upon a short length of rails, so that when desired it can be brought away from the end of the cylinder, and leave the latter open for examination and repair. The gaseous products pass out of the cylinder into a dust-chamber H, constructed of brickwork, and thence are discharged into suitable flues.

When the roasting is completed, the cylinder is stopped with its doors D D immediately over two trucks T T, which are placed so as to receive the hot roasted material as it is raked through the doors. Lateral movement of the cylinder is prevented by the rollers K K, which are placed so as to bear upon either side of one of the rings L L, whereby the cylinder is supported on the friction rollers. These revolving cylinders have been widely adopted for roasting copper matte and auriferous pyritic material prior to chlorination.[1] They differ mainly in being either continuous in their discharge (White Howell) or intermittent (Brückner).

Another form of reverberatory furnace for roasting ores and matte—the O'Hara furnace—is much used in America, and to some extent in South Wales. It resembles the ordinary roaster, but has in addition an endless chain mounted upon rollers and provided with a series of plough-shaped scrapers. The chain is kept in motion by means of suitable gearing, so that the scrapers are continually exposing fresh surfaces of ore to the action of the heated current of gases from gas-producers.

Furnaces having fixed flat beds and some form of travelling rabble form a numerous class. It may here be mentioned that the chief difficulty found is in maintaining the rabbles or rakes in an efficient condition, since these necessarily have metallic parts, and are exposed at elevated temperatures to the action of oxygen and of sulphur compounds that attack them. The more recent forms, therefore, of the furnaces of this class provide that either the rakes are continuously cooled by artificial means, or else that they are frequently withdrawn from the heated zone and allowed to cool. Pearce's Turret furnace is an example of the first-named expedient, and Brown's Horseshoe furnace of the second.

Pearce's furnace (fig. 164) consists of an annular tunnel of brickwork with a flat floor, which forms the bed in which the roasting takes place. The inner vertical wall of this tunnel is provided with a continuous horizontal slot, and in consequence of this it is necessary to suspend the inner abutment of the arched roof from a framework of girders supported from the outside. The slot is closed by a wide steel band carried by the frame on which the rabbles are suspended. At two or three points along the outside wall a fireplace is provided, with the wall itself forming a kind of fire-bridge, so that the flame from the fire can pass by a short cross flue into the bed. This flame

[1] Rose, *Metallurgy of Gold.*

is compelled to pass one way to the chimney by a swinging baffle-door, and, after passing round the bed, is taken from the roof by a cross flue and conducted downwards so that it traverses, but in the reverse direction, a large dust-chamber placed beneath the furnace. It is then conducted to the chimney which is outside the tunnel, and connected, as are the fireplaces, by cross flues. The ore is fed on to the bed near to the point at which the chimney is connected, and is withdrawn from the side after it has been taken successively past the fires. Its conveyance and stirring is effected by means of a series of rabbles, each mounted on a radial arm that passes through the horizontal slit already described as being in the furnace-wall. These radial arms also support the steel band by which the slit is kept closed. The arms are themselves all mounted on a central and pivoted

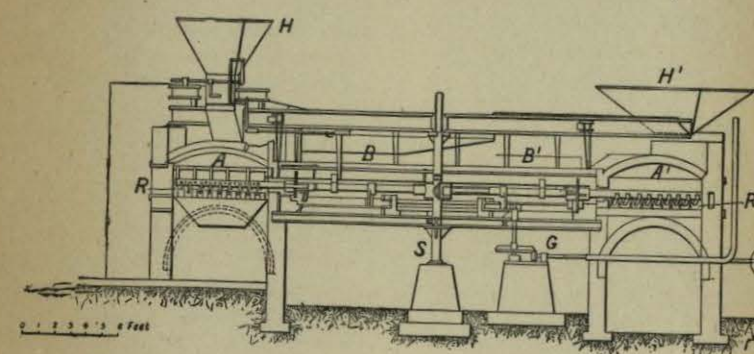


Fig. 164.—Pearce Turret Furnace. The tunnel is shown at A A' and the rabbles at R R'. These rabbles are moved from the central support S by the gearing G. Hoppers are indicated at H H'; B B' are the supporting girders of the tunnel.

pillar, which can be rotated by the usual mechanical agencies, and thus cause the rabbles to continuously traverse the roasting chamber in the direction that the ore or other material under treatment has to go, and against the current of heated air from the fires. In order that these arms and rabbles should not themselves be unduly heated, the rotating system, of which they form parts, is made with iron tubes through which the air that is required to be supplied to the bed for the roasting is continuously forced: the heating of the air which is thereby effected is itself an incidental advantage.

The Brown furnace attains the same ends as the Pearce, but by different means. There is a tunnel of brickwork, either circular in plan or formed of straight portions, joined by circular curves. This tunnel has, like the former example, a series of external fireplaces and a chimney all connected by short cross flues to it, but the chimney is more conveniently placed in the

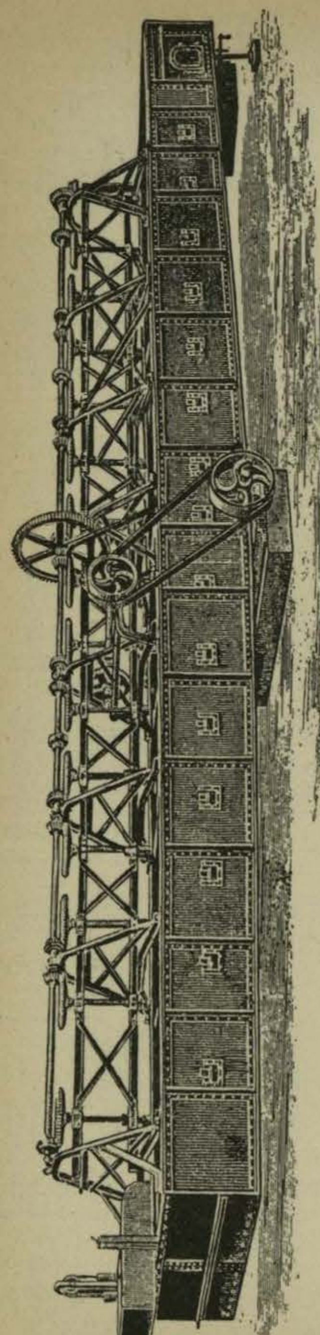


FIG. 165.—The Edwards Roaster.

centre of the circle. The tunnel, however, is not quite continuous: there being a considerable portion of the bed that does not have any roof; this necessitates the provision of two swinging doors, one at each end of the tunnel, so as to close it. The ore is mechanically fed in from above, and withdrawn through the floor after it has traversed the furnace. The rakes or rabbles are in sets, each mounted on a little carriage that is drawn through the tunnel by means of a wire rope lying and sheltered from the sulphurous fumes in a brickwork channel through which the supply of air to the furnace is made. The wire rope is prevented from coming into contact with the brickwork by means of iron pulleys, and these are placed in the air-inlets, so that, with the rope, they are kept cool and in fresh air.

The rakes will, during their passage completely round the circuit, have a period during which they pass through the open air, and are cooled before being again used. When it is desired to roast at high temperatures, this period can easily be made equal to that during which they are in the hot zone; the furnace then can be advantageously made as a straight tunnel, with the return path for the rakes behind it.

The older forms of straight mechanical furnaces were usually much shorter, and the rakes were moved to and fro

by the agency of straight iron rods, the movement being usually intermittent, so that the rakes were resting in sheltered portions of the furnace during the intervals between the successive movements.

The Edwards[1] calcining furnace is a single-hearthed reverberatory furnace, enclosed in a casing of boiler-plate and provided with mechanical rakes.

A general view of one type of Edwards' furnace is shown in fig. 165, a sectional view through the receiving end showing the

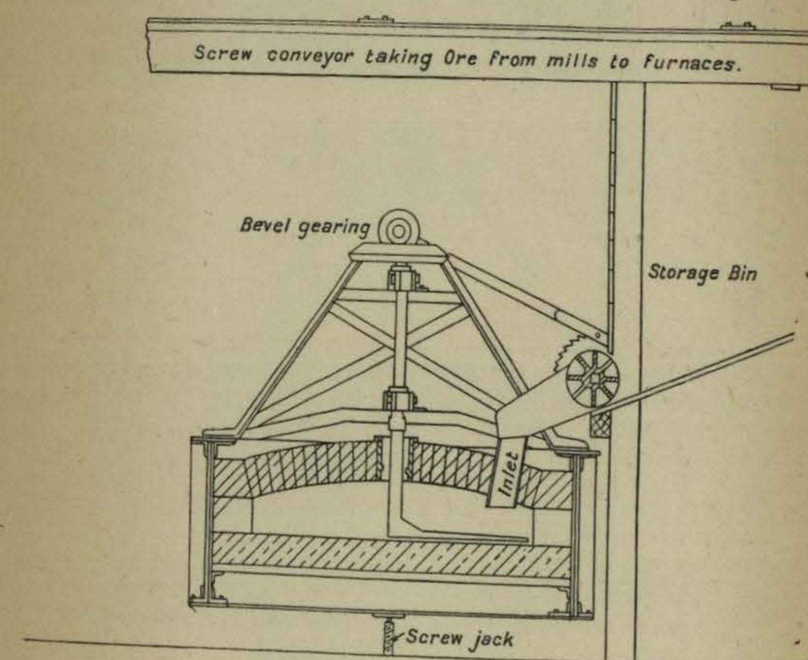


FIG. 166.—Section through Receiving End of Edwards Furnace showing Fluted Roll Feeding.

fluted roll feeder in fig. 166; and a sectional view through the discharge end, showing a water-jacketed rabble, is shown in fig. 167. The sides are made of two girders, each 60 feet long, built on the cantilever principle, and the ends of plain $\frac{1}{4}$-inch plate; whilst stout corrugated iron sheets, bolted to the lower webs of the girders, act as the support for the 6-feet wide bed or hearth.

The frame of the hearth, properly stayed and strengthened where necessary, is supported, about 2 feet clear of the ground, upon a couple of pivots placed midway between the ends, and it is held rigidly at the desired inclination by a couple of screw-jacks. The rabbling is done by a line of fifteen revolving rakes,

[1] *Trans. Inst. Min. and Met.*, xiii., 1903–4, p. 27.

with vertical stems or shafts passing through the furnace-arch; the actual stirrers are five small removable ploughs attached to a cast-iron arm which describes a horizontal circle in the ore. Each revolving rake or rabble moves in the opposite direction to its immediate neighbour, and the ore is thus made to travel in a zigzag course along the bed of the furnace.

All the mechanism is easily accessible, the rabble bearings, gear wheels, shafting, etc. being held in position in an iron framework on top of the furnace.

The five rabbles nearest to the fire-box are hollow, and are kept cool by a stream of water which is constantly passing down through a central pipe in each, and after ascending, escapes into

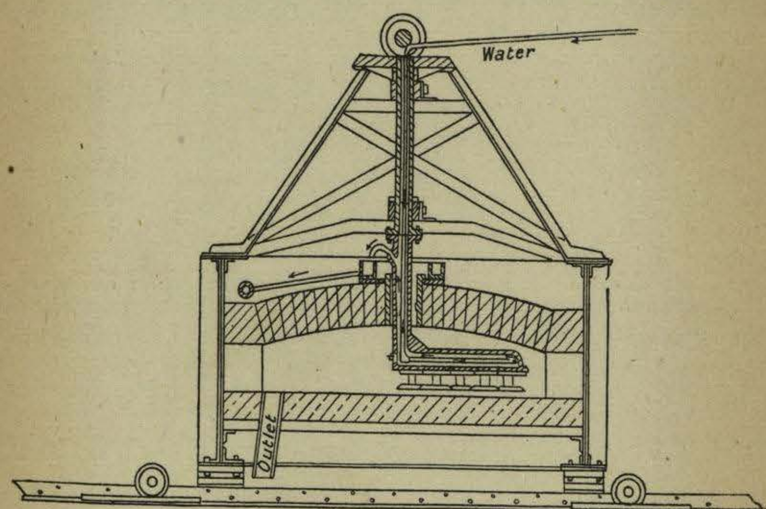


FIG. 167.—Section through Discharge End of Edwards Furnace showing Water-Cooled Rabble.

a channel ring encircling the rabble axle on top of the arch. The layer of ore is usually 2 to 3 inches deep on the hearth, and two hours are occupied in its journey from the inlet to the discharge.

Each furnace is fed by what is known as a "fluted roll," which is a cast-iron cylinder, 3 feet long and 10 inches in diameter, with eight V-shaped channels on its circumference. It is carried by a horizontal axle, to which is also keyed a ratchet-wheel with forty teeth. The roll is let into the front of the bin on a level with the bottom, and is always partly embedded in the powdered ore which fills the channels, and is discharged into the furnace as the roll rotates.

The rate of feed depends on the rate at which the roll revolves, and this is regulated by the ratchet mechanism. The power is

obtained through an adjustable eccentric, keyed on to the shaft which drives the furnace rabbles. The capacity can be altered by varying the angle of inclination of its hearth to suit the composition of the material being treated. A heavy sulphide would require a very small inclination so as to make it travel slowly towards the flame, while a partially oxidised material could be treated more rapidly by having the furnace tilted at a greater angle. This is decidedly advantageous in a customs works treating many different parcels of concentrates, etc.; but on a mine, where, as a rule, the ore does not suddenly alter in composition, the possibility of varying the inclination is of little or no use, and the tilting arrangement is left out.

The Merton[1] furnace, which is made in various types according to the nature of the material to be treated, has proved to be most successful, and is largely used for calcining various ores. In its main features it is somewhat similar to the Edwards calciner, but is generally built with three superimposed hearths, all perfectly level, and communicating with one another by vertical channels. The rabbles, five in number, are similar to those used in the Edwards furnace, but each rabble-stem passes through all three hearths and is supported by a footstep underneath the lowest hearth, the arms or rakes being clamped on at heights to suit the different hearths. The furnace is arranged so that the heat is gradually increased from the time the ore enters the first hearth until it leaves the third or bottom hearth, after which it passes into a finishing hearth next the fireplace, where a very high temperature is attained, which ensures the breaking up of any sulphates formed during the first part of the roast.

The M'Dougal furnace is very successful and consists of six superimposed hearths, enclosed by iron cylinders and lined with brick. It contains a vertical solid iron shaft to which are attached the six sets of arms for carrying the ploughs by means of which the ore is stirred on the different hearths.

IV. **Closed-vessel Furnaces.**—In furnaces of this class the material to be heated is separated from the fuel by an envelope in the form of a closed vessel. The vessel is heated by being in contact with the fuel, or by the flame developed from a fire on a grate, or, lastly, by the gases from a producer. The form of the vessel is determined by the process that is to be undertaken. Thus, for simple heating, the muffle is employed, whilst for fusion, crucibles are used. Retorts and similar vessels are used exclusively for distillation and sublimation.

The ordinary assay furnace may be taken as typical of the wind-furnaces used by the brassfounder. These furnaces vary according to the size and number of crucibles inserted in them. The crucible gas-furnace used for melting steel consists of a long hearth, on which the crucibles are placed in pairs. This hearth

[1] *Trans. Inst. Min. and Met.*, xiii., 1903–4, p. 31.

has a movable roof through which the crucibles may be withdrawn, and on the long sides are the flues from the regenerators, the construction of which is similar to that of other regenerative furnaces.

The best example of a retort-furnace is afforded by the furnace used in Belgium for smelting zinc ores. In this furnace the ores are reduced in a number of fire-clay retorts with a bellied fire-clay nozzle in which the zinc condenses, to which a sheet-iron tube is sometimes added in which any zinc oxide is collected. The retorts are placed in rows in a vertical arched chamber with a fire-place at the base. All modern furnaces of this kind are arranged for gas firing, and fitted with regenerators similar to those used in steel-furnaces.

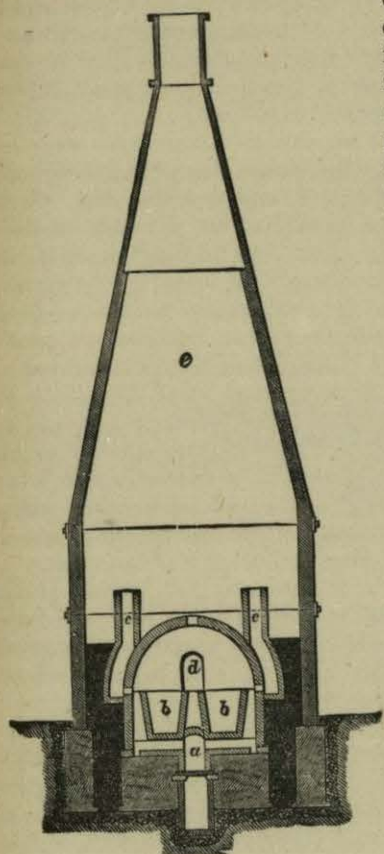


FIG. 168.—Cementation-Furnace.

The furnaces are usually built in pairs, back to back. At Angleur they contain 100 retorts on either side. The charge for each retort is 66 lbs. of powdered roasted blende and 26·5 lbs. of coal.

The tube-furnace is occasionally employed in the extraction of bismuth from its ores by liquation. Native bismuth melts at 266°, and advantage is taken of this fact to separate it from the more or less infusible materials accompanying it. This process has, however, been almost entirely supplanted by ordinary smelting and wet methods. The liquation-furnace used at Schneeberg, in Saxony, contains a series of cast-iron tubes, oval in section, and inclining towards the front, where the ore is placed. The liquated metal is received in iron vessels heated by a separate fire.

A furnace of the closed-vessel type is used in the manufacture of steel by the addition of carbon to malleable iron, a process termed *cementation*. The furnace (fig. 168) consists of a rectangular chamber supplied with chimneys *c c*, and divided into

two parts by a fire-place *a*, on either side of which is a rectangular fire-brick vessel, or *converting-pot*, *b*, varying from 8 to 15 feet in length and 3 feet in width and depth. These pots are thoroughly heated by the flames, and the products of combustion reach the conical hood *e*, some 40 feet in height, which serves to prevent loss of heat by radiation as well as to carry off the smoke. At *d* there is a manhole, built up during the working of the furnace, but opened for cooling down and for the withdrawal of the charge.

The Bessemer Converter.—This furnace, fig. 169, is pear-shaped, the form originally given it by Bessemer. Unlike most smelting furnaces, the converter is usually not fixed, but supported on standards by trunnions. To one of these a pinion is keyed, by means of which the vessel can be moved through an angle of 170°, so that the molten metal may be poured from its mouth. The other trunnion is hollow, and admits the blast to the vessel. A pipe from this trunnion passes to the tuyère-box forming the bottom of the converter, which is perforated by ten to nineteen circular holes, into each of which is placed a conical fire-clay tuyère, perforated with twelve holes, each $\frac{3}{8}$-inch in diameter.

The Bessemer process was first patented on October 17, 1855, and was described in a paper read before the British Association, in which the inventor claimed a method of making wrought iron without using fuel, but it must be remembered that the combustion of the carbon, silicon, and other elements in the pig-iron during their elimination provides the heat necessary for maintaining even molten wrought iron in a fluid state. The process consists essentially in blowing large quantities of compressed air through numerous small jets into a molten mass of pig-iron, thereby effecting the rapid combustion of the carbon, silicon, and manganese present in the metal. The excitement caused by the invention in all iron-making countries was immense, as it was thought that the wrought-iron industry was doomed, since the quantity of pig-iron (about 3 tons) that a puddling-furnace could treat in twenty-four hours could be dealt with in the Bessemer converter in twenty minutes. It was, however, soon found that the expectations were not completely fulfilled; good steel could not be obtained from all kinds of pig-iron, as all the impurities could not be removed. Phosphorus, of which 1 to 2 thousandths suffice to render steel brittle and cold-short, was not removed in the ordinary Bessemer process. It was therefore necessary to employ pure pig-iron containing but a low proportion of phosphorus, until the introduction of the Basic process overcame the difficulties.

Certain modifications of the Bessemer converter have been used for many years, for example the Clapp-Griffiths, which is a small converter adapted for charges varying from 1 to 3 tons. In this case the tuyères are horizontal, and are symmetrically arranged in the walls of the converter, near the base. The Tropenas

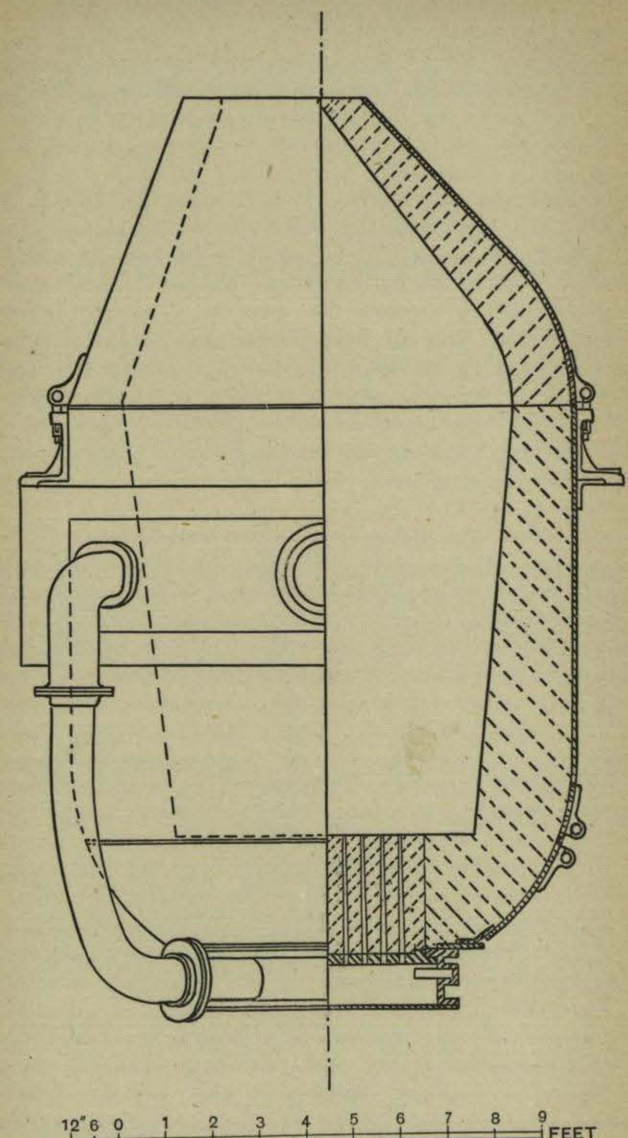


Fig. 169.—Bessemer Converter.

converter,[1] also a small one, is being successfully employed for

[1] *Mineral Industries*, vol. vii., 1899, p. 416.

manufacture of steel castings. Two blasts of air are admitted, one just above and one just below the surface of the metal, with the object of burning the carbonic oxide and so increasing the temperature of the metallic charge.

The Bessemer converter has been modified and employed for treating copper regulus. The early experiments were not successful. In 1880, however, Pierre Manhès, the proprietor of the Vedènes Copperworks, Department of Vaucluse, France, obtained patents for its use in copper-smelting, and smelting works were erected at Eguilles, near Avignon.[1]

More recently, the concentration of matte and its reduction to metallic copper in a Bessemer converter has received considerable attention, and many forms of modified converters have been patented.[2] Those in use at the present time are either vertical or horizontal cylindrical vessels. The former type resembles more closely the ordinary steel converter, except that the blast is admitted round the sides, and not through the bottom. This position of the tuyères is necessary in order to ensure that they do not come below the surface of the reduced copper, which oxidises very easily, and sets if the cold blast passes into the metal.

In 1884 the horizontal cylindrical or trough converter was designed by Manhès and David, and has since been used to a very large extent both in Europe and in America.

The earliest converters were of very small size, treating only 20 to 30 cwt. of matte for a charge. They were rotated by hand, and the operation was conducted in two stages, but gradually their dimensions were increased, and at the present time there are trough converters at Anaconda measuring 12 feet by 8 feet, and at Butte, for a special purpose, 20 feet by 8 feet, and even low-grade matte can be blown to copper in one operation.

A general view of the trough converter is shown in fig. 170.

The saving in fuel effected by the use of the converter is very considerable, and it is claimed that the Manhès process renders copper-smelting possible in countries where, owing to the high price of fuel, the Welsh process is out of the question. The Welsh process formerly consisted of six to eight successive roastings and fusions in order to obtain coarse copper from the ore, all the operations being effected in large reverberatory furnaces. In the Manhès process, by blowing air through the copper matte produced in the first smelting operation, metallic copper may be obtained ready for the refinery.

V. **Electric Furnaces.**—The electric furnace, originally devised by Sir W. Siemens, has become a powerful instrument of research, and of considerable importance in commerce.

By the aid of a small electric furnace, and using a current varying from 25 to 450 amperes, with a difference of potential

[1] *Annales des Mines*, 8th Series, vol. iii., 1883, p. 429.
[2] Peters, *Copper Smelting*, 1895, pp. 528–575.

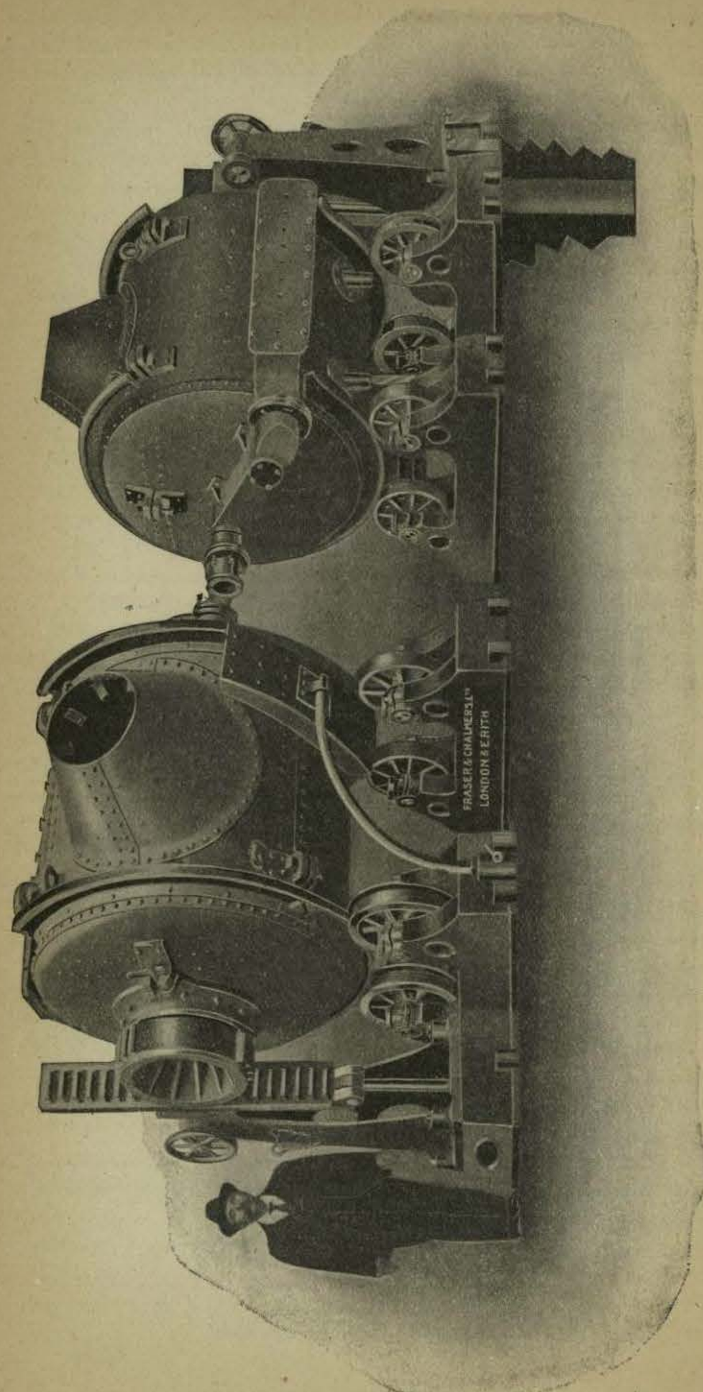


Fig. 170.—3-ton Bisbee Converter for the Treatment of Copper Matte.

at the terminals of the furnace of from 45 to 70 volts, Moissan[1] succeeded in fusing such refractory substances as lime, and in readily preparing samples of the difficultly reducible metals, such as zirconium, chromium, calcium. He also[2] made the furnace reverberatory by placing the material to be treated in a hollow tube of pure carbon placed at right angles to the electrodes. The heating and electrolytic effects of the arc are thus kept distinct. The arc may be deflected on to the material to be heated by means of a suitably disposed magnet. The work of Moissan with the electric furnace has since been published in book form.[3]

Electric smelting-furnaces employed in metallurgical operations may conveniently be divided into three main types:[4]—

(1) Induction-furnaces.
(2) Resistance-furnaces.
(3) Arc-furnaces.

The first type is especially adapted for melting as distinct from smelting—that is to say, for melting down mixtures of different metals to form certain definite alloys, rather than for the reduction of the metals from their ores; the second type can be used either as a melting or smelting furnace by varying the construction, and the third type can also be adapted to either purpose. In all cases, whatever the type of furnace employed, the object is to supply the heat necessary for the particular operation by means of electric energy; in this way the electric energy simply replaces the coal, coke, or gas used for heating, and it will readily be realised that in countries where fuel is cheap, as it is in England, the circumstances are comparatively few where it can be commercially employed.

The furnaces in which an electrolytic action takes place in addition to the heating effect produced by the current may be considered as modifications of the resistance-furnaces.

For certain purposes, however, where it is important to obtain a finished product of great purity, where intense local heat and a non-oxidising atmosphere are required, electric energy enables us to meet the conditions more economically than can be done in any other way.

The induction-furnace is a large crucible in which the steel or other metal is melted by an induced current out of contact with any electrodes, completely protected from the action of any furnace gases, and practically protected from oxidation. It gives, from a metallurgical point of view, by far the nearest approach to the conditions of the crucible. The best-known furnace of

[1] *Comptes Rendus*, vol. cxv. (1892), p. 1031.
[2] *Ibid.*, vol. cxvii. (1893), p. 679.
[3] *Le Four Electrique*, Paris, 1897; English translation, 1904.
[4] See Harbord on Recent Developments in Electric Smelting in Connection with Iron and Steel, *Transactions Faraday Soc.*, vol. i., 1905; also paper, West of Scotland, *Iron and Steel Inst. Journ.*, 1909.

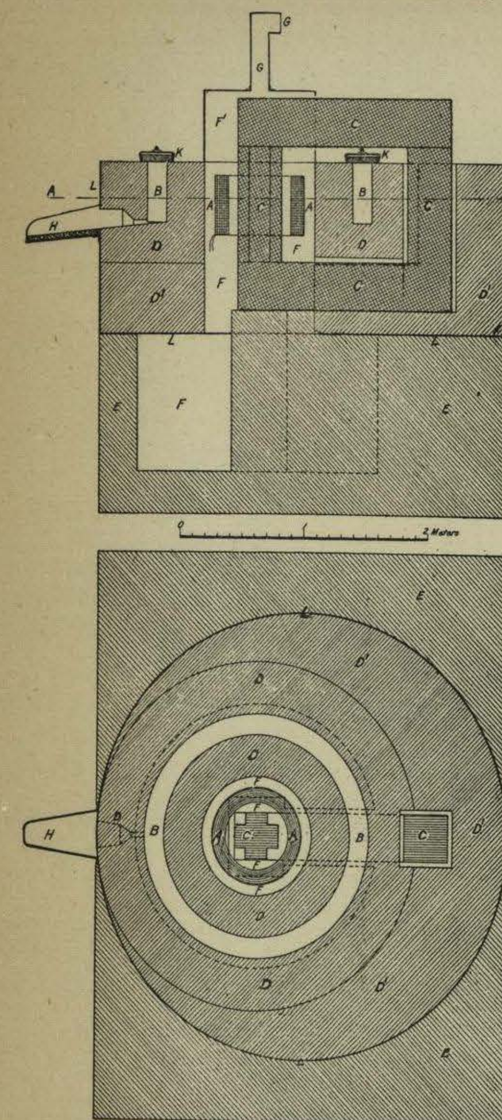
this type is the Kjellin furnace, which has been in operation at Gysinge, Sweden, for steel-making since 1900. Figs. 171 and 172, taken from the Canadian Commission Report, are a plan and sectional elevation of this furnace. This furnace is in effect a step-down transformer, in which the contents in the hearth or crucible form the secondary circuit of the transformer. The furnace is of 225 H.P. capacity, and to the primary, A A, fig. 171, is delivered an alternating current of 90 amperes and 3000 volts, which induces a current in the secondary, B B, of 3000 amperes and 7 volts. The primary, A A, consists of an insulated copper wire wound round one leg of the laminated core, C C C C, which forms the magnetic circuit. When an alternating current is passed through the coil it excites a magnetic flux in the core, and the intensity of the current induced in the steel is then almost the same as the primary current multiplied by the turns of the wire in the primary coil. The tension of the current is naturally reduced in almost the same ratio as the intensity is increased. In this way it is possible to use an alternating-current generator of high tension, and to obtain a current of low voltage and great intensity in the furnace.

In starting the furnace, a little molten pig-iron is poured into the circular trough, B, to form the secondary circuit, and at the finish of each heat sufficient molten steel is left in the furnace to maintain this circuit. The circular hearth or crucible has movable covers on the top, of a size which can be easily raised by means of a bar, and the materials are charged in at the top by removing these covers. The charge at Gysinge usually consisted of best Swedish pig-iron, Walloon iron, and steel scrap, and the proportions of pig-iron and steel scrap are varied according to the grade of steel it is desired to produce. Any grade of steel can be produced in this furnace from 0·10 to 1·50 per cent. or more of carbon, the only thing necessary being to have ample power to ensure rapid melting, and to obtain a sufficiently high temperature to enable the steel to be cast into ingot moulds.

The Rœchling-Rodenhauser furnace is a modification of the Kjellin furnace, and may be regarded as a combination of an induction- and resistance-furnace. In it certain difficulties met with in the Kjellin type of furnace have been largely overcome. In its latest form it is operated by a three-phase instead of a single-phase current, which enables a 15-ton furnace to be operated with a frequency of 50 periods instead of 25, and standard generators to be used instead of specially constructed expensive generators. A special feature of this furnace is the rotation of the charge, due to the presence of a rotary field, which ensures an automatic circulation in the bath. The charging-door is at one end of the furnace, the tapping-hole at the other, and the whole is built as a tilting-furnace.

In the resistance-furnace the heat is generated by the resistance

offered by the whole or a portion of the furnace-charge to a very powerful electric current. It is best represented by the Héroult



Section A B

Figs. 171 and 172.—Kjellin Furnace. Vertical section through the tap-hole and sectional plan on A B.—A A, primary coil of insulated copper wire wound round laminated core, C, and to which is delivered an alternating current of 90 amperes at 3000 volts; B B, annular crucible or hearth, in which charge is melted and forms the secondary; C C, laminated core; D′ D′, fire-brick; D D, silica or magnesite brick; E E, ordinary brick foundation; F F, air-space for cooling primary; F′ and G, iron cylinder with pipe attached to maintain a current of air flowing round primary; H, spout from tap-hole; K K, covers for annular crucible; L L, cylindrical iron casing of furnace. The covers of the crucible are on a level with the working-floor, and the furnace is charged by removing these and throwing the scrap and iron into the crucible, B.

and Keller furnaces, both of which are employed commercially in the manufacture of steel and alloys of iron.

The Héroult furnace for the manufacture of steel has been in successful operation now for several years. The furnace shown in fig. 173, taken from the Canadian Commission Report, is a tilting-furnace, so far as the construction of the body of the

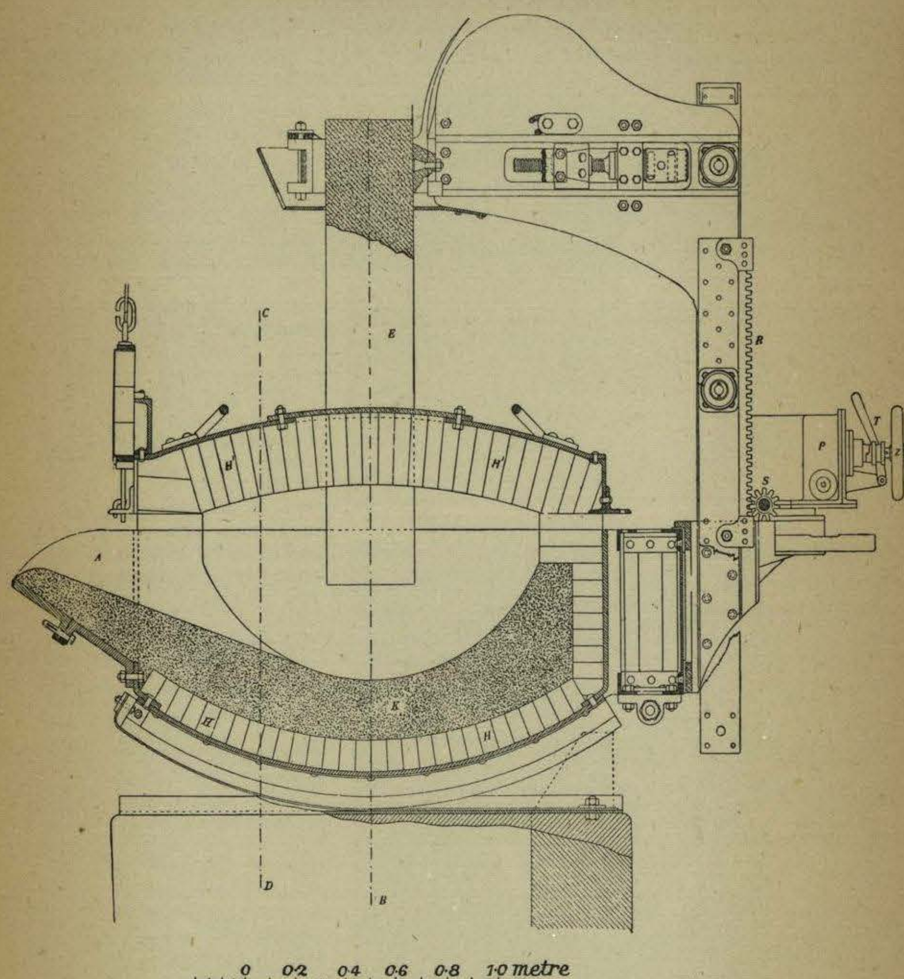


FIG. 173.—Héroult Furnace. Vertical section through the pouring spout.—A, pouring spout; E, suspended electrode, of which there are two, passing through roof; H, basic or burnt Dolomite bricks; H′, silica bricks of roof; K, rammed basic material; P, motor for driving automatic regulator; T, lever for throwing motor, P, out of action; Z, handwheel operating pinion, S′, for regulating electrodes by hand; R, rack gearing with S, by which electrode is raised or lowered. An alternating current of 4000 amperes and 110 volts is used.

furnace is concerned, very similar to that of the well-known Wellman and Campbell tilting-furnaces. The furnace-hearth is

basic-lined, as in the ordinary basic open-hearth process, and two large electrodes pass vertically through the roof, and can be raised or lowered either by hand or automatically by a specially constructed regulator. An alternating current of 4000 amperes and 110 volts is used at La Praz, and the intensity of the current passing through the bath is regulated by increasing or decreasing the width of the air-gap between the electrodes and the slag-line.

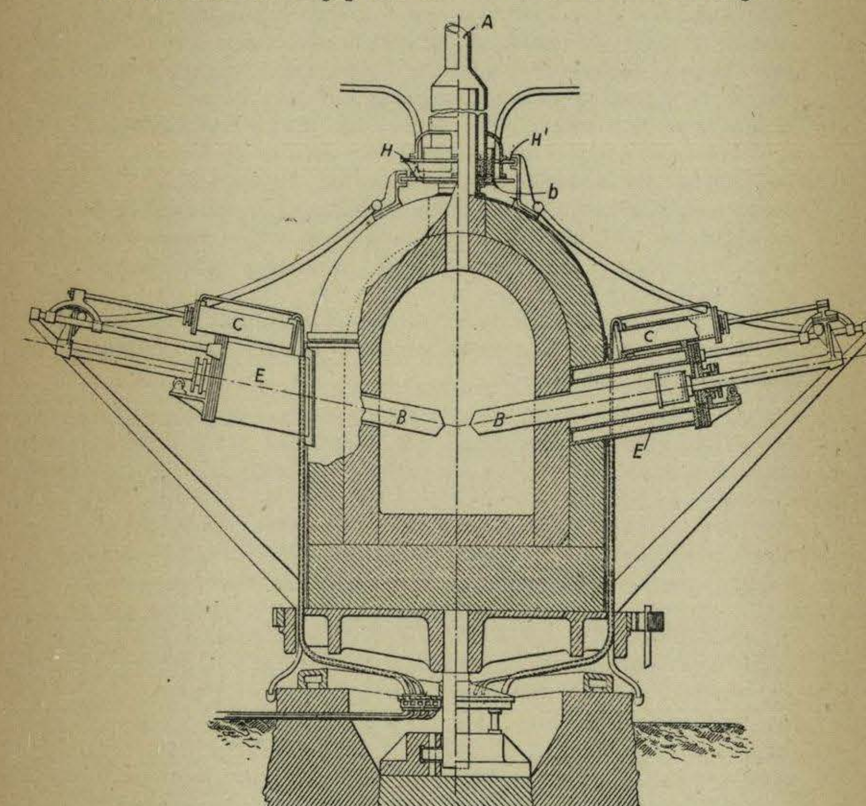


FIG. 174.—Stassano Electric Furnace. A, tube to lead off volatile products; B B, electrodes; C C, hydraulic cylinders for regulating electrodes; E E, water-jackets for electrodes.

The section of the roof between the electrodes is usually made of bronze, in order that no magnetic circuit may surround them. The electrodes may or may not be water-jacketed where they pass through the roof, but water-cooling not only increases the life of the furnace and electrodes, but enables a considerably larger output to be obtained.

In the Arc furnace the necessary heat is obtained by direct radiation from the arc and by reflection from the roof and sides of the furnace. As far back as 1879 the late Sir William Siemens designed a small crucible-furnace capable of melting a few pounds of steel on this principle, and the Stassano furnace is the best-known furnace of this type used for the smelting of iron and steel. It is shown in fig. 174. The furnace rotates round an axis inclined about 7° to the vertical. There are three electrodes, which nearly meet in the centre of the furnace, their distance being regulated by a hydraulic ram. A three-phase alternating current is used, and distributed between the three electrodes. The Stassano furnace is rotated by mechanism underneath the furnace during the operation of smelting, but this is not essential to this type of furnace. The furnace is lined with magnesia bricks, and there is provided a tap-hole for metal at the bottom of the furnace and a slag-hole at a somewhat higher level. The charge is fed through a hopper and inclined shoot to deliver below the electrodes. Furnaces of this type are now used commercially in the production of zinc, the volatilised metal being condensed in suitable chambers.

Electric furnaces are now receiving a large amount of attention, and there is no doubt that great advances will be made in this direction in the near future.

CHAPTER X.

THE SUPPLY OF AIR TO FURNACES.

Methods of producing Draught.—In every furnace it is necessary to conduct away the gaseous products of combustion to enable fresh air to enter and to give up its oxygen to the fuel. This passage of the fire-gases from the furnace and of the air to the furnace may be effected in two ways: first, by exhausting the products of combustion; and second, by forcing in air for combustion. In the former method a space containing rarefied air is formed in the furnace, and atmospheric air flows in from outside so as to preserve the equilibrium; whilst in the latter method the pressure in the furnace is greater than that of the air outside, and consequently the air and the fire-gases are forced out. Although the current is usually the same in both cases, the influence on the combustion may be different when the movement is effected by the compression or rarefaction of the air.

The exhaustion of the air is usually effected by means of chimneys. The chimney or stack may be regarded as a vertical pipe containing heated and expanded gaseous products of combustion. The column of gas within the chimney is, in consequence of the expansion due to heat, considerably lighter than a column of air of the same height at the ordinary temperature. The consequence is that, owing to the difference of weight, there is an excess of pressure of air under the grate, and movement ensues. This difference in the weight of the hot and cold columns is equal to the weight of the increase in volume that would be produced by heating the cold column of air to the temperature of the chimney. If the elongation thus produced be represented by h, the velocity of the movement $v = \sqrt{2gh}$; but h is dependent both on the height of the cold column of air and on the difference of temperature within and outside the chimney, whence it follows that theoretically the velocity of a current of gas within a chimney increases proportionately with the square root of the height and the square root of the difference of the