. The best design is the round-nosed stopper and the nozzle with a seat sloping quite gently from the central opening to the outside surface. This type seldom gives trouble by refusal to seat properly.

Sleeves of clay brick, each with a tenon to fit inside a mortise in the one below, are slipped over the rod. All joints in the sleeves are smeared with clay before putting the sleeves in place. To hold them tightly in position, washers are put over the uppermost, and a key driven through a slot in the rod. A thread and nut should never be used for this purpose, because the thread is sure to jam from heat and abuse.

Before placing a nozzle and making up a stopper rod for it, nozzle and stopper should be matched to see that they fit closely. This can be determined by pressing the stopper into its seat in the nozzle and turning it around. It should touch the surface of the nozzle at all points.

The stopper rod is fastened to the "goose-neck," which in turn is inserted in its socket on the ladle slide. Small ladles may be heated up with stopper rod and goose neck removed, and the rod dried out separately. For large ladles, it is necessary to leave the stopper rod in place, and merely raise the stopper off its seat while heating the ladle.

In any case, the stopper should be carefully adjusted before the ladle is heated, so that it closes the hole in the nozzle exactly. To ascertain if the stopper leaks, it is seated firmly and a little fine sand thrown around it. This testing with sand should be repeated when the stopper is put in place or lowered into position, after heating the ladle, and a ladle should not be filled until the ladle man is sure that it does not leak.

Some ladle men prefer, especially for large ladles, to arrange the stopper so that it strikes the outside of its seat in the nozzle, and slides into position as it is pressed home. It is generally best, however, to have the stopper come vertically down upon its seat.

In pouring through a nozzle, the rod should be raised slowly the first time the nozzle is opened, and the pourer will do well, soon after he has got his stream going, to close off once or twice. By so doing he clears away from the nozzle any half-melted sand that may be sticking to it, and ensures a clean shut-off. The first few times the nozzle is seated after the first opening, it often will not shut off clean.

Should the stopper get stuck hard to the nozzle, it should be poked off with a pricker from below, rather than trying to pull it off with the ladle handle. Too much enthusiasm at the handle sometimes pulls a stopper head off the rod. A frozen nozzle in large ladles is pricked open in the same way. Wooden prickers are better for this purpose than steel ones, as they do not freeze to the metal in the nozzle. But a steel pricker often has to be used for a badly frozen nozzle. In pouring a small ladle, if the nozzle freezes up, the steel had better be poured over the lip.

... steel ... analysis ... sand for the work. The sand must be sufficiently high in silica to be quite refractory, in order that it may not be melted or softened by the heat of the steel. The average size and shape of the particles is also of importance, since they affect the porosity and bonding power of the sand. The practice in past years has been largely rule of thumb, and even to-day there is no way of making sure that a sand is suitable, without trying it. The mixture of several brands of

The stopper rod is fastened to the "goose-neck," which in turn is inserted in its socket on the ladle slide. Small ladles may be heated up with stopper rod and goose neck removed, and the rod dried out separately. For large ladles, it is necessary to leave the stopper rod in place, and merely raise the stopper off its seat while heating the ladle.

In any case, the stopper shou
ladle is heated, so that it closes
ascertain if the stopper leaks, it i
thrown around it. This testing
the stopper is put in place or low
ladle, and a ladle should not be fi
it does not leak.

Some ladle men prefer, especi
stopper so that it strikes the ou
slides into position as it is presse
ever, to have the stopper come v

In pouring through a nozzle,
first time the nozzle is opened, ar
he has got his stream going, to c
he clears away from the nozzle
sticking to it, and ensures a clea
nozzle is seated after the first ope

Should the stopper get stuck h
off with a pricker from below, rat
ladle handle. Too much enthus
a stopper head off the rod. A fr
open in the same way. Wooden
than steel ones, as they do not fre
a steel pricker often has to be u
pouring a small ladle, if the nozz
poured over the lip.

CHAPTER VIII

...G AND DIGGING OUT

d pouring methods used upon the
eat that in order to be useful to a
obliged to be thoroughly familiar
ed necessarily be a foundry expert,
ding practice, the use of machines,
of different methods upon his steel
oundry makes a practice of holding
blow holes, hot checks, shrinkage
n the trouble is really the result of
tice, and the melting shop men too
thing is wrong about their metal,
beautiful castings ever seen, if only
nen who knew their business. To
of foundry and melting shop, often
part of the superintendent that too
attempt is made to cut the Gordian
intendent charge of both moulding
en a man can be found who is well
partments, no better arrangement
ver, the man who is an expert in
but a smattering of the principles
e the lives of the melting shop men

Mixing the Sand.—The moulding sands that are used in a steel foundry must be selected with care, and generally chemical analysis is needed at intervals to determine the suitability of a given sand for the work. The sand must be sufficiently high in silica to be quite refractory, in order that it may not be melted or softened by the heat of the steel. The average size and shape of the particles is also of importance, since they affect the porosity and bonding power of the sand. The practice in past years has been largely rule of thumb, and even to-day there is no way of making sure that a sand is suitable, without trying it. The mixture of several brands of

The stopper rod is fastened to the "goose-neck," which in turn is inserted in its socket on the ladle slide. Small ladles may be heated up with stopper rod and goose neck removed, and the rod dried out separately. For large ladles, it is necessary to leave the stopper rod in place, and merely raise the stopper off its seat while heating the ladle.

In any case, the stopper should be carefully adjusted before the ladle is heated, so that it closes the hole in the nozzle [illegible] ascertain if the stopper leaks, it is seated firmly and a little fine sand thrown around it. This testing with sand should be repeated when the stopper is put in place or lowered into position, after [illegible] ladle, and a ladle should not be filled until the ladle man is sure that it does not leak.

Some ladle men prefer, especially for large ladles, to arrange the stopper so that it strikes the outside of its seat in the nozzle, and slides into position as it is pressed home. It is generally best, however, to have the stopper co[illegible] its seat.

In pouring through a nozzle, the rod should be raised slowly the first time the nozzle is opene[illegible] he has got his stream going, [illegible] be closed off once or twice. By so doing he clears away from the nozzle any half melted sand that may be sticking to it, and ensures a clean shut-off. The first few times the nozzle is seated after the first opening, it often will not shut off clean.

Should the stopper get stuck hard to the nozzle, it should be poked off with a pricker from below, rather than trying to pull it off with the ladle handle. Too much enthusiasm at the handle sometimes pulls a stopper head off the rod. A frozen nozzle in large ladles is pricked open in the same way. Wooden prickers are better for this purpose than steel ones, as they do not freeze to the metal in the nozzle. But a steel pricker often has to be used for a badly frozen nozzle. In pouring a small ladle, if the nozzle freezes up, the steel had better be poured over the lip.

CHAPTER VIII

MOULDING, POURING AND DIGGING OUT

The effect of the moulding and pouring methods used upon the soundness of the [illegible] so great that in order to be useful to a [illegible] ist is obliged to be thoroughly familiar with the subject. [illegible] he need necessarily be a foundry expert, [illegible] moulding practice, the use of machines, etc., but as [illegible] ects of different methods upon his steel [illegible] y a foundry makes a practice of holding the steel [illegible] for blow holes, hot checks, shrinkage [illegible], when the trouble is really the result of ignorant or careless foundry practice, and the melting shop men too [illegible] t nothing is wrong about their metal, which would pour into the most beautiful castings ever seen, if only the foundry were in charge of men who knew their business. To prevent this [illegible] tude of foundry and melting shop, often calls for a [illegible] the part of the superintendent that too few men [illegible] y an attempt is made to cut the Gordian [illegible] superintendent charge of both moulding and steel making, [illegible] d when a man can be found who is well versed in the [illegible] th departments, no better arrangement can be made. [illegible] however, the man who is an expert in handling the [illegible] esses but a smattering of the principles of steel making, [illegible] is rule the lives of the melting shop men are made a burden to them.

Mixing the Sand.—The moulding sands that are used in a steel foundry must be selected with care, and generally chemical analysis is needed at intervals to determine the suitability of a given sand for the work. The sand must be sufficiently high in silica to be quite refractory, in order that it may not be melted or softened by the heat of the steel. The average size and shape of the particles is also of importance, since they affect the porosity and bonding power of the sand. The practice in past years has been largely rule of thumb, and even to-day there is no way of making sure that a sand is suitable, without trying it. The mixture of several brands of

The stopper rod is fastened to the "goose-neck," which in turn is inserted in its socket on the ladle slide. Small ladles may be heated up with stopper rod and goose neck removed, and the rod dried out separately. For large ladles, it is necessary to leave the stopper rod in place, and merely raise the stopper off its seat while heating the ladle.

In any case, the stopper should be carefully adjusted before the ladle is heated, so that it closes the hole in the nozzle exactly. To ascertain if the stopper leaks, it is seated firmly and a little fine sand thrown around it. This testing with sand should be repeated when the stopper is put in place or lowered into position, after heating the ladle, and a ladle should not be filled until the ladle man is sure that it does not leak.

Some ladle men prefer, especially for large ladles, to arrange the stopper so that it strikes the outside of its seat in the nozzle, and slides into position as it is pressed home. It is generally best, however, to have the stopper come vertically down upon its seat.

In pouring through a nozzle, the rod should be raised slowly the first time the nozzle is opened, and the pourer will do well, soon after he has got his stream going, to close off once or twice. By so doing he clears away from the nozzle any half-melted sand that may be sticking to it, and ensures a clean shut-off. The first few times the nozzle is seated after the first opening, it often will not shut off clean.

Should the stopper get stuck hard to the nozzle, it should be poked off with a pricker from below, rather than trying to pull it off with the ladle handle. Too much enthusiasm at the handle sometimes pulls a stopper head off the rod. A frozen nozzle in large ladles is pricked open in the same way. Wooden prickers are better for this purpose than steel ones, as they do not freeze to the metal in the nozzle. But a steel pricker often has to be used for a badly frozen nozzle. In pouring a small ladle, if the nozzle freezes up, the steel had better be poured over the lip.

CHAPTER VIII

MOULDING, POURING AND DIGGING OUT

The effect of the moulding and pouring methods used upon the soundness of the castings is so great that in order to be useful to a steel foundry, the metallurgist is obliged to be thoroughly familiar with the subject. Not that he need necessarily be a foundry expert, versed in the economies of moulding practice, the use of machines, etc., but as concerns the effects of different methods upon his steel he must be an expert. Many a foundry makes a practice of holding the steel maker responsible for blow holes, hot checks, shrinkage cavities, etc., in the castings, when the trouble is really the result of ignorant or careless foundry practice, and the melting shop men too often take the attitude that nothing is wrong about their metal, which would pour into the most beautiful castings ever seen, if only the foundry were in charge of men who knew their business. To prevent this cat and dog attitude of foundry and melting shop, often calls for a degree of tact on the part of the superintendent that too few men possess. Frequently an attempt is made to cut the Gordian knot by giving the foundry superintendent charge of both moulding and steel making, and indeed when a man can be found who is well versed in the practice of both departments, no better arrangement can be made. Too often, however, the man who is an expert in handling the moulding, possesses but a smattering of the principles of steel making, and under his rule the lives of the melting shop men are made a burden to them.

Mixing the Sand.—The moulding sands that are used in a steel foundry must be selected with care, and generally chemical analysis is needed at intervals to determine the suitability of a given sand for the work. The sand must be sufficiently high in silica to be quite refractory, in order that it may not be melted or softened by the heat of the steel. The average size and shape of the particles is also of importance, since they affect the porosity and bonding power of the sand. The practice in past years has been largely rule of thumb, and even to-day there is no way of making sure that a sand is suitable, without trying it. The mixture of several brands of