CHAPTER VI

THE ELECTRIC FURNACE

The usefulness of the electric furnace in steel-foundry work (or other steel making, for that matter) is due almost wholly to the fact that it enables the steel-maker to carry the elimination of phosphorus, sulphur, and oxides and gases, to a point not possibly to be attained with any other steel-making process. This is especially true of sulphur and oxides. The ability to attain such a high degree of purification of the steel is due to the opportunity offered to expose the metal to conditions either oxidizing, neutral or reducing, at the will of the operator. By making an oxidizing slag with iron ore, lime, etc., we can expose our steel to oxidizing conditions. Then, as the atmosphere of the electric furnace can be made entirely neutral (or non-oxidizing), by scraping off this slag and making a new one of lime and fluorspar, and using reducing agents such as powdered coke and ferrosilicon, we can produce conditions almost as reducing as we please. Moreover, the very high temperature attainable enables us to melt slags composed almost wholly of silicate of lime and very free from metallic oxides, which deoxidize and desulphurize the steel almost completely.

The ideal finishing conditions for a heat of steel, a non-oxidizing atmosphere, and a slag (and therefore a steel) practically free from oxides of iron, can only be approximated in the open-hearth furnace. This is true, first, because the flame is always oxidizing, and second, becaus it is not feasible to melt slags very free from iron oxides and composed almost wholly of silicate of lime, on account of their high melting point. These ideal, but heretofore unattainable, conditions were put at our disposal by the development of the electric refining furnace, and at first sight it almost makes us expect the millenium.

Why, then, with the ideal steel-making furnace at last put at our disposal after working for centuries with what metallurgically considered are but make-shift methods, have we not at once abandoned the imperfect instruments and turned unanimously to the new way? The reason is not far to seek, and can be given in that single mighty little word "cost." Compared with other means of contributing

heat to metal, either to melt it or to keep it melted and superheated, the electric current is expensive. True, we can make steel in an electric furnace somewhat more cheaply than by the old-fashioned crucible process, and the steel if properly made is as good, or better. But when we compare electric furnace steel made from cold stock with Bessemer or open-hearth steel, we see we are attaining high quality at great expense. To melt cold stock and refine it to good steel, all with the heat of electric current, requires from 750 to 1200 kw.-hr. of power per ton of steel, and with power at 1 cent per kilowatt-hour, that means a "fuel" charge of $7.50 to $12.00. Even keeping previously melted metal hot and refining it requires some 150 to 300 kw-hr. per ton. These considerations make it clear why the electric furnace has not been widely adopted by the steel foundries.

There are no limitations to the process from the point of view of the kinds of steel that can be made. We have seen that the crucible process is not strikingly adapted to the manufacture of low carbon steels; that the Bessemer process, on account of the fact that all carbon is eliminated, and the desired amounts restored in the shape of ferromanganese, pig iron, etc., demands fluid additions for high carbon and high alloy steels, and will not make certain steels easily; and that the same is true of the basic open-hearth process when very low sulphur and phosphorus are to be attained, since in this case we frequently have to eliminate nearly all the carbon before we can get the impurities down to the desired point. In the electric furnace, on the other hand, additions of alloys of any kind, in any desired amount, can be made to the furnace, the alloys melted, and the whole bath brought up to high temperature, not only without change in the composition of the bath to which the alloys are added, but even without great loss of the alloys. This is owing to the fact already mentioned, that we can hold our steel for an indefinite period in a neutral atmosphere, under a slag that does not act on the carbon, silicon, manganese, or added alloys of the metal.

Still another advantage of the electric furnace has already been mentioned in discussing manganese steel, and is to be inferred from the previous paragraph. This is its ability to melt steel scrap containing costly alloys, without the oxidation and loss of the alloys that occurs in working up the scrap by Bessemer or open-hearth methods, or the great gain in carbon so difficult to avoid in crucible melting. None of these troubles occur with the electric furnace; we can remelt our scrap practically without change of composition, correct the trifling change that does occur with suitable additions, and pour our steel. As we have seen already, however, we do this at a high price, since to melt with electric power is costly; and it may or may not pay to remelt alloy steel scrap in the electric furnace, depending upon the value of the alloy in question.

Summarizing the sunny side of the question; the electric furnace gives us metal of unsurpassed quality, which is very hot, and will run the lightest sections with ease. The price of these blessings is growing less as time goes by. The furnace can be run intermittently as it is not essential to its operation that it be kept continuously hot; but the cost of installation, especially when a source of power must be provided, and consequent overhead expense, make idle hours an expensive luxury. The process is flexible when small units are used, as has already been explained at length in the introductory chapters; in large installations flexibility is attained only at a sacrifice of some of the excellencies of the process. Steel of any sort can be produced at will.

Aside from the cost of the steel several considerations have retarded the progress of the electric furnace. These are, first, newness; by which is meant the inevitable handicap imposed upon any new process or apparatus by the lack of available men competent to handle it. This is but a temporary condition, and grows less marked every year. Second, the development of the electrical efficiency of the apparatus more or less at the expense of metallurgical efficiency. This condition is due to the fact that the electric furnace was developed, perhaps naturally, by electrical rather than metallurgical engineers. Lack of familiarity with the fine points of steel making on the part of the men developing the furnace was to have been expected, and has been shown in a number of details of design and operation. For instance, devices to increase the electrical efficiency of the furnace have in many cases been adopted without due regard to the limitations imposed by convenience of handling steel and slag; and sometimes these devices have made the furnace far from "fool proof," a fatal objection to a furnace which must be manned at least in part by unskilled labor. Another instance has been in the methods adopted for setting bottoms in the furnaces. Sometimes from lack of familiarity with the proper methods to pursue, sometimes because the furnace is so designed as to make long lining life impossible electric furnace bottoms have up to a few years ago made but a few heats. Open-hearth men soon learned to set a bottom a bit at a time, and make it a solid mass capable of almost indefinite life, and the electric furnace operators might easily have profited by their experience. Yet they had to learn all over again that a bottom set in one operation can never be satisfactory.

A third disadvantage that the electric furnace has had to contend with is really but a corollary to that of high cost of steel. This is that the very high quality of steel which the electric furnace produces, is not yet in general demand at a price that will yield a profit to the maker of steel castings. Better and better steel is being sought for a great many purposes, however, and when electric steel castings have been upon the market a few years the demand for them is sure to come. At the same time the costs of production cannot fail to grow less as metallurgical engineers and electrical engineers work together upon the problem, and a point must eventually be reached where the demand for really high-grade castings will create a price which will yield a good profit to the maker.

The cost of installation of an electric furnace is rather high compared to that of other processes, especially if the engine and generator to supply power have to be installed. Upkeep costs have in the past been very high, partly, it is to be supposed, owing to the above-mentioned lack of familiarity with good practice that has been shown by the men in charge of the furnaces. Electrode costs on arc furnaces are not so high now as they were only a year or two ago, as great improvements in the design and manufacture of electrodes have come very rapidly. The rapid wearing out of roofs of arc furnaces, due to the great heat radiated from the arc, is a problem that so far has defied the efforts made to solve it in a completely satisfactory manner.

TYPES OF ELECTRIC FURNACES

Electric furnaces may be divided into three general classes, determined by the manner of generating the heat and applying it to the bath. One or both of two means of converting electric current into heat are made use of in all the furnaces so far built, the first being to utilize the great heat of the electric arc; the second, to use the heat generated in the metal by its resistance to the passage through it, of a heavy electric current. Thus we at once have two types, the arc furnace and the resistance furnace, and the first type is subdivided into the arc furnace pure and simple, and the arc-resistance furnace.

A table of the principal makes of furnaces now on the market will be useful in considering this subject, and is presented below:

Furnaces	Arc (Stassano)	
	Arc-resistance	Heroult
		Girod
		Nathusius
		Keller
		Gronwall
	Resistance	Kjellin
		Röchling-Rodenhauser
		Colby
		Frick
		Hiorth

The following description of these furnaces has been purposely made as general as possible and an effort has been made to point

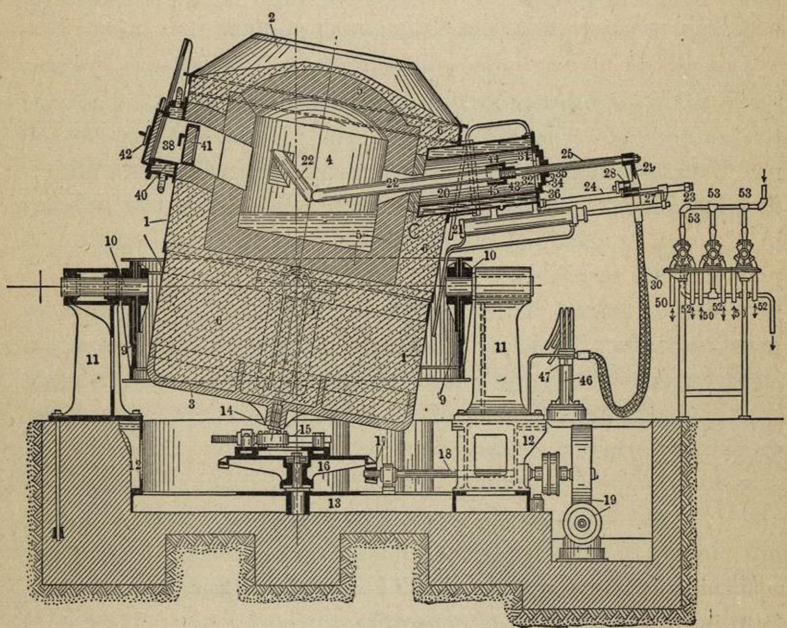

FIG. 11.—Stassano electric furnace. Vertical section. From "Metallurgical and Chemical Engineering."

out the merits or defects of a class only, not of a single design. The emphasis has been put on the metallurgical rather than the electrical features, and no attempt has been made to assign definite figures for current consumption to each furnace.

The pure arc furnace of Stassano consists of a cylindrical vessel of steel plate, lined with refractory material, and mounted at a

slight inclination, with means for revolving it about its major axis.[1] Three carbon electrodes are introduced through the side walls of the furnace near the top, inclined downward toward the bath, and with their tips separated a suitable distance, after the arc is struck. The current is carried to the electrodes from sliding contacts, and the arc plays between the extremities of the electrodes. The charge is thus heated entirely by the heat of the arc. When melting cold stock, however, the arc frequently jumps to one piece of scrap after another, and the fluctuations in the power consumption are then very considerable. The Stassano furnace requires rather

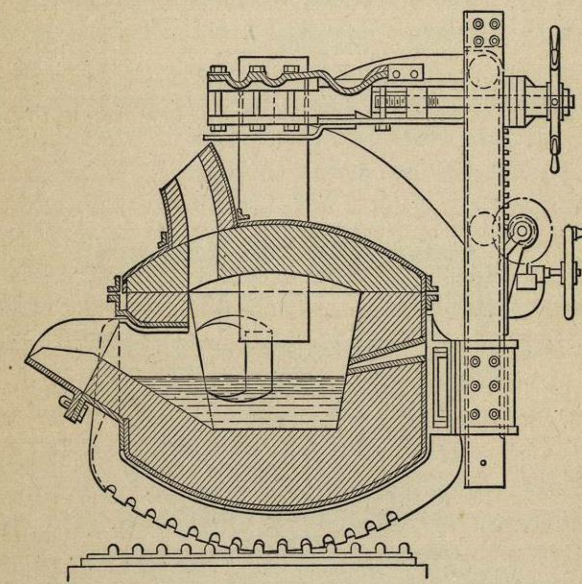

FIG. 12.—Heroult electric furnace with two electrodes. Transverse section. From "The Iron Trade Review."

more power per ton of steel than arc-resistance furnaces. The single chamber containing the metal in a bath, with working doors, is convenient for making additions to the metal.

The arc-resistance furnaces strike the arc between the ends of vertical electrodes and the metal being melted, or the molten bath. In the Heroult furnace, which is built much like the hearth portion of a tilting open-hearth furnace, all the electrodes are above the metal, and current travels from electrode to metal, through metal

(1) In the newest design of the furnace, shown in Fig. 11 the furnace does not actually rotate, but oscillates. This construction much simplifies the connections to the electrodes and does away with sliding contacts.

(or metal and slag), to the next electrode and so out. The bath is thus heated both by the heat of the arc and by the heat produced by the resistance of steel and slag to the passage of the current through them.

Modifications of this type consist for the most part in having all the (carbon), electrodes above the bath positive, and the negative electrodes in the bottom, or banks of the furnace, so that the current is forced to pass through the whole bath. The Girod furnace is provided with a number of iron electrodes built into the bottom of the furnace; in the Nathusius, the bottom itself, which becomes a conductor of electricity when hot, conducts the current from the

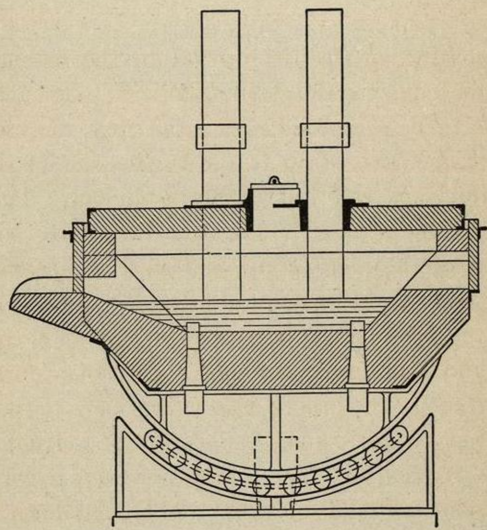

FIG. 13.—Girod electric furnace with four electrodes. Transverse section. From "The Iron Trade Review."

negative poles to the bath; the Keller is somewhat similar to the Nathusius, with a conducting bottom of iron rods and magnesite; the Gronwall has a carbon block next to the bottom plate, covered by the magnesite, which becomes a conductor when hot; and other modifications have been made.

Almost all the arc furnaces are made tilting, to avoid tap-hole troubles; and in most cases the roof is readily removable, to facilitate replacement, which is necessary at intervals too frequent to suit the ideas of men who are used to open-hearth practice. The great heat from the arcs wears away the silica brick roof very rapidly, and so far no means have been found to prevent it.

Aside from their electrical efficiency, which is better than that of the pure arc furnaces, the advantage of these bath furnaces, as they may be called, is chiefly that by means of the doors in sides and ends, the bath can readily be got at in working the furnace. There are advantages claimed for the submerged electrode types, in that a greater proportion of the heat is obtained by resistance, and hence a more uniform heating of the bath secured; while in the Heroult type the heat is largely concentrated at and near the arcs, so that with every increase in the surface of the bath the number of suspended electrodes needed is increased. This matter of multiplicity of electrodes is not confined to the Heroult type, however, since in all arc-resistance furnaces of large size, a number of electrodes have to be used.

Since in working an electric furnace for the refining of impure metal the first oxidizing and dephosphorizing slag, and sometimes a second, has to be scraped off from the steel, the desirability of having the charge concentrated in a single space of simple shape, all parts of which are readily accessible, is obvious. This advantage is possessed by the arc and arc-resistance furnaces, and from the point of view of the metallurgist and steel maker these furnaces are the most like "real furnaces" of any.

All these furnaces take alternating current at a comparatively low voltage and high amperage; consequently transformers to step down the current to the proper extent form part of the equipment, and very heavy copper connections carry the current to the electrodes. The frequency of the current, however, is normal.

The electrodes are made movable, and are fed down as they burn away, sometimes by hand, sometimes by electrically controlled apparatus that keeps the arc at a given length. They are made of graphite, or of amorphous carbon.

In melting cold stock, the current during the first hour fluctuates violently, owing to the jumping of the arc from one piece of scrap or pig to another. Frequently the arc "goes out" altogether, and the furnace man has to "stand by" and manipulate the electrodes. During this lively first hour or so, the power consumption jumps wildly from zero to almost anything you please. This state of affairs puts a heavy strain on a power line that is supplying other machines, unless the demands of the furnace are but a small fraction of the total power carried by the line. Thus a 1-ton furnace that operates on a line carrying several thousand kilowatts does not affect other machines on the line; while a large furnace in a manufacturing city, which took power from a private company, upset the entire town when the owners tried to melt cold stock in it.

The resistance furnaces that have been brought to the attention of the steel maker are all of the so-called "induction" type. That is, the furnace and transformer are one, the bath of steel being the secondary circuit of the transformer. The original Kjellin furnace consisted of a circular trough, lined with refractory material, which contained the metal to be melted; a core piece of iron, of which one leg was at the center of the circle of the trough, and one outside; and a primary winding, inclosing the outer leg of the core piece. In such a furnace, by passing a high-voltage current through the primary, a current is induced in the metal in the trough, whose voltage will be to that of the primary current as one (the number of turns in the secondary) is to the number of turns in the primary. Thus a low-voltage, high-amperage current in maintained in the trough.

Cooling devices for the primary winding are necessary, and of course suitable covers for the trough, tipping mechanism and spout, etc. In starting the furnace, a ring of iron or steel is placed in the trough in order to make a closed circuit for the current, and when this is melted cold scrap is charged. After one heat is made, by leaving a part of the metal behind after pouring, a ring is left to start the current. In refining molten metal from another furnace, of course, this is not necessary.

Of the modifications that have been made in this type of furnace, most have two objects: increasing the electrical efficiency, and providing a working chamber more easily got at than the ring. The Röchling-Rodenhauser furnace was designed to provide for both these improvements. In this furnace, the electrical efficiency was increased by surrounding both poles with a ring of steel, thereby catching a greater proportion of the magnetic flux lines; a large central bath was provided at the intersection of the two rings; and in addition, electrodes were bedded in the bottom at each end of the central bath which transmit current through the bottom material (as soon as the bottom becomes hot), thereby increasing the available supply of heat. This furnace is an improvement in electrical efficiency over the original single ring type; though the metallurgist feels a natural dread of the thin bit of bottom over the two end electrodes, lest a careless workman cut away the lining at that point in charging a chunk of metal, and expose the bare electrode.

Considered as a class, the induction furnaces have several dis-

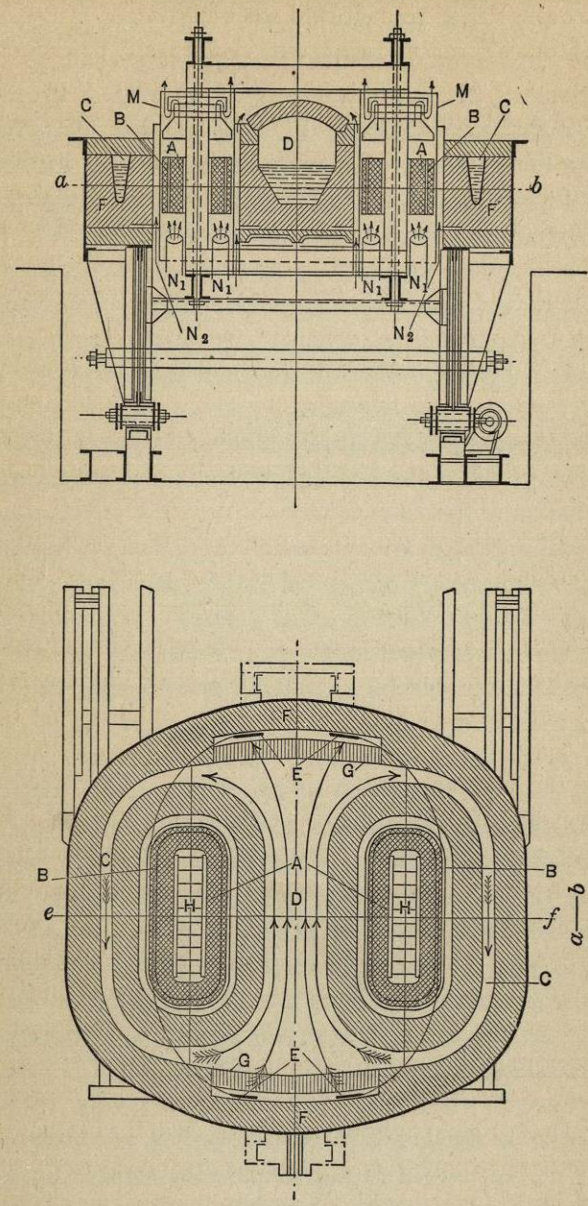

FIG. 14.—Röchling-Rodenhauser electric furnace, double ring type. Vertical and horizontal sections. From D. Carnegie, "Liquid Steel."

advantages, and one advantage, over the arc furnace. The first disadvantage is what has been dubbed the "pinch effect," and consists in the drawing in of the ring of metal at some point in its cross-section, as the current density is increased, resulting in breaking the circuit momentarily. This has hampered the electrical engineers in the development of the furnace, but since the induction furnaces as offered to the steel maker are not troubled by the phenomenon, it need not be considered here. Mr. Hering, indeed, has recently invented a most ingenious furnace whose prime feature is a means of utilizing this "pinch effect" to heat a large bath, by applying the current to one or more wells, as it were, in the bath's bottom. Several advantages are claimed for this design.

The low frequency of the current required by many of the induction furnaces is also a disadvantage in some cases, as it necessitates the installation of special generators.

The metallurgical disadvantages of the induction furnaces are, first, that as the heat is generated in the metal, and contributed to the slag only by conduction, it is impossible to maintain a very basic slag fluid; and for that reason, as we shall see a little later, desulphurizing of impure steel is not readily carried to the point that can be attained with arc furnaces.

The second is, that owing to the shape of the space containing the bath, it is not feasible to scrape off all of the oxidizing slag used for dephosphorizing, but a considerable amount of this slag has to be left in the furnace. The reducing conditions used to desulphurize the bath, at once reduce phosphorus from the slag left from the dephosphorizing period, so that a considerable rephosphorizing of the metal takes place. Thus it has been found that the degree of purification that can be attained in these furnaces is not as high as can quite readily be secured with arc furnaces.

The third disadvantage is the circulation of the bath in the narrow annular passages, which results in a mechanical erosion of the lining, in addition to the usual cutting action of the slag. In order to reduce the effect of this motion to a minimum, the annular passages are made of as great cross-section as possible; but there is a very definite and precise limit to the enlargement of the cross-section of the channels, inasmuch as the current density must be kept high in order to produce the requisite heat in the metal.

The advantage referred to is that the consumption of current in melting cold scrap is steady, so that no trouble on the rest of the line, such as has been described above, need occur in melting with an induction furnace. The power consumption figures that are available indicate also (though trustworthy figures are difficult to obtain) that the induction furnace will melt cold stock with less power than arc furnaces; so that for melting pure materials that need little refining, the induction furnace may have a certain advantage over arc furnaces. In this way it competes with the crucible process for the production of pure steel from pure raw materials.

Setting the Bottom.—Ordinarily, the bottom of an arc electric furnace is made up of magnesite, or occasionally dolomite, and is all placed at once by mixing the magnesite with enough hot tar to make it plastic, and ramming the mixture into position. The bottom is then dried out with a wood fire or oil burner, and set by melting down a small charge of scrap or pig, or by putting in a layer of coke, lowering the electrodes until they touch the coke and turning on the current.

A bottom so made cannot be properly set and baked in place and will last but a few heats. It is very prone to "come up" in chunks, and to cut through, resulting in break outs. In order to make a proper bottom that will "stay put" and last for a long time, the same method should be followed that has long been used in open-hearth practice; that is, placing but 1 or 2 in. of bottom at a time, and sintering each layer before the next is added. The method of heating used to set each layer is immaterial, so long as a high enough temperature is attained to partially fuse the refractory magnesite. By means of oil burners, or by covering each layer of bottom as shoveled in with coke and turning on the current, the furnace should be run up to a high heat and each layer well sintered. When the proper thickness of bottom has been attained, a wash heat of slag, or of pig and scrap, may be melted, the slag well splashed up on the banks and the bottom soaked as full of slag as possible. The bottoms containing large areas of iron conductors of course cannot be so set in.

If an acid lining is used it is set in just as an acid open-hearth lining is, and is made of the same materials.

Induction furnace linings cannot be put in by this method, and have in many cases given a great deal of trouble. Specially prepared refractory brick are commonly used for the purpose, and are said to last several months. Compared to that of an open-hearth bottom, or of some types of arc-furnace bottoms, this life is very poor.

Melting and Refining.—In the production of very pure steel from stock high in phosphorus and sulphur, the operation is divided into two distinct periods—the dephosphorizing and the desulphurizing stages. If cold scrap is melted, the dephosphorizing period overlaps the melting, as a proper slag is produced as soon as a part of the charge is melted, and melting and dephosphorizing go on together.

There will be a certain amount of FeO produced in melting, due to oxidation of iron, and some will come from the scale and rust on the stock. The oxidation of silicon in the scrap produces some SiO_2, which unites with the FeO and the added lime, to produce a fluid silicate of lime and iron. Steel foundry scrap will frequently have so much sand sticking to it, that a great deal of lime will be required to produce a basic slag. The bulk of the adhering sand should, therefore, be knocked off. By charging iron ore, or scale, and lime with the metal, a basic oxidizing slag is secured from the start. As melting proceeds, more lime and iron ore are added as needed. If molten metal is charged, the slag has to be made up by shoveling in iron ore, lime and a little silica. The slag desired is a silicate of lime and iron, very high in lime, in order that it may be able to hold the phosphorus in solution as phosphate of lime. Fluorspar is used to assist in liquefying the highly basic slag; and the metal is exposed to the action of this slag until the fracture of a test piece or a quick analysis shows that the phosphorus has been eliminated to the desired degree. In treating stock containing a very high percentage of phosphorus, the first slag frequently cannot be made to carry the elimination to the desired point, without increasing its bulk so much that it will be unmanageable. In this event the first slag is scraped off the steel with hooks and rabbles, and a second similar one made.

When the phosphorus is as low as desired (or a little lower, to allow for the inevitable rephosphorizing due to the slag that cannot be got out of the furnace), the slag is removed, and the metal is ready for the desulphurizing stage.

As the conditions to which the steel is now to be subjected are reducing, and as the steel is conveniently bare at this stage, the additions necessary to provide the carbon, manganese, etc., desired are often made after the dephosporizing slag is removed. Ferromanganese, ferrosilicon, pig iron, etc., are thrown in and melted; and the desulphurizing and deoxidizing slag is then formed.

Desulphurizing and deoxidizing are carried out by the addition of ferrosilicon and ferromanganese to the steel, the silicon reacting with the oxide of iron to form SiO_2 and metallic iron; and by forming of lime, sand and fluorspar, a slag composed largely of silicate of lime, which promotes the formation of sulphide of lime, and the elimination of the sulphur. In arc furnaces, coke dust is sprinkled over the surface of the slag, and acts partly as a deoxidizer, reducing FeO and MnO in the slag and sending iron and manganese into the steel; and partly as a desulphurizer, by the formation of calcium carbide. The latter is supposed to attack the sulphur in the steel, forming calcium sulphide, which is dissolved by the slag. Sometimes the coke dust is sprinkled upon the bare metal before the addition of lime and fluorspar, instead of on the slag. The additions of lime, coke and ferrosilicon are kept up until the slag is practically white, and falls to powder when allowed to cool.

Tests are taken every little while, which, when the steel is ready to pour, should set quietly in the mould and of course should pour cleanly from the spoon. These tests may be analyzed for sulphur, if very pure steel is desired. Sometimes a small steam hammer is used to pound the tests out flat; low carbon steel when sufficiently deoxidized should flatten out without cracks. The fracture of a test piece can be taken as an indication of the condition of the steel; when thoroughly deoxidized and fit to pour, the test should be perfectly sound, and of course should not rise and sparkle in the mould. Final additions are then made to bring the carbon, manganese, and especially the silicon, of the steel to the desired composition.

The Acid-lined Electric Furnace.—As there is no elimination of phosphorus or sulphur in melting scrap or treating hot metal in an acid-lined electric furnace, the metal supplied to the furnace must be low in those impurities. Indeed, owing to a slight loss of iron in melting, there may be an increase in phosphorus and sulphur, which, if the foundry scrap is remelted, can be figured about as in the case of crucible melting.

It is, of course, impossible to maintain a basic slag on an acid lining. Hence the elimination of phosphorus and sulphur is impossible in an acid furnace, and the only effects of treating the metal are to increase its temperature, to give the gases a chance to separate, and to deoxidize it by the absorption of silicon, which is reduced from the silica of the lining and slag by the carbon of the bath; the relative affinities of carbon and silicon for oxygen being reversed at the high temperature of the electric furnace.

So strong is this tendency to reduce not only the oxides of iron and manganese, but also the silica, that additions of iron ore have to be made at frequent intervals to flux the silica of the slag, and thereby diminish its reduction, by providing oxides which are attacked by carbon in preference to silica. In fact, the proportion of oxides in the slag is kept high throughout the operation. Were it not, the amount of silicon absorbed by the steel would be excessive.

The carbon of the bath is generally brought to the desired point early in the operation. If fluid metal is charged, it is recarburized by proper additions at once; if cold stock is melted, it is either so proportioned as to have the desired carbon content when melted, or recarburized after melting. The carbon content of the metal is steadily diminished throughout the process by the reaction of the carbon with the oxides of the slag; hence additions of pig iron are made every little while to keep it to the desired figure.

It will be clear from this that the reduction of the oxides of the metal is quite complete in the acid-lined furnace. The difficulty of keeping down the absorption of silicon, however, and the high cost of the low phosphorus (and sulphur) raw materials needed for the process, make the use of the acid-lined furnace of doubtful value, when the basic can be used for the production of steel of probably equal quality at a lower cost.

Aside from its use in treating hot metal from a basic open-hearth furnace, the acid-lined electric furnace is utilized chiefly to melt down very pure materials, following the precedent established by crucible practice. Whether there is any advantage in this procedure over the use of a basic-lined furnace melting impure stock, is open to question. The time-honored adage, "you can't make a silk purse out of a sow's ear," and the commanding position so long held by crucible steel made from very pure raw materials, together with the tremendous conservatism of mankind in the mass, will probably for some time to come keep alive the ancient methods. Actually, however, the use of very pure raw materials for the manufacture of fine crucible steels was not a matter of choice; it was forced upon us by the fact that we had no method of steel making that would refine our metal to the necessary degree. Now, however, when we have at our disposal a furnace in which we can first eliminate phosphorus from our steel, then by creating reducing conditions remove sulphur, and at the same time reduce oxides practically completely; and as these conditions undoubtedly produce from strongly oxidized and impure metal a steel as free from injurious impurities as any the world has ever seen, there seems to be but one reason for the melting

of pure materials in a furnace that can be made so refining, and that reason is the caution of mankind.

Yet there is precedent on the side of the conservatives. The advent of the Bessemer converter was hailed as the doom of the puddling furnace and of wrought iron, yet we have wrought iron with us to-day, very much alive, and we have crucible steel made from wrought iron. The users of wrought iron and crucible steel would not abandon them until they were convinced that the new material was "just as good," and for some purposes it proved inferior. So we shall have to wait a few years to know whether the melters of pure pig and scrap in an electric furnace are or are not wrong in supposing that they make a better steel than those who refine cheap metal, melted in the furnace, or supplied hot by open-hearth or Bessemer furnaces.

The steel foundry, at any rate, is more than safe in using refining methods rather than the melting of pure and costly materials, since it has been thoroughly demonstrated that steel castings can be made from impure stock refined in an electric furnace, that are at least as good as any now made by other processes, and for many purposes considerably too good for the market.

Greene's Process.—Mr. Albert E. Greene proposes to supplement the usual reactions of the electric furnace by creating in the melting chamber an atmosphere of producer gas containing CO_2 and CO in proportions fixed within rather narrow limits, and has taken out patents on the process. Such an atmosphere at the temperature of the electric furnace can be used for the slow oxidation of carbon, phosphorus and sulphur with little or no loss of silicon, manganese, and some other alloys. For commercial purposes it is not quite clear that in order to avoid the loss and readdition of these comparatively inexpensive alloys it is worth while to install the gas producers and incur the necessary expense for coal and labor. There is, however, one application of this process which might be valuable, which is, to use it for the treatment of alloy steel scrap containing alloys not lost in the process during the elimination of carbon. In such a process it would in some cases be possible to remelt the scrap in a cupola, thereby obtaining it in a molten condition at the lowest possible cost, and then remove to the desired extent the excess carbon absorbed from the coke. In most cases, however, this would involve the elimination of a great deal of carbon, and would require a good deal of time. Even in this process it is not by any means