CHAPTER IV

THE BESSEMER PROCESS

The Bessemer process for converting pig iron or its equivalent into steel was invented by Sir Henry Bessemer in the 1850's, and was the first method ever developed for the production of steel in large heats and at a low price. It is an indirect method—that is, it converts pig iron, the first product made from the ore, into steel—and owes its cheapness to the tremendous tonnage that can be turned out with a comparatively inexpensive installation.

The process consists in blowing air through a molten mass of pig iron, high in carbon, silicon and manganese, contained in a cylindrical vessel lined with refractory material and open at the upper end for the escape of the gases. The oxygen of the air oxidizes the silicon, manganese and carbon very rapidly, the silicon and manganese forming SiO_2 and MnO, which unite with FeO produced by the oxidation of some of the iron to form a slag; the carbon escaping into the air as CO and burning at the vessel's mouth to CO_2, producing an intensely bright flame. In from 8 to 15 minutes the impurities in the steel are all oxidized, and iron begins to burn rapidly, producing a great deal of FeO, some of which is absorbed by the metal, the rest going into the slag.

The combustion of the silicon to SiO_2, and to a less degree that of manganese to MnO, produces a great amount of heat. That of carbon to CO adds only slightly to the heat of the steel. The heat produced by the combustion of these elements raises the temperature of the molten iron the amount necessary to maintain it fluid when the impurities are all removed and a bath of metallic iron remains.

It was the FeO absorbed by the steel at the end of the blow that hampered the early experiments of Bessemer, and for a time rendered the success of the process doubtful. The metal when tapped from the stationary vessels first used, was so heavily oxidized and full of gas that it was "wild" in the moulds, full of blow holes, weak, and generally worthless. Nevertheless, plants were built to produce Bessemer steel and constant efforts made to overcome this difficulty.

In Sweden, the process was a success practically from the start, and many plants were erected that produced excellent steel without difficulty. Upon investigation, it was found that the Swedish pig iron used for the process was so high in manganese that much of this element remained unburned till near the end of the process; and that as the Swedes had adopted the procedure of stopping the blow when about the amount of carbon was left in the metal that was desired in the finished product, much manganese remained in the blown steel. It was thought, rightly as it proved, that this manganese counteracted the injurious effects of the oxidation of iron, and that in blowing pig iron low in manganese, the addition of spiegel (pig iron containing 10 to 20 per cent. of manganese) might overcome the difficulties that were being experienced in English practice. The surmise proved correct, the low manganese pig iron blown as usual and then treated with molten spiegel to add manganese (and at the same time the desired carbon), was found to produce excellent steel, and from that time on the success of the process was assured. In 1856 Sir Henry Bessemer read his paper on "making wrought iron and steel without fuel," and acknowledged the necessity of manganese—Mushet obtained a patent on the use of manganese the same year.

The development of the process for making steel of all grades from soft structural steel to medium hard steel for rails, and even high carbon steel for tools, was very rapid. Inventors in all countries vied with one another in improving the mechanical devices used in the process, and increasing the size of the vessels and the output. The vessel was mounted on trunnoins, whereby the speed of handling was greatly increased; in place of melting the pig iron in cupolas, the fluid pig from the blast furnaces was kept hot for use in the Bessemer plant in a "mixer" (a tilting furnace of large capacity); the spiegel necessary for deoxidizing and recarburizing was melted in cupolas instead of reverberatory furnaces; and the cranes, casting pits and other apparatus for getting the steel into the ladles and thence to the moulds were greatly improved. At the same time the size of the vessels was increased, until in place of the 2- and 3-ton vessels first used, the standard steel works size in America to-day is from 10 to 2c tons.

In the manufacture of castings, the large bottom-blown vessel has been used to a certain extent from the first, but the application of the Bessemer process to the steel foundry soon involved the design of small units, and was hampered by the difficulty of producing steel in small heats that was hot and fluid enough to be run into light castings. In the efforts that were made to overcome this difficulty two lines were followed. The first was to retain the bottom-blown type of vessel and find means to produce higher temperatures by changes in the volume of air blown through the metal, that is, speeding up the process; by changes in the amount of heat-producing elements contained in the pig iron; and by adding heat-producing elements at some stage or stages of the blow. The second was to utilize the principle soon invented for warming up cold heats in the ordinary vessel, of blowing at or over the surface of the bath and attaining extra temperature by the combustion of iron and the burning of CO to CO_2 within the vessel. This led to the perfection of the side-blown vessel.

It was soon found that of the manganese added to Bessemer steel, a part was found chemically combined in the steel, a part disappeared. Moreover, within limits, the more manganese was added, the greater was the actual weight of manganese lost. As we now know, the manganese reduces the FeO in the steel by the reaction

$$FeO + Mn = MnO + Fe,$$

and the manganese oxide goes largely into the slag. Part of it is retained in the steel, but its influence is not so harmful as that of FeO.

A second function of the manganese is to unite with the sulphur of the steel, which normally exists as sulphide of iron, FeS, to produce sulphide of manganese, MnS. Owing to its existing in the steel as more or less rounded globules, instead of in strings between the crystals, MnS does not make steel "red short" (*i.e.*, weak and brittle when hot) to anything like the same degree as does FeS; and as iron does not dissolve the sulphides of other metals readily, some of the MnS floats out of the steel. These two functions of manganese are the basis of modern steel making.

A point to be clearly remembered in this connection is that, as already stated, more actual weight of manganese added increases the weight of manganese lost, that is the manganese converted to MnO and slagged. This means that the reaction between manganese and oxide of iron does not readily complete itself, owing to the tenacity with which metallic iron retains its own oxide in solution; and that in order to force the maximum amount of FeO to react with the manganese, we must have a considerable excess of the latter present. It is almost as if the manganese were a weight, the iron a sponge, and the FeO the water held in the interstices of the sponge. By setting a 4-oz. weight on the sponge we force out part of the water, putting on 4 oz. more expels still more water, and so on. We never can force all the water from the sponge by pressure; and by the reducing action of manganese alone, especially in the Bessemer process in which the manganese has but a short time to act, we can never expel all the FeO from the steel. A proportion remains, which depends largely upon the amount of manganese added, and the time allowed for it to act. It is to this residue of dissolved FeO, as well as to the gases absorbed and never completely expelled, that the inferiority of Bessemer steel is attributed.

The advantages of the process for the production of light castings are:

1. Cheapness of installation.
2. Cheapness of steel produced.
3. Large output per dollar invested.
4. High temperature of steel.
5. Suitability for intermittent operation.
6. Small heats at short intervals.

The installation costs of a small Bessemer plant are low, especially if a side-blown vessel is used, as the chief items of expense for the side-blown plant are vessel, cupolas, positive pressure blowers and motors to drive them. No very expensive foundation work is required, and the equipment is quite simple. The bottom-blown shop requires, instead of positive pressure blowers, a blowing engine of considerable size and boilers to supply it with steam, making the equipment more costly than that of the side-blown shop.

In the introductory chapters, figures have been given that show the comparatively low cost of the steel per ton, and the great output per dollar invested. The side-blown vessel falls somewhat below the bottom-blown in these respects, owing to the heavier loss of metal in blowing, and to the lower output resulting from slower blowing.

The side-blown vessel produces metal that is considerably hotter than that of the bottom-blown, but either if properly handled can be counted on to turn out steel that will pour into light castings without undue difficulty.

Intermittent operation of a small Bessemer plant is the rule rather than the exception. If the cupolas are run every day, and in the case of the bottom-blown vessel, if the vessel is run every day, the operation of the shop will be more uniform. The fuel required to heat up the vessel and cupolas does not cost much, however, and as the installation costs, especially of small side-blown shops, are quite low, many such shops are regularly run only part time.

For a foundry making small castings, the light heats of the Bessemer vessel, coming at frequent intervals, are an advantage in pouring for two reasons. First, the metal can be brought very hot to the moulds and all poured before it cools off. Second, the work of the moulders is not greatly hindered by the pouring, since only part of the shop is invaded by the pouring gang at each heat and the men elsewhere can go on moulding undisturbed.

The disadvantages of the small vessel in steel foundries are: 1. Quality—the steel not being as good as crucible or electric steel, with which it competes, nor on the average as good as acid open-hearth steel. 2. Small heats—the pouring of castings of over four times the gross weight of the steel that can be produced at one heat is extremely difficult with a bottom-blown vessel, and over twice or three times the weight of a heat with a side-blown. This disadvantage, however, is more apparent than real, since it affects only the production of heavy work and the small converter is seldom able to compete successfully with the open-hearth foundries in heavy carbon steel castings. In some kinds of specialty work, where the specialty is an alloy steel made in castings of all weights from a few ounces to 10 to 12 tons, this disadvantage becomes a real one, and makes it probable that the ideal shop of this kind would have both open-hearth and Bessemer equipment, using the latter for the special steel in small sizes, and the former for the heavy special steel orders and for a miscellaneous trade in machinery castings of the better class. 3. Flexibility, by which is meant the ability to produce readily several different kinds of steel in small lots. In Bessemer practice, the only way to make several kinds of steel from one heat is to put molten recarburizers in two or more ladles and add a weighed amount of the soft metal from the vessel. When a very sticky slag is made (in the Bessemer process the slag is sometimes semi-solid), it is not difficult to hold back the slag with a skimmer, and thus get the correct amount of metal in the ladle. When a fluid slag is made, it becomes well-nigh impossible to weigh the metal accurately.

This practice, moreover, cannot be carried very far in Bessemer work because the chilling of the steel in the vessel is so rapid that not

more than two compositions of steel are readily made, and if the heat has been blown too cold, not even two.

The Bottom-blown Vessel.—The bottom-blown converter of small size is not widely used in this country, so that there is but one general type made. This is a plain cylindrical vessel, generally of about 3 tons capacity, with tapered nose, built all in one piece except the bottom and wind box, which are arranged to be readily removed from the body of the vessel. The vessel is mounted on trunnions, is revolved by a hydraulic cylinder with a rack working on a pinion on one vessel trunnion, or by an electric motor. The blast main enters through one trunnion, goes down the side of the vessel, and is attached to the wind box through a coupling readily broken when the bottom is removed. The bottom and wind box are permanently fastened together, and clamped to the body of the vessel in such a way as to be readily taken off when a new bottom is needed.

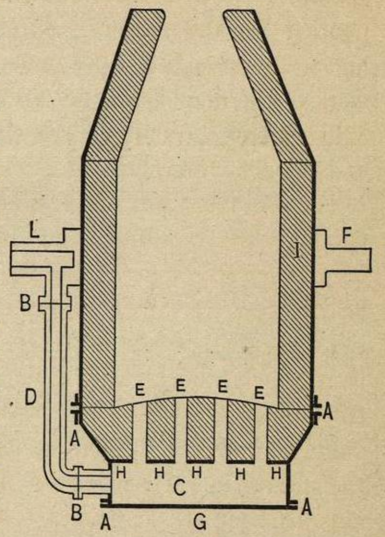

Fig. 5.—Bottom-blown Bessemer converter. Vertical section. A, Clamping lugs; B, joints in blast pipe; L, F, trunnions; D, blast pipe; G, wind box cover; C, wind box; H, bottom plate; E, tuyères; I, lining.

The vessel proper is generally lined up with flat slabs of so-called mica schist or of silica rock, beginning at the nose and working upward (the vessel being swung into position with nose down), until the whole is filled. The lining in the main part of the vessel is made about 10 in. to a foot thick, the slabs are wedged tightly in place, breaking joints carefully, and the whole well plastered with siliceous ganister (old silica brick or silica sand and pebbles ground up with enough clay to make the mass plastic). The bottom of the converter is provided with holes between wind box and lined space, on which the clay tuyères are set. These are bricks some 2 or 3 ft. long, each pierced with a number of small holes about $\frac{1}{2}$ in. in diameter through which the air passes. The outside of the bottom is lined with mica schist or rock of the same sort as that used in the body of the vessel, the space around the tuyères is partly filled up with large bricks set on end, and the remaining space is then packed with ganister ground very dry, shoveled in a few inches at a time, and tamped down with moulders' rammers. The whole is brought to a slightly convex surface, and is then dried out in an ordinary flask oven. The tuyères, bricks and ganister used for bottoms should be selected with care, as the life of bottoms is short enough at the best, and to use tuyères that melt or slag away rapidly greatly shortens this life.

The number of tuyères used for a 3-ton vessel is such that the total tuyère area is about 6 to 10 sq. in. If each tuyère has seven holes $\frac{3}{8}$ in. in diameter, and nine tuyères are used, this gives 6.95 sq. in. tuyère area. By varying the size of holes in one or more of the

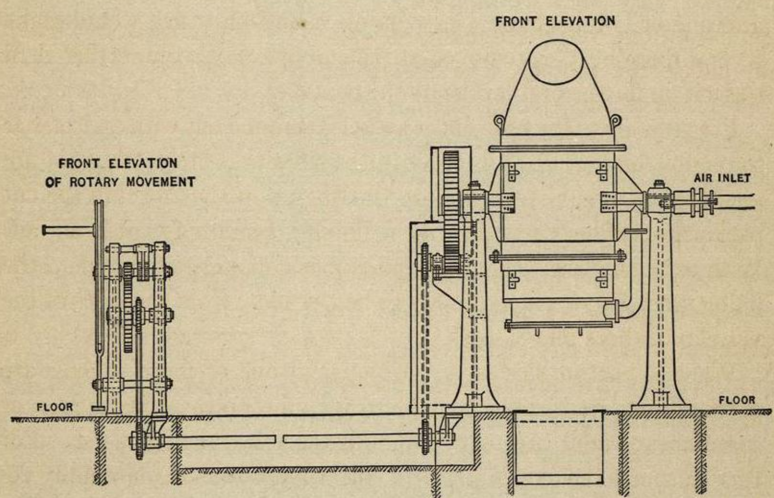

Fig. 6.—Walrand-Lègenisel converter. Front elevation. From Journal of the Iron and Steel Institute.

tuyères, and sometimes by omitting one tuyère, this area can be varied to meet the requirements. In general, with a given equipment, to reduce the tuyère area means slower blowing and less "slopping." The pressure of the blast can be changed to accomplish the same ends. The blast ordinarily used is supplied at a pressure of from 15 to 30 lb. per square inch.

The life of a vessel lining should be from six months to a year. The composition of the metal charged in the vessel, by its influence on the slag produced, affects the life of linings, and especially of bottoms, very considerably. A high silicon, low manganese mixture produces a very siliceous, sticky slag, which cuts the linings hardly at all, while higher manganese produces a slag rich in oxide of manganese,

fluid, and greedy for silica, which cuts linings and bottoms severely. In general, it is better to proportion the ganister used to give the greatest possible life of linings and bottoms with a given iron mixture, rather than to suit the mixture to the lining. This is especially the case where scrap can be used as a substitute for part of the pig, resulting in a considerable saving, though at the expense of linings on account of manganese in the scrap. It costs so little to line a vessel that the decreased life of lining is much more than offset by the saving in materials.

Bottoms will last from 15 to 40 heats—the latter figure is a high one. Frequently, on account of the delay incident to changing bottoms in the middle of a day's run, and the cold steel inevitably blown in the first one or two heats on a new lining, a bottom which would make several more heats is removed at the end of a day's run, rather than leave it on for the first few heats the next day.

Between heats the nose of the vessel is scraped out with an iron bar to remove loose slag, and places in the sides that are cutting out are plastered with ganister. Before starting up in the morning the cut places are similarly patched, if the lining is tending to cut itself out. With very siliceous slags the tendency is sometimes to build up the lining, and slag occasionally has to be cut away from the sides of the vessel with bars and sledges.

When a bottom is nearly used up and one or more tuyères are getting short, it is necessary to blank off a few holes in the tuyères, or sometimes a whole tuyère, by ramming the holes full of ganister. For this purpose the cover plate of the wind box is made readily removable, so that between heats the plate can be taken off and tuyères blanked off from the bottom. Holes in long tuyères that get stopped up are at the same time poked out with small bars.

Bottoms are put on by turning the vessel upside down, shoveling a good layer of ganister on the lining where the joint comes, setting on the bottom and tightening up the bolts, at the same time ramming the ganister tight with moulders' rammers.

Before blowing steel, the vessel has to be brought up to a good yellow heat. This is generally done by building a wood fire in it, turning on a gentle blast, and then dumping in lumps of soft coal. The fire is kept going three or four hours, and serves very well. The same thing can of course be done with an oil burner or other form of torch.

It is hardly possible to give the crew needed to handle the shop, as this varies considerably with the tonnage made, furnaces used for melting recarburizers, etc. Omitting the firemen on the boilers, and the engineer of the blowing engine, the men needed are:

Blower—generally foreman of the whole shop. He works, when blowing, in the "pulpit" where he can see the flame of the vessel and as much as possible of the shop. In the "pulpit" are the levers controlling the blast and the revolving mechanism of the vessel, engine-room push buttons or whistle cord, etc.

Vessel foreman—in charge of vessel and ladles.

Ladle man and two or three helpers, who also assist on the vessel.

One (or two) men on vessel charging platform, who may be part of ladle gang.

Cupola tender and helper.

One cupola charger—if mechanical charging be used.

Yard gang, who handle raw materials for cupolas, and charge the latter in many shops.

Physic furnace foreman and helpers.

For vessel, ladles, etc., and cupolas, eight or nine men should be able to take care of 15 or more heats a day, including loading slag on small cars. If the slag is wheeled out in barrows, extra men must be provided for this job.

The Side-blown Vessel.—The side-blown vessel, which is the type almost universally used in steel foundries in America, differs from the bottom-blown chiefly in the construction of the vessel, and the pressure and method of application of the blast. It can be successfully used in smaller sizes, 2 tons being the most common capacity. In the original type of side-blown converter, the tuyères were placed around the sides of the vessel, somewhat below the surface of the metal. In consequence, a fairly high-blast pressure was required. These vessels may be considered as merely a modification of the bottom-blown type. The heavy wear on the lining at the tuyères, coming on the sides instead of on the removable bottom, is a great disadvantage because it renders necessary repairs to the lining itself every 20 to 30 heats. These converters are now little if at all used in America and will not be considered in this work.

The true side-blown vessel is one in which the blast is introduced through tuyères in one side of the vessel, above or *at the surface of the bath.* The Tropenas vessel was one of the first of this design to be widely used in America. In its original form it was provided with two rows of tuyères, the upper being designed to introduce extra air and burn CO to CO_2 more advantageously than by blowing an excess of air through the lower set. The extra set, however, proved to be

difficult to manipulate and are now seldom used. To prevent undue oxidation of iron, the bath in this vessel has been made very deep. In placing a tamped lining in the Tropenas vessel, a collapsible form is used. The tuyères, which are commonly of brick, are comparatively short, and are said to require replacing every 20 heats or so.

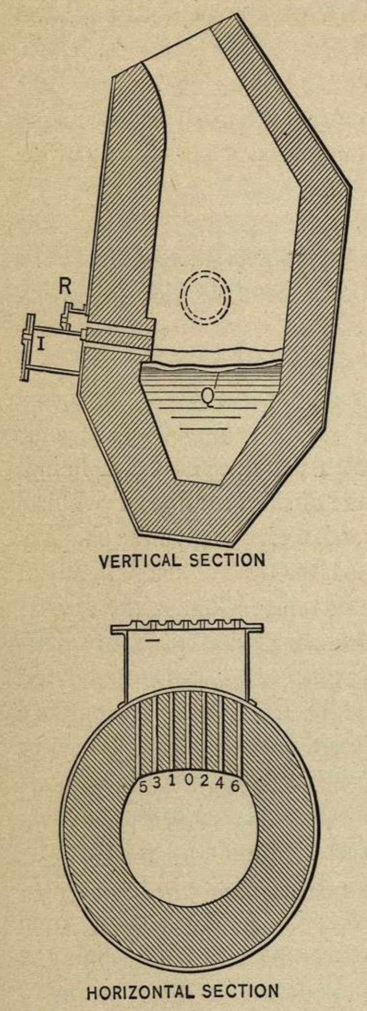

FIG. 7.—Tropenas converter. From Transactions of the American Institute of Mining Engineers.

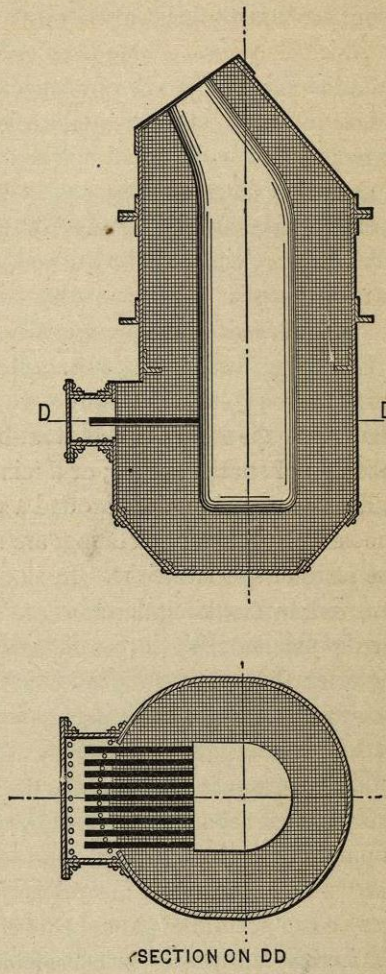

FIG. 8.—Stoughton long-tuyere converter. Vertical and horizontal section. From Transactions of the American Institute of Mining Engineers.

In recent years, several designs of two-piece vessels have been placed upon the market, in which either the top or the bottom half is made removable and is clamped on much as are the bottoms of bottom-blown vessels. The Stoughton converter is of this type, the bottom half, with the tuyères and wind box, being removable. This feature facilitates relining, as a solid wooden form is used for each part in placing tamped linings, and is said to allow of the use of a single vessel for continuous operation. Further features of this converter for which advantages are claimed are the use of iron or steel pipes for tuyères, held in place by a casting on the side of the vessel, in which they have a long bearing, some 9 in.; the thickening of the lining at this point, whereby longer tuyères are used; and increased height of vessel, whereby slopping is minimized. The placing of the tuyères is much simplified by the use of the solid bearing for them, and as they burn off they can be pushed forward a little and the lining patched around them. By the use of a thicker lining at the tuyères it is claimed that 25 to 30 heats can be made without putting in new tuyères. The removable bottom allows of extensive repairs to the lower half of the lining without disturbing the upper half.

The linings used in these converters are of three types: silica rock, (ganister rock), or mica schist slabs set in the converter in the same manner as the lining of a bottom-blown vessel; silica brick linings made up of special shapes; or a mixture of silica sand (and pebbles) and clay tamped in place around a wooden core to give the shape of the inside. When brick linings are used, the tuyères are generally in the form of special bricks. In stone or tamped linings the tuyères are made by moulding the lining round wooden forms (which are afterward pulled out), by the use of brick tuyères, or by using iron or steel pipes for the purpose which are left in place. In making a tamped lining one course of brick is generally used next to the shell, and the bottom is built up of brick for one or two courses.

The tuyères are generally arranged in fan shape, in order to cover every part of the converter with the blast. Minor repairs in the way of patching the lining, especially at the tuyères, have to be made for every run. The vessel is used only every other day, making from 7 to 12 heats, and the patching done on the idle days. The lining at the tuyères is generally patched from the outside by cutting it away at this point and replacing tuyères and lining through the wind box opening. For this reason it is commonly necessary, in order to blow steel every day, to have two or three vessels, since the converter cools off too slowly to enable the men to work at it and have it ready for use every day.

To overcome this difficulty, the Tropenas Company has introduced, in small sizes, a drop-bottom converter. In this design, the bottom is closed by a swinging door, such as those used on cupolas, which is dropped after the day's run, and the bottom punched out. With both ends of the vessel open it cools quite rapidly, and repairs can be made to the lining each morning without difficulty.

The top section of the lining of two-piece vessels lasts several months with only a little patching. In one shop, running a vessel every other day, making about 8 heats a day or 24 a week, a ganister lining is said to last about 9 months.

The side-blown vessel is heated up every day before steel is blown, sometimes with a coal fire, but more often by means of an oil burner introduced through one of the tuyères.

The blast used in these converters is at a pressure of 3 to 4 lb. per square inch, occasionally 5 lb. In order to furnish blast at this pressure in the necessary quantity, a positive pressure blower is required.

Special Types of Converters.—Two special designs of small converter deserve notice here, before the general description of Bessemer practice is taken up. The first of these is the Stock converter, in which the pig iron and scrap are charged cold and melted with oil burners introduced through the tuyères, after which the vessel is turned up and the metal blown. During the melting period the hot gases from the oil burners are taken off through an "economizer" or brick chamber containing iron pipes, which is opposite the nose of the converter while oil is being burned. When the metal is melted, the vessel is turned up to blowing position and the blast is taken through the pipes of the economizer, whereby its temperature is considerably raised. By the use of hot blast a very high blowing temperature is said to be attained. The advantages of this type of vessel are the high temperature of the metal, and the fact that in oil melting there is no absorption of impurities from the fuel, whereby the increase of sulphur in the iron, which is often so troublesome in regular practice, is avoided. This vessel has a distinct field of its own—the production of a very small tonnage of small steel castings as an accessory to shops not contemplating the production of steel in quantity, in localities where coke is costly. For this field its cheapness of installation commends its use. To attempt to compete with users of regular types of converters in localities where coke is cheap is quite another matter. To begin with, the melting of the metal will be considerably more costly by this process than by cupola melting, when enough steel is to be made to give the cupola a good run. In the second place, the Stock vessel will turn out steel at the rate of only about 1 heat every two hours. Compared with the regular vessel which produces 2 or 3 heats an hour, therefore, the Stock converter is at a disadvantage, as it would require from four to six of these vessels to equal the production of one converter of equal size supplied by a cupola. As the economy in installation is confined to cost of cupola and its blowers, we can readily see that for considerable tonnages this saving will vanish, since one cupola with blower or fan can be installed more cheaply than three to five extra vessels.

The field for the Stock converter will therefore be found in places where coke is costly and oil cheap. Under such conditions oil melting may be cheaper than cupola melting, but even then the disadvantage of being obliged to use a number of vessels to attain high output will remain. To take advantage of cheap oil and costly coke under these circumstances it might be more economical as far as melting costs go, for the production of a considerable tonnage of small castings, to install oil-burning melting furnaces and use them to supply a single converter of the usual type. The first cost of such an installation, however, would be greater than that of a battery of Stock converters, and if a regenerative furnace were used it could not be run intermittently, as converter plants can.

Bessemer Electric.—The second special type of vessel is the combined Bessemer converter and electric furnace, in which metal is first blown and afterward refined with electric current. The discussion of this type properly belongs with that of electric furnaces in general, and both this design and the open-hearth electric furnace will be described in the chapter devoted to electric furnace melting.

LAY-OUT OF BESSEMER SHOP

The lay-out of a shop depends so much upon the conditions in each case that it is not easy to give more than the general rules that apply to the subject, and many of them are rather negative than positive, stating rather what not to do than what to do. For convenience we will assume that our shop is of fair size containing say a 3-ton bottom-blown vessel or two 2-ton side-blown vessels, and that we shall produce about 8 to 15 heats per day. This comparatively large production is taken as a basis, since a shop making but a few heats a day, or a few heats a week, does not involve the problems in economical handling of material that demand attention in laying out the plant.

The shop will consist of

1. Engine room.
   - Bottom blown
     - Blowing engine and boilers
     - Pump for moving vessel by hydraulic power
     - Fan or compressor for cupolas (and for melting furnaces for recarburizers)
   - Side blown...
     - Compressor for vessel
     - Fan or compressor for cupola (and for melting furnaces for recarburizers)
2.
   - Cupolas
   - Vessel
   - (Melting furnaces for recarburizers)
3.
   - Ladle handling and heating fires (or oil burners)
   - Extra bottom handling and oven (bottom blown)
4. Yard for storage of..
   - Coal for boilers—bottom blown and for recarburizer furnaces, if crucible coal holes are used
   - Coke for cupolas.
   - Pig iron
   - Purchased scrap
   - Shop scrap
   - Ferromanganese, ferrosilicon, etc.

In the general arrangement of the shop, care should be taken in the first place to see that the units are so placed that they will not be in each other's way when the increasing output of the shop calls for extensions. In a bottom-blown shop, with its bulky installation of boilers, blowing engine, etc., this heavy machinery cannot readily be moved to allow for errors in original placing, and care should be exercised to locate it so that the other units of the plant can readily be extended without being interfered with by a badly placed engine room. At first sight this seems a simple matter, but when it is considered that the blowing engine must be fairly close to the vessel (because the engineer must see what is going on), the problem becomes more difficult. As the large blowing engine of the bottom-blown vessel is generally steam driven it will frequently be economical to install steam-driven pumps and to provide hydraulic power to rotate the vessel, and other small steam equipment.

The engine room equipment for a side-blown vessel is so much less bulky that it is far easier to place to advantage. The compressors are generally driven by electric motors, and occupy relatively little space. The vessel is most often turned over by an electric motor, and this still further reduces the total of equipment.

The cupola or cupolas for melting the vessel charge should be so placed as to most easily transfer the metal from them to the vessel. Though in small shops the cupolas are generally tapped near the ground and the metal brought to the vessel by lifting the ladles with the overhead crane, the economy of time and labor necessary where many heats are to be made points strongly to the desirability of placing the cupolas with their tapping level above the charging level of the vessels. This is especially desirable when several consecutive heats are to be blown for one casting, as delays in crane service may then retard the rapid production of the heats so essential to success. It may be objected that the extra height to which the pig iron and coke have to be hoisted is a disadvantage; but they have to be hoisted anyway, and if an elevator is to be used a few feet of extra lift do not materially affect the cost of hoisting. If the material is to be delivered to the cupola charging platform by an overhead crane in the stock yard, the extra height of crane runways needed for the higher cupolas would be a more serious matter, but in the majority of small steel foundries other means of yard handling are generally cheaper than an overhead crane so that this objection will not often be a valid one.

It is, therefore, generally most advantageous to have the cupolas at a higher level, discharging into a ladle on a vessel charging floor. This ladle may be swung with a crane, or mounted on trunnions (often on a platform scale, in order to weigh the amount of metal for each heat), and turned by a wheel with gear and pinion, running the metal through a spout into the vessel.

To facilitate the use of cupola metal for recarburizing high carbon heats, a swinging cupola spout will be of great advantage. By this means small ladles on a platform scale can be filled from the cupola with the proper amount of metal, and their contents poured into the vessel; or if the recarburizing is done in the ladles, the latter can be set upon the scale and filled direct from the cupola. Either arrangement would be more convenient than taking metal from the ladle used to weigh vessel charges.

The bottom-blown vessel is swung into a horizontal position for charging, and generally is charged when turned over in one direction, and poured when turned the other way. This necessitates the use of two spouts if recarburizing is to be done in the vessel, one to run in the blowing charge, and one to run in recarburizer. The side-blown vessel, on the other hand, generally is charged and poured on the same side. Hence if the recarburizers are to be added to the vessel,

they can be run in by means of the same spout as that used to pour in the blowing charge.

Melting furnaces may or may not be installed for premelting "physic" (that is recarburizer), depending largely upon the grade of steel to be produced. If much hard steel, or steel containing a high percentage of alloys, is made, they are frequently a necessity, though at times the use of fluid metal from the main cupolas is all that is necessary.

The melting furnaces used for recarburizers should be of a type that can be operated intermittently, because of the generally intermittent, or at least single-turn operation, of the shop as a whole. Depending largely upon the kind and quantity of metal to be melted, we may use:

1. Small cupola.
2. Air furnace (coal or oil fired).
3. Crucible furnace.
4. Electric furnace.

The question of choice among these methods of melting is discussed in the section on the use of recarburizers.

If furnaces are used for melting recarburizers they should be placed so that they can readily pour their metal into the steel ladles, set on scales; or into a small ladle that can be poured into the vessel. When cupolas are used, they can be placed in such a way as to tap on the same level as those used to melt the vessel metal. In small shops where speed of operation is not particularly essential, the cupolas used for recarburizers are generally set at the general level of the foundry, and the metal taken to the vessel by cranes.

The main working floor should be as roomy as circumstances allow. Nothing is more fatiguing and exasperating to the men than a crowded shop where they have no elbow room and no place to jump to when the vessel "slops." As has already been pointed out in discussing crucible steel foundries, the greatest pains should be taken to provide means of throwing open in summer all places where men have to work—main floor, vessel platform, cupola tapping and charging platforms, physic furnaces, etc. Neglect of this important feature of design frequently adds considerably to the labor cost of shops when they grow to a good size and handle metal in bulk, since a hot stuffy working place simply means that the amount of work each man is physically able to accomplish per day is reduced and working forces are artificially enlarged.

Working space for lining and drying out ladles, fixing up stopper