CHAPTER V

Electric Furnaces for Steel Making

The electric furnace has been brought into quite prominent use in the last few years for the making of steel. In certain ways it has proved itself to be a commercial success, while in others it is still in the experimental stage, but from the present progress (1910) in the art it would look as though the electric furnace was destined to supplant the expensive crucible method of steel making, and if electricity could be obtained cheap enough it might even be a strong competitor to the open-hearth method.

When a good ore can be procured the electric furnace can produce a metal with a higher degree of purity than any of the other processes, owing to the absence of sulphurous and oxidizing gases. Mr. Harbord, the Canadian government expert, said, "Steel equal in all respects to the best high-grade Sheffield crucible steel can be produced in the electric furnace at a less cost than by the ordinary crucible methods."

Owing to the extremely high temperature available a more perfect elimination of the detrimental metalloids can be secured and because of the neutral or reducing atmosphere it is possible to secure a more perfect deoxidation. It cannot remove arsenic and copper, but it practically eliminates phosphorus and sulphur, and thus removes the injurious effects of these. The sulphur is oxidized out until only a trace is left and the phosphorus remains in the metal only in very small percentages. For the high-grade steels such as tungsten, nickel-chrome, self-hardening and high-speed tool, which are made out of blast-furnace products and scrap it has given good satisfaction in several steel plants in Germany, France, Sweden, and Italy.

STASSANO REVOLVING FURNACES

In the Stassano furnaces, shown in Fig. 31, that are being operated in Turin, Italy, the heat is generated by three electrodes which come together in the center of an enclosed furnace immediately over the metal. This furnace is also mechanically revolved in order to agitate the metal and thus accelerate the chemical reaction and reduce the time of operation to a minimum. It is also built without the revolving mechanism for some uses.

The electrodes are cooled by water-jackets that surround them on the outside of the furnace, and the cylindrical melting chamber is enclosed so that the atmosphere throughout it will be neutral. The

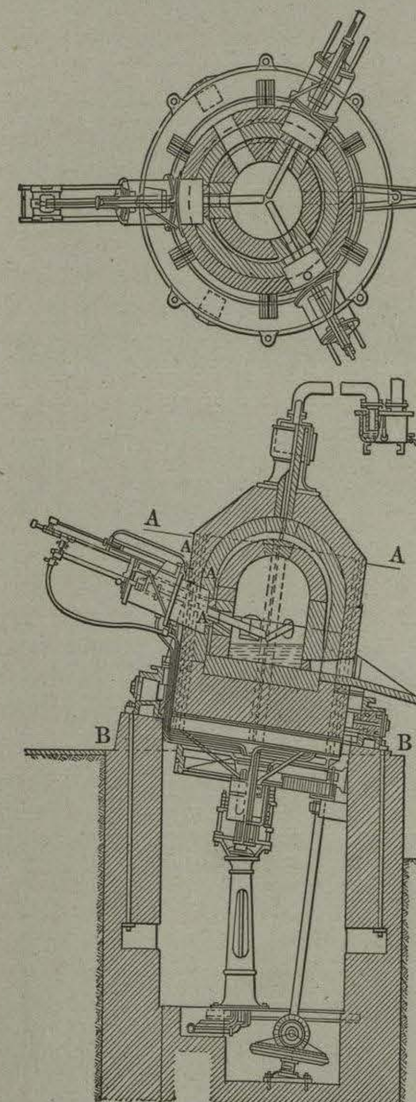


Fig. 31.—Stassano revolving electric furnace.

material treated is not in contact with the electrodes or other material, and therefore its composition is not subjected to any alteration, as the furnace only furnishes the heat to produce the reaction between the substances in the charge, and does not introduce other elements.

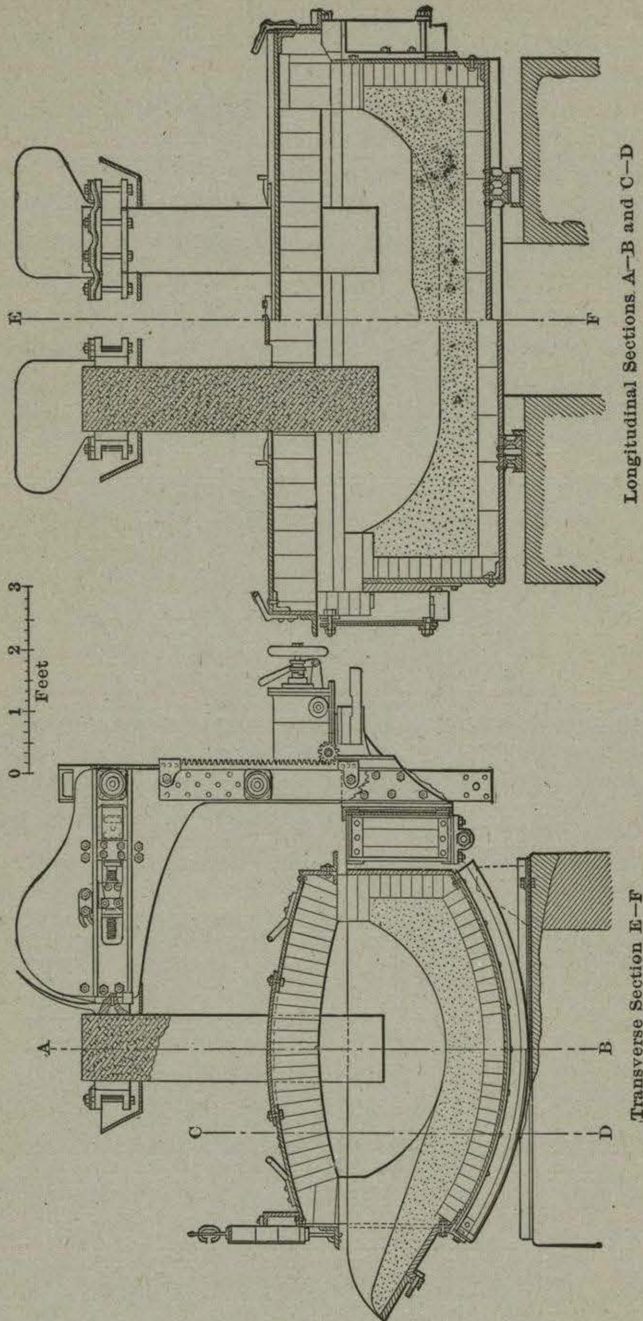


Fig. 32. — Heroult arc and resistor furnace.

Among the different oxides contained in commercial iron ore that of iron is the first one which is reduced. The remaining oxides (SO_3, MnO, MnO_2, CaO, MgO, etc.) are, therefore, left unreduced and are forced to pass, with the assistance of a flux, into the slag. In the same way, if pig iron or iron scrap is used, mixed with slag-forming materials, the pig iron and impure iron may be successfully refined in the same furnace, and this is accomplished by starting from predetermined quantities without any tests during the process.

When refining pig iron or impure iron, oxide of iron must be added, which may be natural or artificial (hammerslag) or powder of rusty scrap. To make the slag, the common fluxes, used in metallurgy, are suitable and may be selected according to convenience and special requirements. Since the atmosphere in the furnace is chemically neutral and the operation can be carried out for any length of time desired, the metal can be freed almost entirely from its impurities without the risk of harmful oxidation.

Refined iron may be obtained direct from the ore in this furnace if it is charged with iron ore mixed with a reducing agent and the proper fluxes, in the correct proportions, to transform the gangue into a slag of a composition that will absorb the impurities in a single operation. Such a charge, being gradually heated with the exclusion of air, cannot absorb oxygen from it, and the flux maintains its quality at a rising temperature so that it is able to perform its mission when the right temperature has been reached.

HEROULT FURNACE

The Heroult furnace, as shown in Fig. 32, is but a modified open-hearth, with the heat introduced above the metal by the electric current in place of gas; no electrical parts being in the furnace proper. Thus the bottom and side can be patched as fast as they may be burned away without interfering with the work of the furnace.

In the later types of Heroult furnace the heat is introduced by means of two electrodes working in series; the current passing through the bath from one electrode to another, and vice-versa. The power being the same in both cases, this necessitates carrying only one half the current that would be needed if the current flowed from one electrode through the bath, and thence through a plate contact in the bottom of the furnace, as shown in Fig. 33.

In this case the heat is generated in the slag and not in the metal itself; thus making the slag the hottest part of the furnace, so that all impurities can be removed by the use of special slags. The poorest kind of scrap can therefore be used, as the sulphur and phosphorus are both removed at a low cost, and the metal can be converted into the finest grade of tool steel.

In a 5-ton furnace starting on cold materials one ton of metal can be melted and partially refined, with 600 kilowatt-hours; for the finishing slag 100 more would be necessary, making 700 kilowatt-hours all told. In a 15-ton furnace these figures would be considerably reduced. If molten metal is charged into the 5-ton furnace and this only needs to be deoxidized, desulphurized, and recarburized, it will take from 140 to 160 kilowatt-hours, and for a 15-ton furnace this would probably be cut down to about 100 kilowatt-hours. In cold melting and continuous work the consumption of electrodes is from 60 to 65 pounds for each

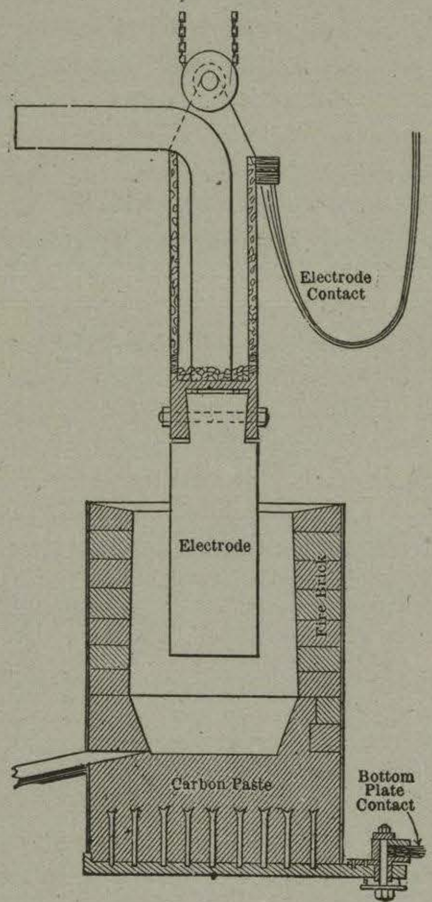


Fig. 33. — Heroult resistance furnace.

ton of steel, which includes the waste ends of the electrodes. When molten metal is charged into the furnace, this consumption is only from 10 to 15 pounds per ton of steel. The electrodes just touch the flux covering the molten metal and can be operated automatically or by hand.

About the best lining for this furnace is good magnesite mixed with basic slag, with tar for a binder; burnt dolomite can also be used successfully. The furnace can be lined by any one who can make a good bottom in a basic open-hearth furnace. The lining is never exposed to silicious slags, and can be repaired after each heat by simply throwing in magnesite or dolomite, as the case may be. This should make it last a long time, and with the furnace run with due care, one year is not too long for it to last, although furnaces have had to be relined in three months. The roof is damaged the most, and this usually has to be replaced once a month. For that reason an extra roof is kept on hand so the change can be made in a few hours.

Two 15-ton Heroult furnaces are now being used by the United States Steel Corporation (August, 1910), and this is about the largest size that can be successfully operated when two slags are used, owing to the difficulties that might be encountered in raking the first slag off the molten metal. The first slag used being an oxidizing one to remove the phosphorus, and the second deoxidizing for the removal of the sulphur and the gases. It is the intention to build 30-ton furnaces, however, where only one slag is used.

The detrimental features of this style of furnace, which are yet to be overcome, are the high electrode costs, and the possibility of increasing the carbon contents of the finished metal. For melting purposes as in steel foundry work it is also difficult to choose a suitable protective flux, that will act as a heating medium, and still not act on the ingredients of the molten metal.

KELLER FURNACE

The Keller furnaces are more or less of the Heroult type, but differ in constructional details. These are shown by Fig. 34, which is a sectional elevation. As will be seen, the carbon electrodes *A* are massive and are lowered into vertical shafts that are separated but connected below by a lateral canal *B*. The electrodes are surrounded by the raw material in these vertical shafts, and the electrical current passes from one electrode to the other, down through this material and through the lateral canal, in which it becomes molten. The molten metal is then drawn off by tapping. A central electrode is located at *C*. This furnace is well adapted for making steel castings, and it can be cleaned by dumping the bottom *D*. When thus used a central stack is added to the furnace shown, that feeds the raw material into the vertical shafts surrounding the electrodes.

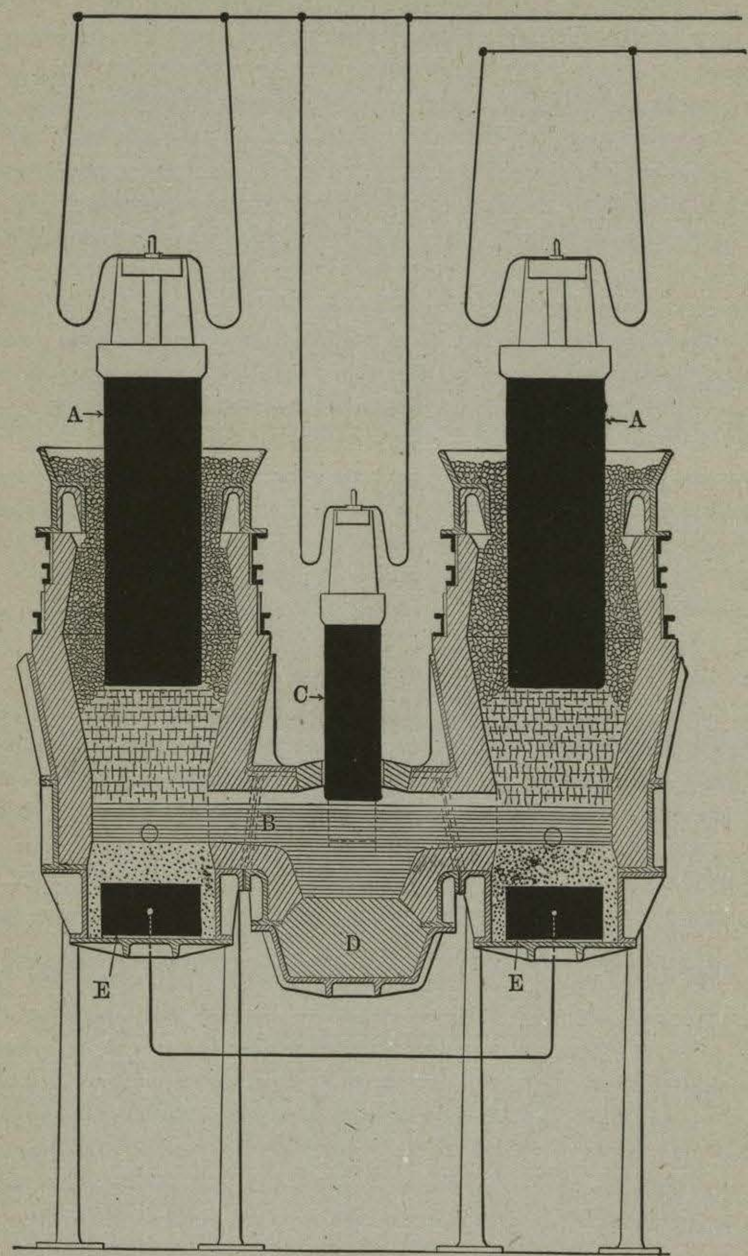


FIG. 34. — Keller electric steel furnace.

KJELLIN AND COLBY FURNACES

Resistance furnaces of the induction type were invented by Mr. E. A. Colby, in the United States in 1887, and independently reinvented by Dr. Kjellin in Sweden twelve years later. As a natural sequence a combination was formed and the patents of both are used on the same furnaces.

In Fig. 35 is shown the principle on which this simple induction furnace is built. It is in reality a transformer, in which the bath of molten

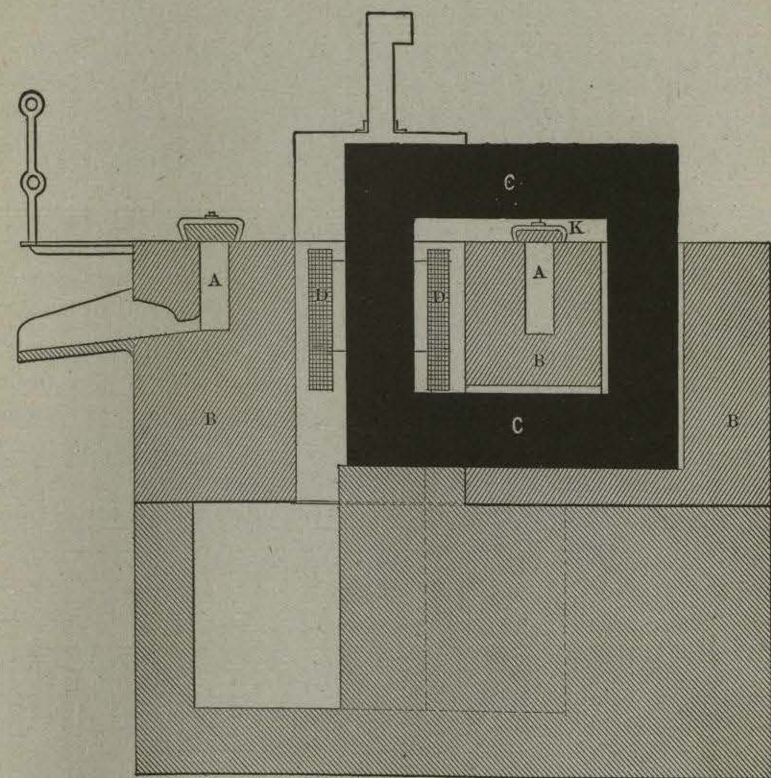


FIG. 35. — Kjellin induction furnace.

metal forms the secondary circuit. The magnetic circuit C is built up of laminated sheet iron like the core of a transformer. The primary circuit is a coil D, consisting of a number of turns of insulated copper wire or tubing surrounding the magnetic circuit. The ring-shaped crucible A, made of suitable refractory materials, also surrounds the magnetic circuit, and when filled with molten metal forms the secondary circuit of the transformer. The annular crucible is supplied with cover K.

When the coil D is connected with the poles of an alternating-current

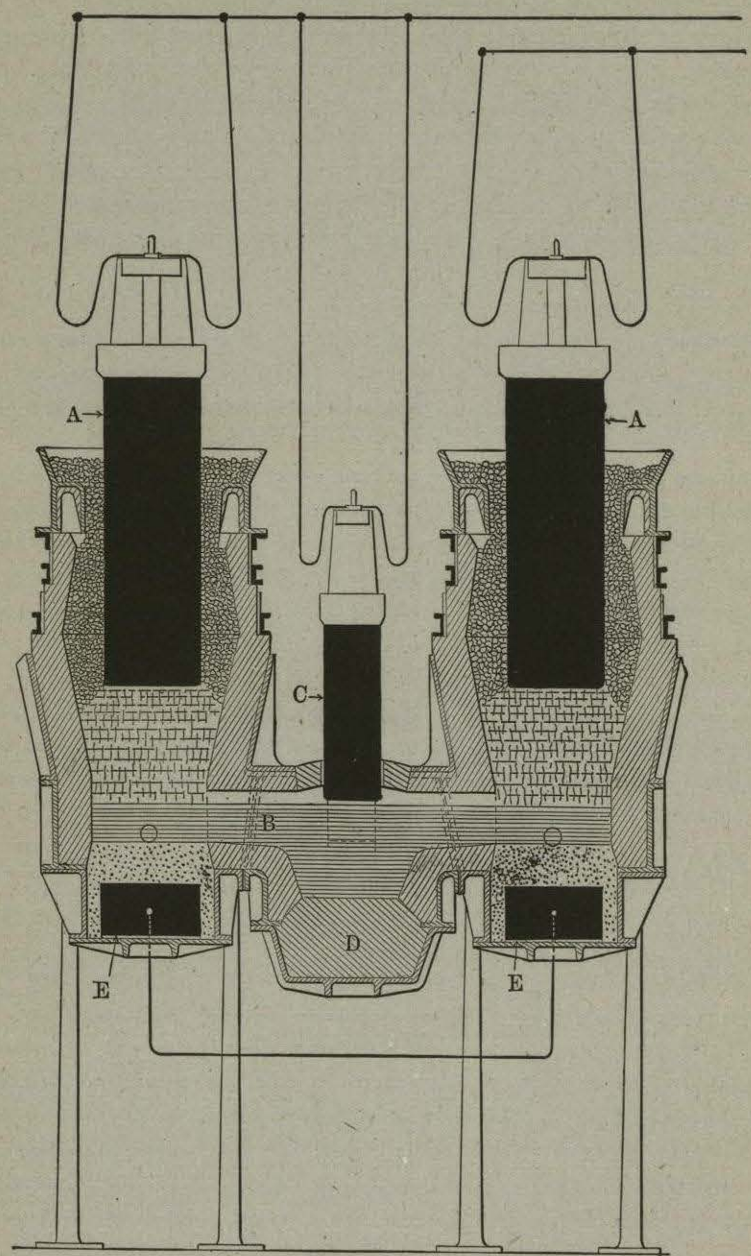


FIG. 34. — Keller electric steel furnace.

KJELLIN AND COLBY FURNACES

Resistance furnaces of the induction type were invented by Mr. E. A. Colby, in the United States in 1887, and independently reinvented by Dr. Kjellin in Sweden twelve years later. As a natural sequence a combination was formed and the patents of both are used on the same furnaces.

In Fig. 35 is shown the principle on which this simple induction furnace is built. It is in reality a transformer, in which the bath of molten

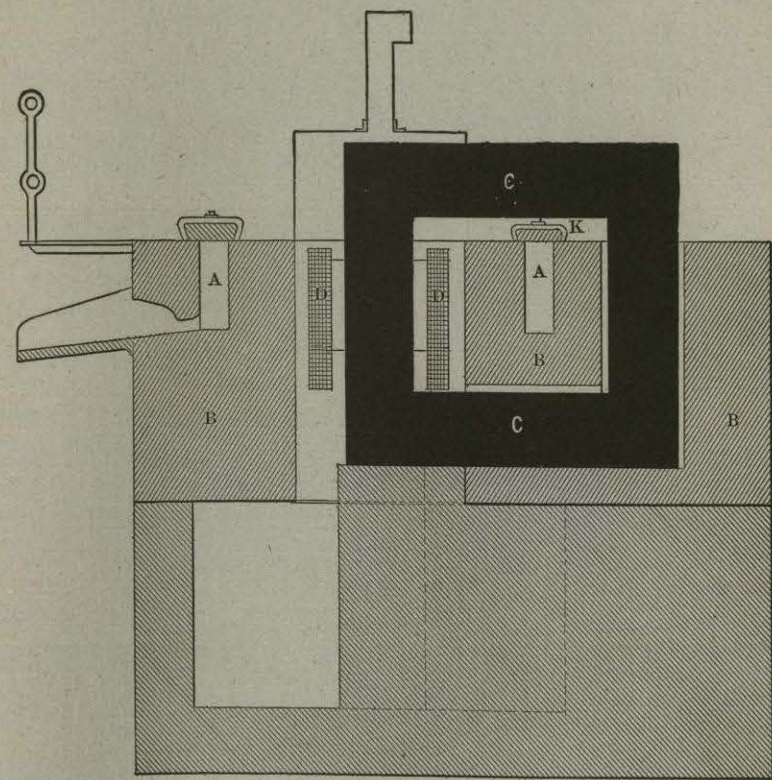


FIG. 35. — Kjellin induction furnace.

metal forms the secondary circuit. The magnetic circuit *C* is built up of laminated sheet iron like the core of a transformer. The primary circuit is a coil *D*, consisting of a number of turns of insulated copper wire or tubing surrounding the magnetic circuit. The ring-shaped crucible *A*, made of suitable refractory materials, also surrounds the magnetic circuit, and when filled with molten metal forms the secondary circuit of the transformer. The annular crucible is supplied with cover *K*.

When the coil *D* is connected with the poles of an alternating-current generator, the current, when passing through the coil, excites a varying magnetic flux in the iron core and the variation in the magnetic flux induces a current in the closed circuit formed by the molten metal in the crucible *A*. The ratio between the primary and secondary current is fixed by the number of turns of the primary, and the magnitude of the current in the steel is then almost the same as the primary current multiplied by the turns of the primary coil. Thus, in a small furnace of this type a current of 500 volts and 280 amperes supplied to *D* induces a current of seven volts and 20,000 amperes in the metallic bath.

In this style of furnace the charge may be either in the hot molten state or in the form of cold scrap, pig iron, etc. When the latter materials are charged one or more metal rings, made of cast iron, wrought iron, or steel, must be placed in the hearth *A* to complete the electrical circuit and start the melting. When molten metal is charged, this of itself forms the circuit, and for continuous working it is customary to leave a sufficient amount of metal in the crucible *A* to establish the bath.

If the charge is made with molten metal a saving in time and power is effected in refining the bath. When scrap and pig iron is charged, the metal ring must be put in and the current turned on until this is melted down. The charge is then gradually added and melted until the full charge is obtained. After this the temperature is raised to any desired point and the necessary additions made to give the required percentages of carbon, manganese, nickel, chrome, tungsten, etc., according to the kind of steel that is to be produced.

This is primarily a melting furnace, and the best results are obtained in melting high-grade materials. As a commercial substitute for the crucible method it has several advantages: High and easily controlled temperatures are attainable, as the temperature is directly dependent upon the primary circuit; the process is clean and gases cannot attack and injure the bath; "overkilling" is practically impossible and a saving in labor is effected. A furnace that will produce 1000 tons of steel per year can be easily handled by three men and a boy per shift.

A Kjellin induction furnace is shown in Fig. 36, as it is tapping 1000 pounds of tool steel into a ladle for pouring into ingot molds. This furnace is hung in a frame on trunnions, and is tilted when it is necessary to pour off the heat, by the aid of gears, electrically operated by a switch from the furnace platform.

One of the difficulties encountered with furnaces of this style, the hearth of which is in the shape of an annular ring, is caused from what is commonly known as the "pinch" phenomena. When an alternating or direct current passes through a liquid conductor, the electromagnetic forces tend to contract that conductor in cross-section. This contraction is apt to localize itself at some certain spot and form a depression

in the molten metal that gives it the appearance of being pinched by an invisible force.

This force is a function of the current, and size and shape of the cross-section of molten metal, and is independent of the resistance, voltage, watts, temperature, heat, length of channel, etc., except where changes in these effect the other quantities. Involved in the actual contraction is also the smoothness of channel, viscosity, fluid friction, weight of floating masses, etc.

The contracting force is small for a current with relatively low den-

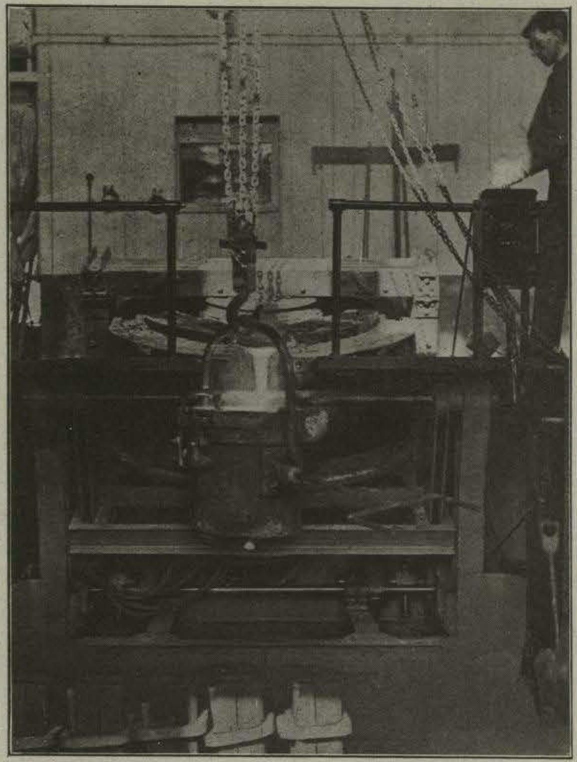


FIG. 36. — Kjellin induction furnace tapping 1000 pounds of tool steel.

sities, but when these become higher the force is great enough to contract the cross-section of molten metal to zero and thus rupture the circuit. When increasing currents are small the level falls slowly at first and then more rapidly. When a certain unstable level is reached the contraction becomes very rapid for the same increments of current. There is also a certain critical current at which rupture might take place immediately.

Into the depression formed is liable to drift the more refractory, solid, floating materials that will prevent a reunion of the molten metal and cause a freezing of the charge before they can be removed. When this

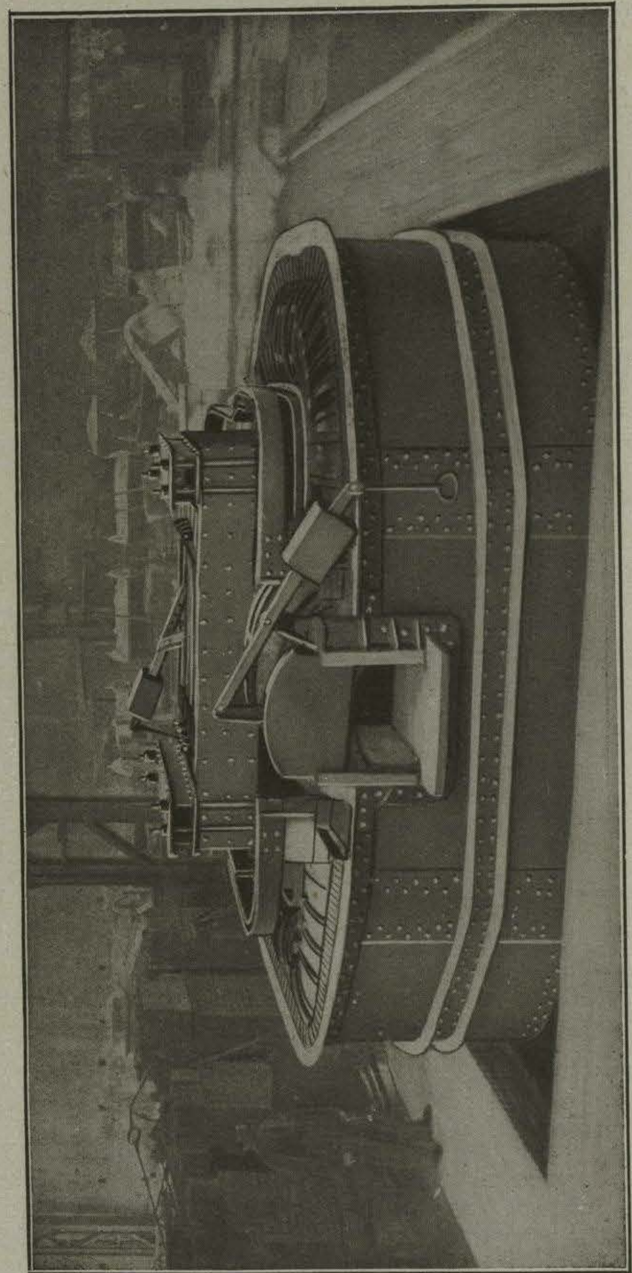


FIG. 37. — Röchling-Rodenhauser 8-ton electric furnace. Single phase.

occurs it is difficult to start the current flowing again so as to melt the metal, and the furnace usually has to be taken apart and rebuilt.

The "pinch" need not be feared in low current density furnaces, except when other causes might produce local contraction, as it only takes place at relatively high current densities. But when it does occur it means a frozen charge or a broken core, unless the separated metal can be quickly brought together by opening the external circuit for an instant and then follow it by a reduce current.

A positive limit, above which the current and thus the temperature cannot go, is fixed by the critical current. This limit is greater with a greater density, lesser viscosity, deeper channel, more regular and smoother channel, and a molten metal surface that is freer from heavy floating masses.

RÖCHLING-RODENHAUSER ELECTRIC FURNACE

The Röchling-Rodenhauser furnaces, of which one of the 8-ton furnaces is shown in Fig. 37, consists of the same arrangement of transformer and primary coils as is shown in the Kjellin furnace. In addition, however, it has a number of steel terminal plates embedded in the lining and these are connected to a few heavy turns of copper, placed outside the primary coils, that collect and feed the induced current in these turns to the terminal plates.

These are, therefore, termed combination furnaces, and are designed to suppress the magnetic leakage that would occur in large furnaces of the simple induction type; the auxiliary turns being located in close proximity to the primary coil and magnet core. The total result is that the main hearth can be made of much larger cross-section, and a good power factor can be obtained even in big furnaces without the use of a current of such low periodicity as was necessary with the original induction furnaces.

This furnace is built for single-phase or three-phase currents; the three phase being more suitable for large quantities of metal and for large daily outputs at a normal periodicity. The principles on which these furnaces are built can be seen in Figs. 38 and 39.

In Fig. 38, *H H* are the two legs of the iron core of the transformer. They are surrounded by primary coils *A*, connected with the alternating-current generator. Through the action of the currents in the primary coils, secondary currents are induced in the two closed circuits formed by the bath; these two circuits being connected so that the whole looks like the figure 8. The primary coils are so arranged that the induced currents in the common part of the two circuits, that is, between the legs *H H* of the iron core, have the same direction.

So far the furnace acts like two combined ordinary induction furnaces.

The difference consists in the use of extra secondary coils *B B*, surrounding the primary coils *A A*. From these secondary coils the currents are conducted to metallic plates *E*. The plates are covered by an elec-

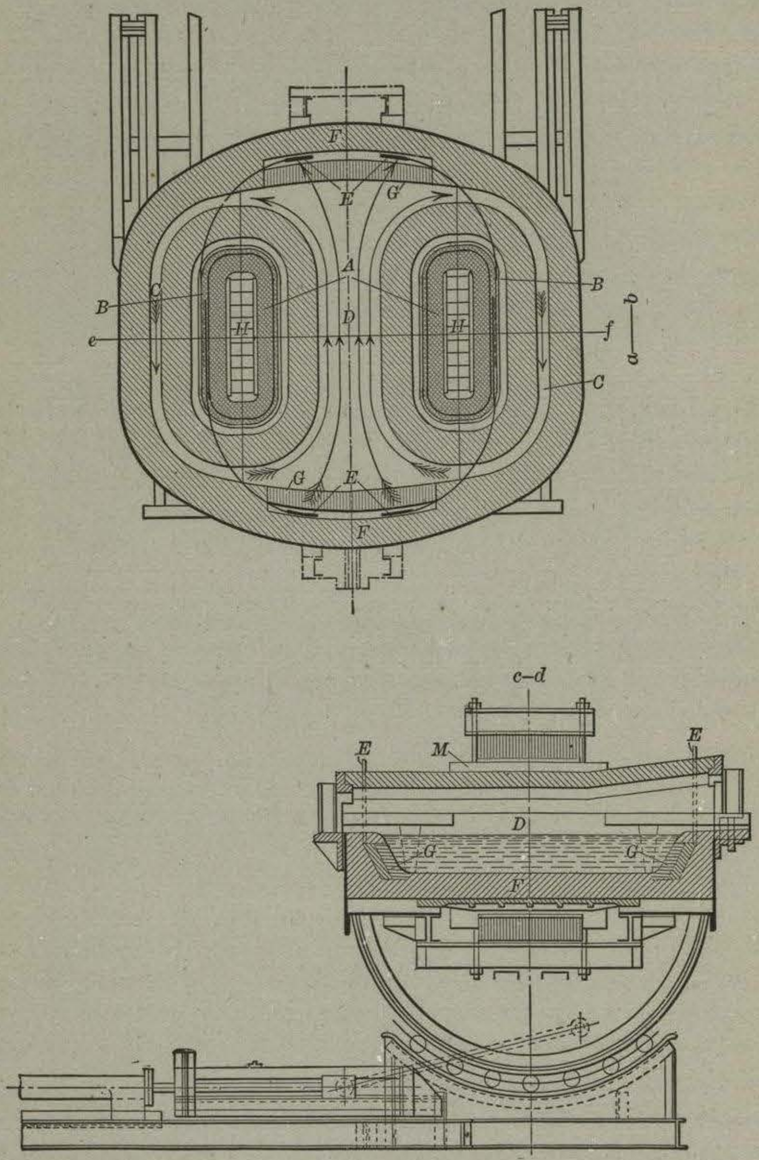


FIG. 38. — Outline sections of single phase. Combination furnace.

trically conducting mixture of refractory material *G*, that forms part of the lining of the furnace.

The currents from the secondaries pass from the plates *E*, through

the lining *G*, and then through the main hearth *D* of the furnace. The channels *C* only act as conductors for the secondary currents induced in the bath. In the main hearth *D* we thus have the currents from the channels *C C*, and also from the extra secondaries *B B*.

The construction of the three-phase furnace is practically the same as that of the single-phase, except that a third transformer is added and therefore only a plan view is shown in Fig. 39.

The amount of extra power that can be given to the furnace by means of the extra coils is of course not unlimited, because increased power means increased current, and consequently increased current density

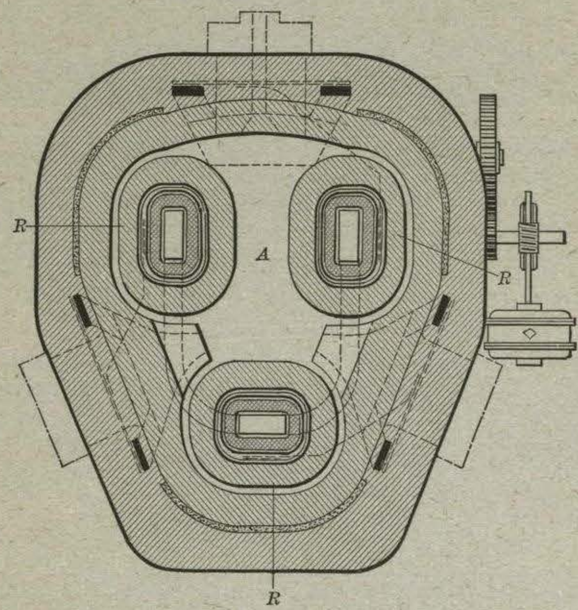


FIG. 39. — Plan view of 3-phase furnace.

in that part of the lining that conducts the current to the steel. This current density must not be driven too far, because the heat evolved when the current passes the lining will increase as the square of the current, and too high a current density would therefore result in the destruction of the lining.

This is the reason why a combination of induced currents and currents taken from the extra coils must be used. It would not, for the reason stated, be possible to conduct all the amount of current through the lining that is necessary for the working of the furnace, not to speak of the pinching effect that would very probably cut off the current at the contact between the steel and the lining, if the current density in the lining were driven too far.

The Röchling-Rodenhauser furnace was designed for refining fluid Bessemer steel from the converter, in order to produce a higher quality of steel rails than before, and also with the intention of making high-class steel in general.

For refining purposes the furnace is worked in the following manner: After tapping, fluid steel, from the converters, is poured into the furnace, and suitable materials — burnt limestone and mill scale — for forming a dephosphorizing basic slag are added. When the reactions are ended this slag is taken off by tilting the furnace. For making rails the phosphorus is brought down sufficiently low in one operation, but for the making of the highest class of steel the operation has to be repeated.

When the phosphorus is removed, the carbon in the steel (if carbon steel is made) is adjusted by adding pure carbon to the bath, and afterwards a new basic slag is formed in order to remove the sulphur. This slag is also formed of burnt lime, sometimes with the addition of fluxes such as fluorspar.

One necessary condition for successful desulphuration is that the slag be free from iron, and therefore sometimes ferro-silicon is added in order to quicken the reduction of the iron in the slag. How far this refining will have to be carried naturally depends on the quality of steel wanted. By repeated refining operation with fresh slag, the phosphorus and sulphur can be brought down to an exceedingly low percentage, but this refining, of course, takes a longer time and consequently more electric energy per ton of finished product.

GIROD ELECTRIC STEEL FURNACE

From the numerous experiments that have been carried on, has been deduced the fact that the best method of insuring practical success in the operation of electrical furnaces is to so design them that they will have the utmost simplicity in the construction of the necessary apparatus. Until the Girod furnace was perfected the Heroult was the simplest and to this was due its success, but now (June, 1910) the Girod heads the list of electrode furnaces in simplicity and safety in construction and operation.

The owners of the process are ready to guarantee the successful working commercially of a 25-ton furnace for refining steel previously made molten in an open-hearth furnace. While this is a cheaper method of producing a good grade of steel than that of melting down the raw materials in the electric furnace and then refining it, Mr. Paul Girod, the inventor of this furnace, claims that steel cannot be produced from a molten charge that has the same good qualities as that made exclusively in the electric furnace from pig iron, scrap, etc. Such qualities, for instance,

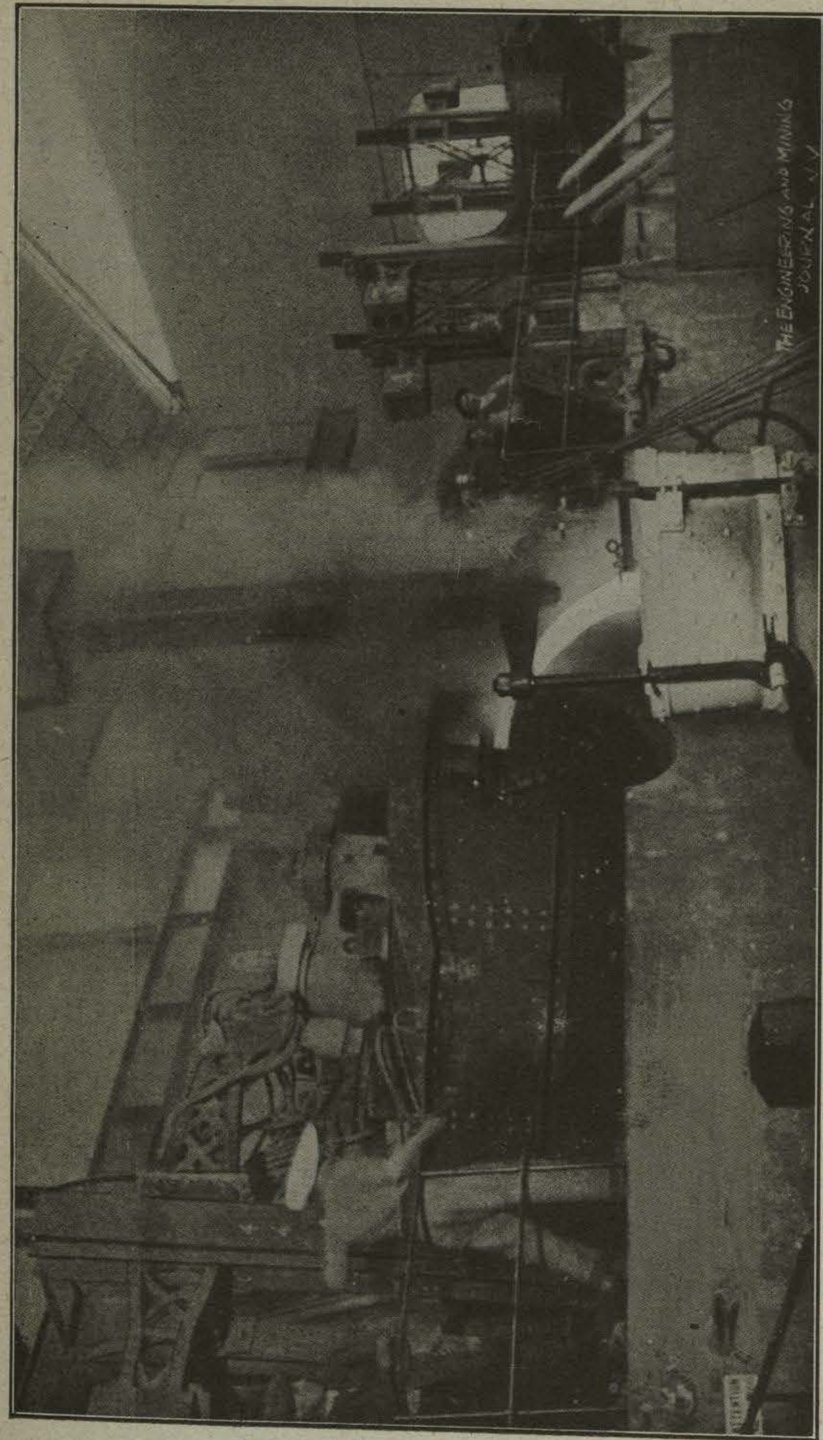


Fig. 40. — Pouring the charge from 12-ton Girod furnace at Ugine, France.

as resistance to shock; and in tool steels, hardness, tenacity, and durability after hardening. In this Mr. Girod is supported by others.

In Fig. 40 is shown a 12-ton Girod furnace as it is pouring the charge into a ladle by tilting. To the right of this will be seen another furnace; the picture being taken at the steel works started by Mr. Girod a few years ago in Ugine, Savoie, France. This company has a good water-

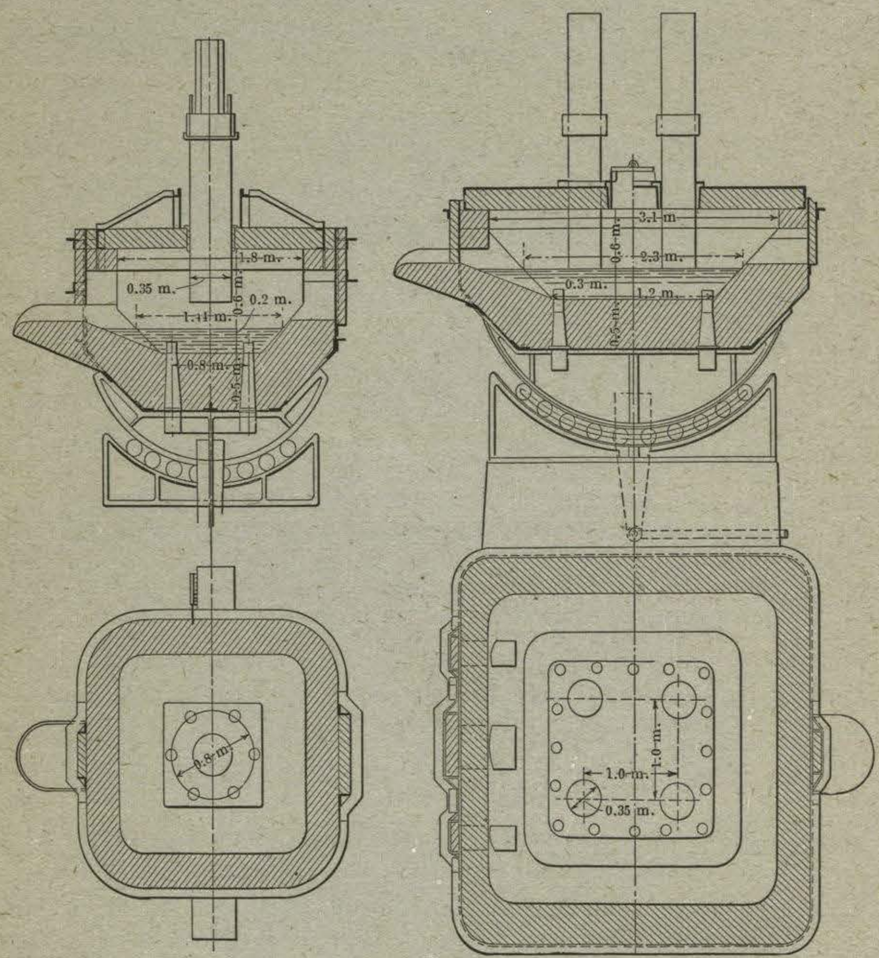


Fig. 41. — Plan and sectional elevation of 12-ton Girod electrical furnace.

power for generating their electricity, and are to-day (June, 1910) operating 19 electric furnaces, with from 400 to 600 electrical horse-power each, while 12 new furnaces are being constructed that will consume 1200 horse-power each. All kinds of steel are being made, from structural up to high-speed tool steel.

The construction of this furnace can be seen by a study of Fig. 41.

While it is classed with the electrode furnaces it is in reality a combination of the resistance and arc heating and seems to work as well in large units as in small ones. One or more electrodes *A* according to the size of the furnace, are lowered through a hole, or holes, in the cover that is lined with silica brick, and the metal *M*, which is from 12 to 14 inches deep, serves as the opposite electrode. The current passes from electrode *A*, in the form of an arc, into the slag S, where a large amount of heat is produced, then into the metal *M*, and finally out through the contact pieces *C* to the current conductor. If a number of electrodes are used above the bath they are in parallel.

The most important principle in the Girod process is the effective

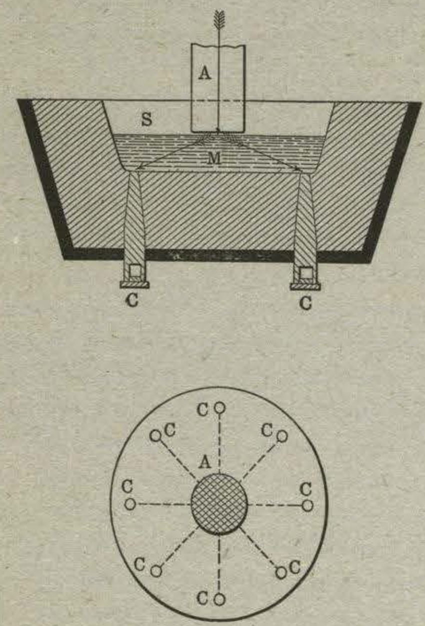


Fig. 41a. — Operating principle of Girod furnace.

manner in which the electric current is made to pass through the molten metallic body and cause it to become an important heat producer.

Water is driven through a passage about 6 inches deep in the outer end of each contact piece *C*, so as to cool them and aid in regulating their temperature and resistance. The length and cross-section of the contact pieces are such that each will take up only a certain part of the whole current and thus none become overheated and greatly increase in resistance. They are made of pure iron to avoid any deterioration of the furnace charge, and are not only connecting rods between the furnace charge and the current generators, but also serve as regulating current distributors, by making the electric current pass uniformly from and to the centrally hanging carbon rod or rods in radial direction to and from the periphery of the bath. This is important, not only for uniformly heating the bath, but also for keeping every part of the liquid metal in constant motion. This movement accelerates the contact between the impurities of the iron and the refining slag swimming on top of the bath.

In operating on cold materials the electrode is lowered until it rests upon the heap of scrap; then the current finds no other way out than by means of numerous small arcs through the whole mass of material, thus breaking it down simultaneously in all parts of the hearth, with no sticking of cold pieces to the bottom. When feeding cold scrap one does not put in the whole charge at once. After the larger part of the charge has been deposited upon the hearth, the current is sent through the heap as described; then the rest of the charge is put into the furnace, together with the first batch of the refining ingredients. Taking the run of a 2-ton furnace as an example, the charge consists of 4500 to 5500 pounds of iron scrap, and the first batch of refining slag usually consists of about 175 pounds of lime (CaO) and 500 pounds of iron oxide ore. Together with the iron oxide that covers the scrap, the iron ore serves as an oxidizing agent.

The smelting of the iron charge and the first batch of refining slag requires 4½ to 5 hours. As the slag becomes exhausted of iron oxide and therefore of its oxidizing power, samples are taken and tested to ascertain the degree of refinement of the molten metal. According to the degree of purification, the furnace now receives (after the first slag has been skimmed off) a second, and if necessary a third batch of lime-iron-oxide slag. After the removal of the last slag the surface of the metal bath is thoroughly cleansed by throwing in about 75 pounds of lime and skimming this off after a while. The further treatment of the bath depends upon the impurities which could not be removed by the lime-iron-oxide refining, and upon the quality of steel to be produced. Thus deoxidizing or other refining agents are employed; such as, ferro-mangano-silicon, ferro-aluminium-silicon, ferro-mangano-aluminium-silicon, and other alloys.

The final step in the production of special steels is the addition of iron alloyed with metals like nickel, tungsten, chromium, and others, after these refining operations.

A removable cast-iron frame is fitted to the cover, and this contains water-jacketed ports through which the electrodes enter the furnace. While the metallic frame is not necessary it serves a useful purpose by stiffening the cover and keeping air from entering the furnace and attacking the bath. As the electrodes have the same polarity, when more than one is used, there is no danger of short circuits through the metal frame and collars and across the cover. The electrodes are easily regulated

automatically by feeding from the generator, on the voltage, in the single electrode furnaces, or on the intensity of the current when this is fed by a transformer, or several electrodes are supplying current equally. The electrode consumption is about 38 pounds in 2-ton, and 31 pounds in 12-ton, furnaces per ton of steel produced.

Two 2½-ton Girod furnaces that are in use in France and Belgium, are shown in Fig. 42. One of this style is used in Switzerland for steel castings only.

SUMMARY

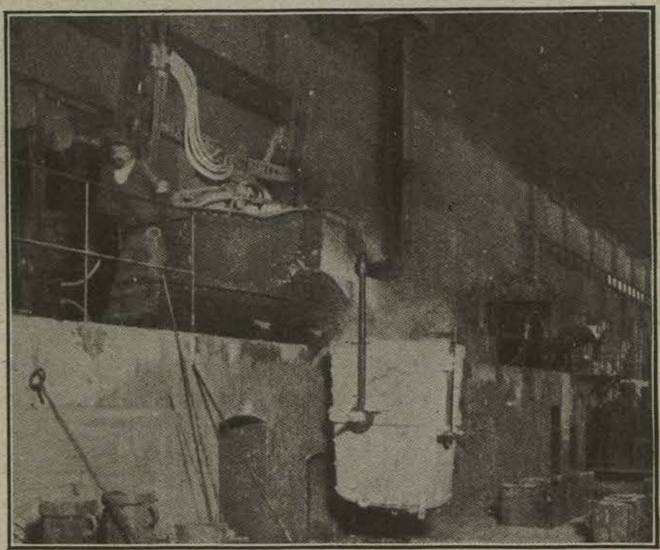
Many others have been and are experimenting with electric furnaces in the hope of improving them and cheapening their operation, among which might be mentioned Gustave Gin, Marcus Ruthenburg, E. A. Greene, F. S. McGregory, Prof. B. Igewsky, and others, but none of these have as yet passed the experimental stage, and been put to practical use. Horace W. Lash, of Cleveland, Ohio, U. S. A., has developed a process that is applicable to the electric furnace, but as it is also applicable to the open-hearth process it cannot be classed with the purely electric steels.

Some years ago Mr. Lash became interested in the direct production of steel from the ore, and made experiments. The outcome of this was a compromise between the direct and refining methods. He found that when an intimate mixture of iron ore, carbon, fluxes, and cast-iron borings was heated, a reduction took place; by proportioning the mixture properly, steel of the desired grade could be produced and practically the whole of the iron in the mixture recovered as good steel.

A typical Lash mixture is as follows: Granulated pig iron, or cast-iron borings, 23%; iron ore, 60%; coke, 11%; lime, 6%. To reduce this in the open-hearth furnace required the addition of pig iron or scrap. A typical charge for 100 tons of steel ingots being: Lash mixture, 122 tons; pig iron, 32 tons; ore, 2 tons. In the electric furnace pig iron or scrap is not necessary, and for 100 tons of steel ingots the charge would be, Lash mixture, 172 tons; ore, 2 tons.

The experiments proved that a superior quality of steel was obtained; the cost of its production was in general lower than when the regular methods of making steel were used; and that the electric furnace was the best method for the process. Companies have been organized in Cleveland and Canada for making steel by the Lash process.

That the electric furnace will produce as high, if not a higher, grade of steel than is produced by any of the other methods has been fully established; that it is cheaper than the crucible process, and may in time equal the open-hearth, is also pretty well recognized. That magnetite and hematite ores can be economically smelted; that sulphur and phosphorus can be reduced to a few thousandths of a per cent. even without manganese; that the percentage of silicon can be altered at will, and that ores containing titanic acid up to 5% can be reduced in the electric furnace, make of it one of the coming factors in the manufacture of steel.



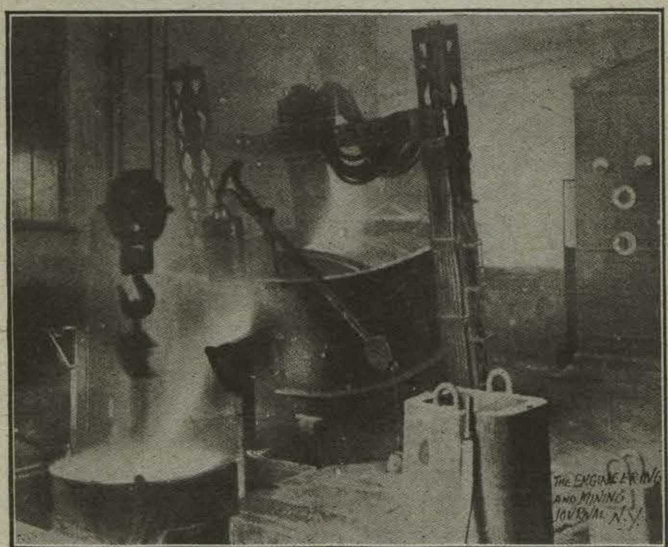


FIG. 42. — 2½ ton Girod furnaces in use in France and Belgium.

In two steels of the same composition, 1 inch square, one of which was made in the electric furnace and the other in a crucible, a considerable difference in torsion was noted. The electric steel was twisted cold until it looked like a corkscrew, while the crucible steel only took half as many

twists before breaking. A Bessemer steel has been made better by merely submitting it to the heat in an electric furnace for a short time. In another case, a tool-steel maker found that he could produce his tool steel with smaller additions of silicon and manganese than was necessary in the crucible process.

The only explanation that appears probable is that the higher heat and reducing, rather than oxidizing, atmosphere of the electric furnace, expels some of the gases that are dissolved in the steel, and possibly aids the removal of the combined oxygen, thus making the deoxidation more complete than in the crucible.

The latest development in the electric furnace experiments has been the combination gas and electric heated furnace. As the United States Steel Corporation have a supply of natural gas at their plants in the Pittsburg district, they have built a tilting open-hearth furnace in which a cold charge is melted down with gas, after which it is turned off and electrodes lowered into the metal, through the top of the furnace, to refine the charge.

This is apparently the most economical method of making electric steel that has yet been suggested, as the natural gas can be obtained for less than 20 cents per thousand feet, and at this rate is much cheaper than electricity, and perhaps just as good for melting down the charge. The use of the electric current can then be confined to removing the impurities from the bath. This, however, is in the experimental stage and what the cost of operation will be, for the quality of steel to be produced, has not yet been established.