CHAPTER VIII

THE KELLER ELECTRIC STEEL REFINING FURNACE

C. A. Keller, head of the well-known French firm of Keller, Leleux et Cie, manufacturers of calcium carbide and ferro-alloys, has designed two distinct types of electric refining furnace for steel production—the first and earlier type with two or more electrodes connected in series; the second and later type, with a compound conducting hearth (or sole) to the furnace. The earlier furnace resembles the Heroult refining furnace, the latter one that of Girod; and the resemblance in each case is sufficiently close to render the question of patent priority and validity somewhat interesting.

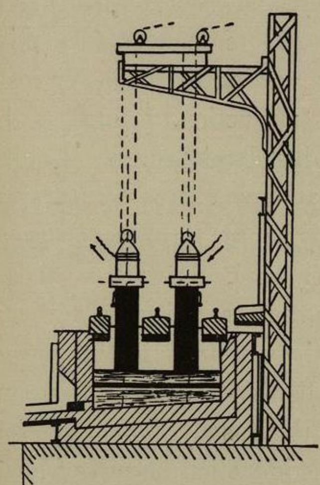

Fig. 61. — Keller's Furnace, early type, diagrammatic section.

Fig. 61 shows a diagrammatic elevation of the earlier Keller smelting and refining furnace. From this the furnace is seen to consist of a fixed sheet-iron chamber lined with basic refractory material, and heated by two massive carbon electrodes suspended vertically above the metal in the furnace. When working the furnace these electrodes were allowed to touch the surface of the molten slag, but not to dip beneath the same, and this appears to have been the chief distinction between the Keller and Heroult processes of electric steel refining.

A furnace of this type of 800-kgs. capacity was erected at Kerrousse in 1902, and was worked there experimentally for

some months. It was transferred later to the works of Keller, Leleux et Cie, at Livet, and a trial run was made here in 1904 with the furnace by the Canadian Commissioners. Unfortunately lack of time to complete the refining operation caused the failure of the test, and no figures were published for the Keller furnace in their report. The experience gained, however, at Kerrousse and Livet in the application of this type of furnace to steel refining led to the design and erection, in 1905, of an 8,000-kg. furnace at the steel works of Jacob Holtzer & Co., at

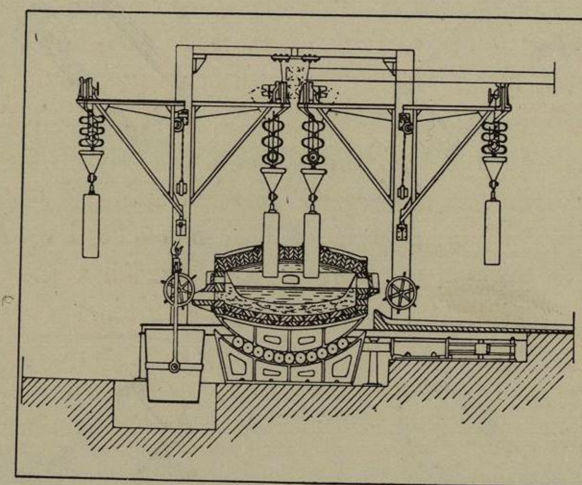

Fig. 62.—Keller's 8,000-kg. Furnace at Unieux (section).

Unieux, France. This installation is claimed by Keller to have been the first example of the introduction of an electric furnace into a modern steel works. Even if this claim be incorrect, Keller appears to have been the first electro-metallurgist to recognise that the electric steel-refining furnace could be most usefully and economically employed for the *final stages* of steel making, rather than for the whole process. For the Keller electric refining furnace had been charged with molten metal during the experimental trial runs at Livet, instead of with cold scrap, and at Unieux, this system of working has been further developed.

Fig. 62 is a sectional elevation of the Unieux furnace, and

Fig. 63 is a plan of the same. The furnace was of the four-pole type, and weighed with its equipment 50 tons. The melting chamber was mounted as shown on rollers, and was provided with hydraulic machinery, by means of which it could be tipped. Four rotating supports were provided for the double electrodes. These when turned inwards came under a central overhead

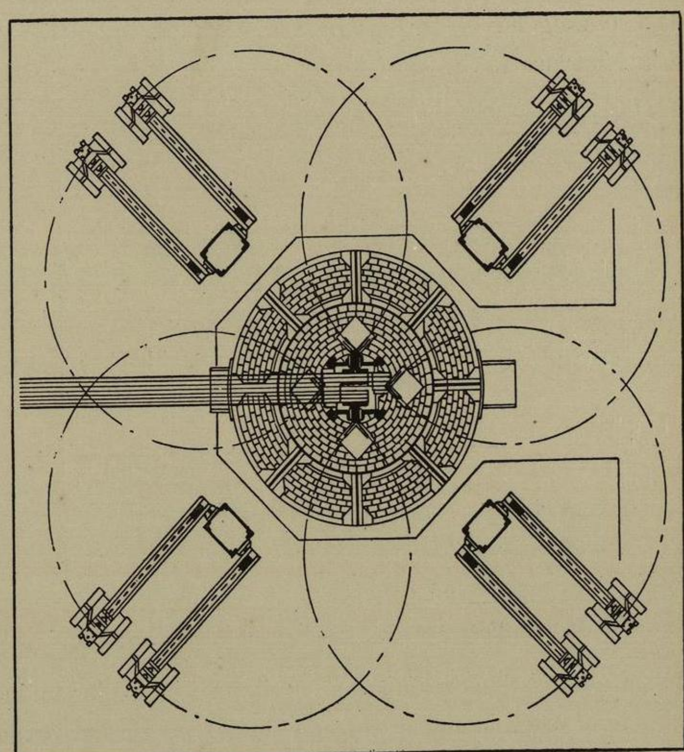

FIG. 63.—Keller's 8,000-kg. Furnace at Unieux (plan).

block, where they made contact with the electric supply mains. The four supports were completely independent of the furnace proper, and it was quite possible to remove the cover of the latter for repairs, without any loss of time in removing the electrodes from their supports.

By this system four zones of heat were produced within the furnace, and the current flowing through each pair of electrodes

could be independently controlled and regulated. The movements of the electrodes in a vertical direction either upwards or downwards were also subject to independent control, one, two or four electrodes being moved as required. The arrangement adopted for the distribution of the current to the eight electrodes was on the star plan, and was designed to reduce the induction losses to a minimum, and to permit the removal and renewal of the carbon electrodes without stopping the furnace. The furnace hearth was lined with magnesia, and was mounted so that it could be tipped either forwards or backwards. The gas generated during the refining process accumulated within the furnace and created a plus pressure, a condition which was favourable to the exclusion of air and the prevention of oxidisation of the finished steel.

Operating Costs.

The following results have been obtained with this furnace at Unieux with molten metal charged into the electric furnace from a Martin open-hearth furnace, by means of a cradle carrier:—

TABLE XXXI.

Molten metal charged, 7,500 kgs.
Composition of ditto, Carbon, ·15 per cent.; Sulphur, ·06 per cent. Phosphorus, ·007 per cent.
Mean power consumption, 750 kw.
Carbon contents desired, ·45 to ·50 per cent.
Time of refining operation, 2 hrs. 45 mins.
Composition of finished steel, Carbon, ·443 per cent.; Sulphur, ·009 per cent.; Phosphorus, ·008 per cent.
Power consumed per metric ton, 275 kw. hours.
Electrode consumption, 10 kgs. costing at 40 frs. per 100 kgs., 4 frs. per ton of steel.

The power-factor with a current of 12,000 amperes was stated to be very high, namely, ·97, and Keller estimated that a furnace of this type, using three-phase current, could purify 250 tons of steel per day, at an inclusive cost of 12*s.* 6*d.* to

15*s.* 6*d.* per ton, when using electric power costing ·15*d.* per kw. hour.

The installation of Unieux appears to have been the only one of the earlier type of Keller furnace, outside the inventor's own works at Livet, and the later industrial developments have occurred with the type provided with a conducting hearth or sole. The description of this furnace is based upon that given by Keller, in a paper read before the Faraday Society in 1909.[1]

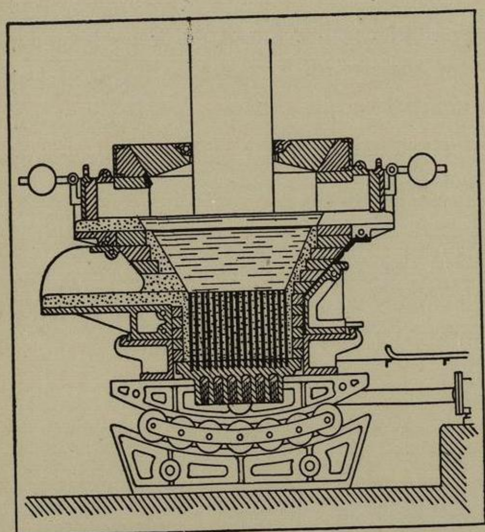

FIG. 64.—Keller's Furnace with Conducting Hearth (sectional elevation).

The whole of the bottom of this type of furnace is made up of a block, which is partly metal and partly refractory material. It is a conductor, and is also practically infusible at all working temperatures of the furnace. The liquid metal does not rest on a masonry bottom, but on a combination, which is to the arrangement of masonry fitted with metallic poles, as reinforced concrete is to the ordinary substance.

Iron bars 25 to 30 mm. in diameter are placed vertically at regular intervals of about 25 to 30 mm. apart. These bars are fixed solidly in the bottom of the furnace, thus forming a bundle which fills the whole of that part of the furnace containing the molten steel. A clay of some agglomerated material, magnesia for preference, is closely rammed when hot between each group of four rods. These latter form in fact a mould, which permits

[1] *Transactions of the Faraday Society*, Vol. V., pp. 118—121.

the mixture to be rammed in with some degree of force. A very compact mass is thus obtained, composed of iron bars and refractory material in regular arrangement. It is a conductor when cold so far as the metal portion of it is concerned, while at high temperatures the refractory material also conducts. This compound hearth or sole is contained in a metal case which is used as a covering, and can be cooled by a current of water. The lower conducting base and all the iron bars are connected, by any suitable means, to one of the poles of the source of energy. The construction described above allows the furnace to be started very easily. The small distance between the bars and the conductivity of the clay cause them to be in parallel throughout their length when the furnace is starting-up, and the current is distributed equally over the whole surface of the hearth. The concentration of the current that is produced at points in a furnace fitted with isolated metallic poles is not created by this arrangement, for the current on leaving the electrode crosses the whole section of the molten metal, and leaves in the same regular way over the whole surface of the hearth. It is in fact claimed by Keller that the electrical resistance of such a conducting hearth is practically negligible, for the extent of the furnace-bottom allows a large number of bars to be employed, while the conductivity of the clay must also be taken into account. As a result, the loss due to resistance is very small. The use of metal conductors of small section gives rise also to a more rational distribution of an alternating current than with other methods of construction.

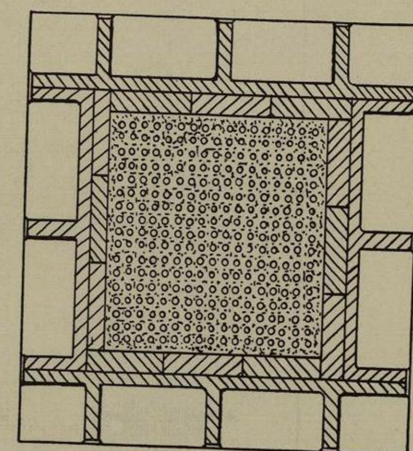

FIG. 65.—Keller's Furnace with Conducting Hearth (plan).

The conducting hearth forms the bottom of the melting chamber of the furnace, which is constructed otherwise on the usual lines, with a double lining of some refractory material to the walls. The shape of the melting chamber is conical, and in order to give the necessary solid foundation a basin of magnesia clay is placed at the bottom of the furnace. This clay is easily repaired when necessary after the melt. The furnace casing is

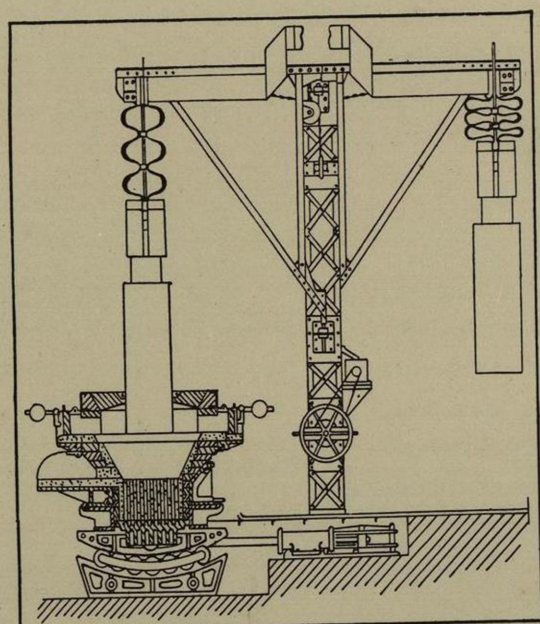

Fig. 66.—Keller's Furnace with Conducting Hearth (section showing method of supporting the electrodes).

cooled up to the level of the upper part of the hearth, in order to protect the junction of the melting chamber with the hearth.

The furnace is closed by an arch, through which the electrode passes. The regulation of this electrode is effected by hand or by an automatic regulator; the latter arrangement is the simpler. In order to obviate the stoppage necessary when changing the electrode, the latter is fixed at the end of a rotating support which carries another electrode ready for use.

A new electrode can be inserted in two or three minutes by merely rotating the supporting arm. The cooling of the furnace sole is carried out on the water-jacket principle, the means employed being similar to those used in the construction of other metallurgical furnaces. The sheathing only of the furnace is cooled by means of cast-iron plates, in which are embedded the iron tubes through which the cooling water circulates. It is claimed that no danger of explosion would follow the breaking of one of these tubes. Furnaces of this type can be employed with three-phase current, the electrical connections being made on the star plan, and the armoured clay hearth of the furnace being made the neutral or middle point of the system. As regards repairs, the hearth of a 1,500-kg. furnace showed no signs of wear when examined after many months of service.

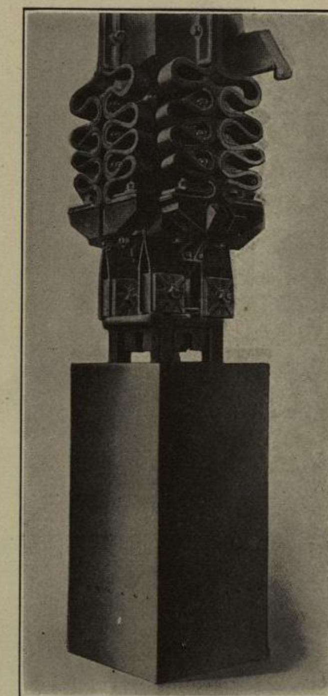

Fig. 67.—Details of Electrode Support for Keller's Furnace.

Furnaces of this second type (with a conducting hearth) have been installed at six works in France, Germany and Italy, but no details concerning their actual costs of operation or success are yet available for publication. A conducting hearth furnace is being used at Livet for melting a ferro-manganese alloy before it is added to liquid steel. Figs. 64—66 are illustrations of the Keller conducting hearth type of furnace.

The details of the method used by Keller for connecting the heavy carbon electrodes to their supports is shown clearly in Fig. 67, and deserves some comment. The supports are constructed of rather wide and flexible thin bars of copper, ½ mm. only in thickness, connected at one end with the fixed current leads and at the other end with the carbon electrode blocks. The head of each carbon is provided with a cavity, into

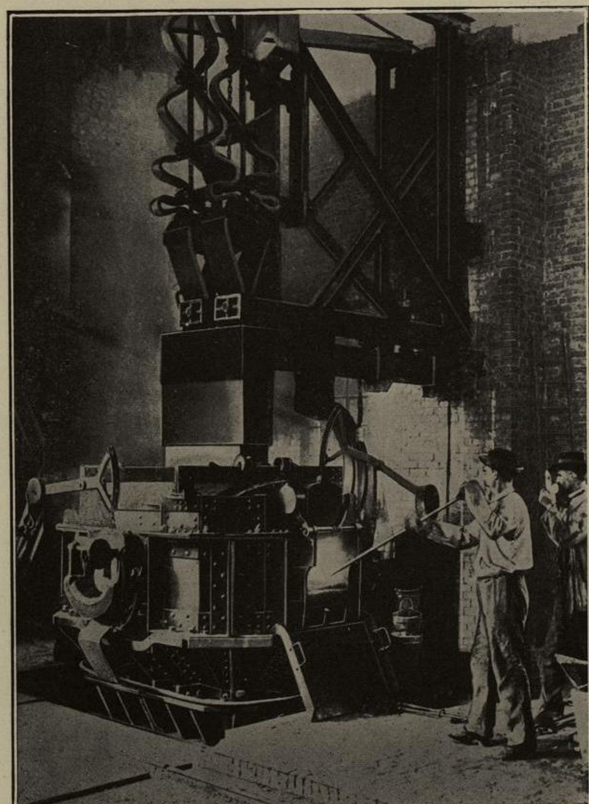

Fig. 68.—General View of Keller's Conducting Hearth Furnace in operation.

which the expanded end of the flat and flexible current lead is fastened, by aid of molten bronze or of some other suitable metal. One obtains in this way a joint which is both electrically and mechanically perfect, while allowing some vertical movement to occur. As already pointed out, the renewal of the electrodes

when consumed up to the head of the carbons is simplified by the revolving arms of the electrode support.

Fig. 68 shows a general view of the Keller conducting hearth

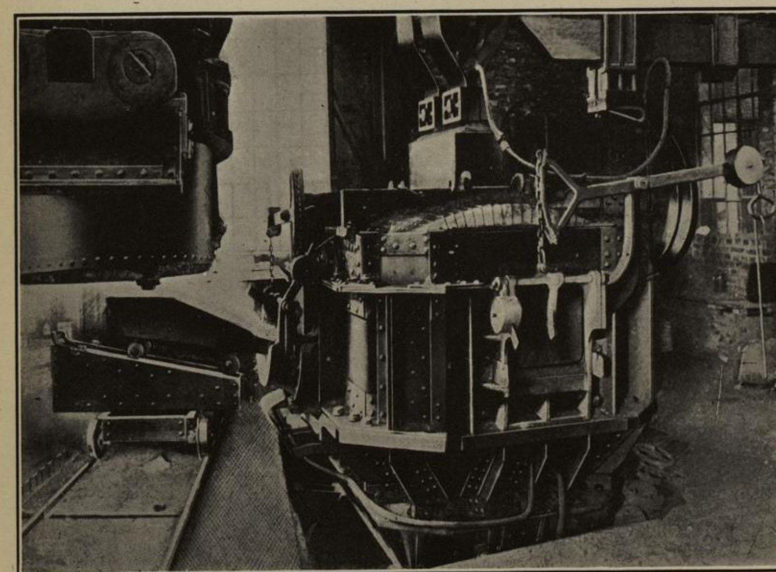

Fig. 69.—Keller's Conducting Hearth Furnace being charged with molten metal.

type of furnace, and Fig. 69 the same furnace being charged with molten metal. A list of the installations of the Keller furnaces in Europe is given in the Appendix of this book.

CHAPTER IX

THE FRICK, GRÖNWALL, HIORTH, AND STOBIE FURNACES

THE previous chapters of this book have dealt with the five electric furnaces for steel refining that have been longest before the public and have received the widest trial. It is now the author's duty to devote some space to descriptions of those furnaces which have not attained so great a success, but are none the less deserving of study and attention. These furnaces have been designed and erected with the data derived from the earlier experiments to guide and warn their patentees; and it is quite possible that some of them may prove of higher efficiency, and be found capable of more economical working, than any that have preceded them.

The information relating to the construction of these furnaces and to their working costs is, of course, not so voluminous as that of the better-known types, and in some cases there is little data available for arriving at any just estimate of their practical value for steel-refining purposes. The present Chapter and Chapter X. contain, however, detailed descriptions of the more important of these furnaces and processes; and information as to the running costs is added, where the figures are available for publication.

The Frick Electric Refining Furnace.

The Frick Refining Furnace is of the induction type, and differs only in comparatively unimportant details from the Kjellin and Colby furnaces. According to Lyman,[1] the furnace consists: (1) of a ring-shaped crucible of uniform cross-section, holding the molten metal and forming the secondary of the transformer; (2) of a magnetic core built of laminated iron, forming a closed magnetic circuit around the coils; and (3) of two primary coils

[1] *Transactions of the American Electro-chemical Society*, Vol. XIX., p. 197.

of insulated copper ribbon, mounted one above and one below the crucible, on the magnetic core. These coils may be wound for any desired voltage up to 6,600 volts.

Fig. 70 is a diagrammatic section of the Frick furnace. A 1,000-h.p. furnace of this type was built for Messrs. Fried. Krupp, at Essen in 1910, and has been in regular use since January of that year. This furnace has a capacity of 20 tons

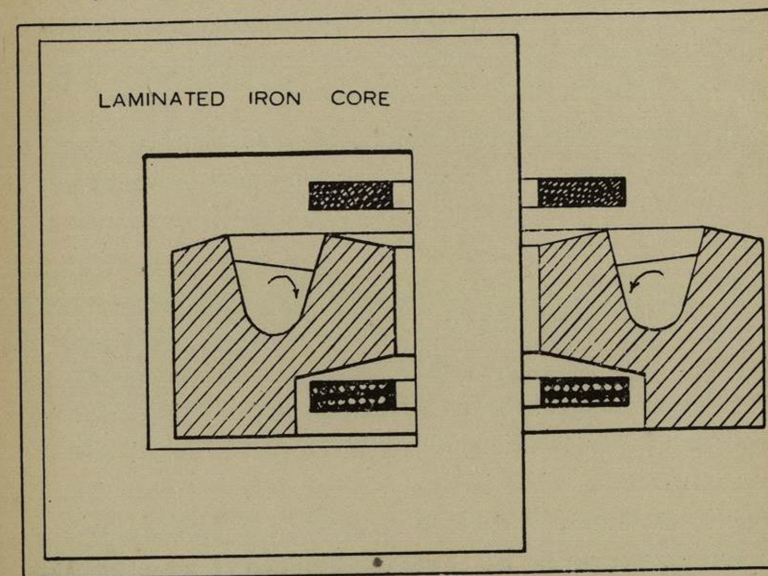

FIG. 70.—Diagrammatic section of the Frick Furnace.

steel per day, when charged with cold scrap, and requires about six and a-half hours to melt and refine each $6\frac{1}{2}$ tons charge.

The following figures for the operation of this furnace during a run of forty-two days are given in the Journal named below[1]:—

TABLE XXXII.

Duration of melting period, June 2—July 14, 1910	42 days.
Number of charges	134
Average time per charge	$6\frac{1}{2}$ hours.
Metal charged	883 tons.
Steel produced	850 "
Loss per cent. on metal charged	3·73 per cent.
Kw. hours per ton of steel produced . . .	663

[1] *The Iron Trade Review*, Nov. 17, 1910.

The power required was approximately, therefore, one kw. hour for each three pounds of steel refined, or 663 kw. hours per ton. To obtain a reasonably high power factor, a special low-frequency current of 360 amperes and 5,000 volts (at 5 to 15 cycles) was used, and an engine-driven generator designed to furnish this low-frequency, single-phase current was also employed. The electrical power supplied was controlled by regulating the generator voltage. The efficiency was said to be about 65 per cent. The power consumed in melting the material (cold iron and slag) and raising this charge to 1,500° C. in a 10-ton furnace, was approximately 600 kw. hours per ton, or 0·3 kw. hour per pound. The power consumed for refining the steel after melting was from 1,800 to 2,000 kw. hours for a 10-ton charge, or approximately 0·1 kw. hour per pound.

As regards the two Frick furnaces which have been erected and operated in Sheffield, England, only limited information is available. A 250-h.p. furnace, with a working capacity of 4,000 lbs. per charge, was erected at the works of Messrs. John Brown & Co. for experimental purposes and is stated to have given satisfaction, while Messrs. William Jessop & Sons have a larger Frick furnace of 6,600 lbs. capacity, and utilising 600 h.p. No working figures for the power consumption of these furnaces have been published.

The Grönwall Refining Furnace.

This furnace is of the "arc" type, and has been designed by the three Swedish engineers, Messrs. Grönwall, Linblad, and Stalhane, who have been responsible for the design and working of the successful Electric Iron Smelting Furnaces at Ludvika and Trollhätten, in Sweden (see Chapter I.). The Grönwall refining furnace is of the two electrode "arc" type, and in principle and appearance differs only slightly from the Girod and Heroult furnaces. The bottom of the furnace is, however, provided with a conducting lining, and the current passes through the molten metal and away by this path when two-phase current is employed,

the hearth being made the neutral return of the system. The advantages of this plan are,—that two-phase current is cheaper to generate and more easy to control than single-phase, while it also produces more circulation in the bath of molten metal.

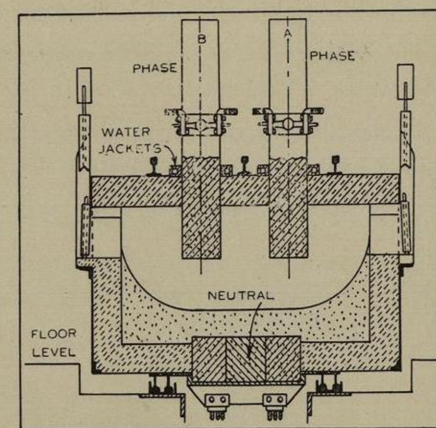

Fig. 71.—Section of Grönwall Furnace.

Figs. 71 and 72 show sectional elevations of the Grönwall furnace at right angles to one another. The furnace is built up on the curved cast-iron plates which form its shell, a lining of magnesite bricks being employed between the ordinary basic lining and the shell of the furnace. The two electrodes are suspended, as shown in Fig. 71, and hang with their free ends just

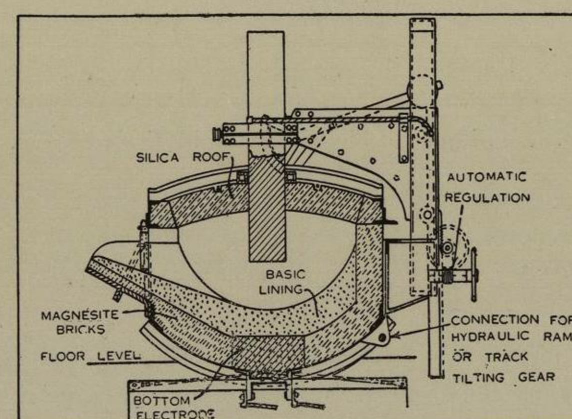

Fig. 72.—Section of Grönwall Furnace.

above the molten slag or metal. In the larger furnaces, at the point where they pass through the furnace crown, they are water-cooled. The furnace can be tilted by aid of the mechanism shown in Fig. 72. The carbon block forming the lower terminal of the furnace is fixed in a casting bolted to the furnace bottom. The top of this bottom electrode does not project above the magnesite brickwork, and it does not therefore weaken the basic lining of the furnace. The roof consists of a channel-iron framework, closed in with silica brickwork, and can be removed from the furnace and repaired when necessary, a new roof being always kept in reserve ready for use.

The special feature of the electrode holders is, that the

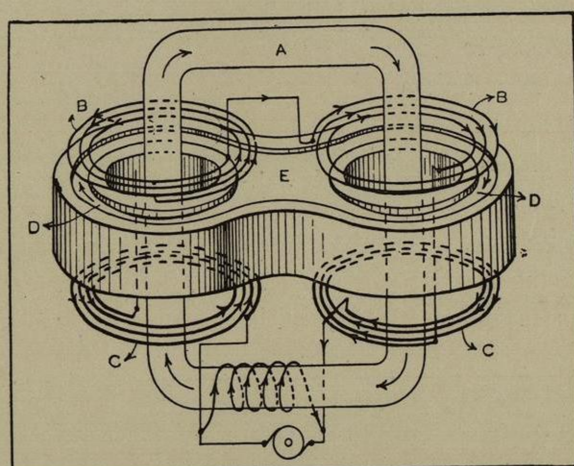

FIG. 73.—Diagram of Electric Circuits in Hiorth Furnace.

electrical contact is made low down, just above the furnace roof; this reduces the energy losses due to the internal resistance of the electrode. The holder consists of strong iron castings and T irons. Owing to the use of two-phase current, and to the fact that each phase is connected to one of the top electrodes, the arcs are formed independently of each other; and even if one arc be broken, the other remains. In other arc furnaces, with the arcs in series, when one arc is interrupted the other is also extinguished, and this leads to disturbance in the supply system.

The details of the process of steel refining in the Grönwall furnace are the same as in the Girod, Heroult, and Keller

furnaces, the high temperature obtainable leading to good purification, and the good circulation to uniform quality of the steel produced. No figures, however, are available showing the power consumption per ton of finished steel, or the total costs of the refining process. These should be rather lower than the corresponding figures for the other furnaces of the "arc" type, owing to the economies resulting (1) from the use of two-phase current, (2) from steadiness in working, and (3) from more even distribution of heat throughout the charge. The Grönwall furnace is installed at the Electric Iron and Steel Works of the Aktiebolaget Elektrometall at Ludvika, Sweden.

The Hiorth Refining Furnace.

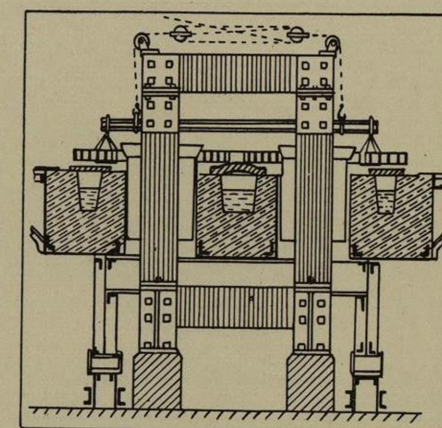

FIG. 74.—Sectional elevation of Hiorth 5-ton Furnace at Jossingfjord.

This furnace is the invention of Albert Hiorth, of Christiania, Norway, and is an improved form of the induction type of furnace. A 5-ton furnace has been operated at the Factory of the Jossingfjord Manufacturing Co., at Jossingfjord, Sogndal, in Dalene, Norway, since the spring of 1910, and the experience gained with this 5-ton furnace has been utilised in designing a larger furnace of 30-ton capacity. The 30-ton furnace, so far as the writer can learn, is not yet working. The following description of the smaller furnace is drawn chiefly from a paper by J. W. Richards, read before the Chicago meeting of the American Electro-chemical Society in 1910.[1]

The Jossingfjord Works are provided with a 500 kw. generator,

[1] *Trans.*, 1910, Vol. XVIII., p. 191.

driven by a Pelton wheel; the power here costs only 17*s.* 8*d.* per h.p. year. The 5-ton furnace is a double-channelled induction furnace, with a primary consisting of four coils connected in series. Fig. 73 shows the electrical principles, E being the steel bath, with its two channels DD, A the magnetic circuit, BB the upper coils, co-extensive with the heating channels, and CC the lower coils. The coils BB are suspended from pulleys with flexible connections, and when running, are close against the covers of the channels DD, but can be raised about 60 cm., when the covers are to be removed. The coils BB are non-insulated bare copper bars, coiled spirally. The coils CC are hollow, water-cooled copper conductors, and in the actual furnace are embedded in the magnesite lining about 40 cm. beneath the channels DD. The voltage employed on the primary is so low that no particular precautions for insulation are needed, and no one can be seriously hurt by it. The space between the magnet A and the furnace wall is a clear 30 cm., which allows of the magnets (weighing several tons) being bolted firmly to the floor, while the furnace can be tilted for pouring. The central space (E) is 30 cm. wide in the middle, 60 cm. wide at the sides, and nearly 2 metres long from front to back. Space enough is therefore provided to re-melt ingots or other scrap.

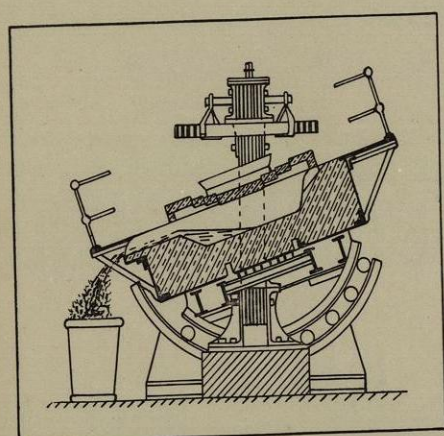

Fig. 75.—Section of Hiorth's 5-ton Furnace at Jossingfjord, tipped for discharging.

The figures in Table XXXIII. (see next page) of a heat with this furnace are given by Richards in the paper referred to above.

Table XXXIII.

P.M.	
12.30.	In furnace, 2,775 kgs. of previous charge of steel containing 1·00 per cent. carbon.
	Charged 1,000 kgs. pig-iron, and 500 kgs. Walloon iron. Current started.
12.30.	Current 1,800 A, 273 V, = 380 kws. cos. φ 0·77.
1.30.	Current 1,840 A, 273 V, = 395 kws. cos. φ 0·80.
2.0.	Current 2,050 A, 265 V, = 380 kws. cos. φ 0·70.
2.30.	Charge melted. Average current 380 kws. for 2 hrs. 10 mins. = 550 kw. hrs. per ton of metal melted.
2.30.	Charged 350 kgs. pig-iron, and 1,150 kgs. Walloon iron.
3.30.	Current 2,275 A, 270 V, = 400 kws. cos. φ 0·65.
4.30.	Charge melted. Average current 400 kws. for 2 hrs. = 530 kw. hrs. per ton of metal melted.
5.30.	Current 2,370 A, 265 V, = 395 kws. cos. φ 0·63.
6.00.	Current 2,425 A, 278 V, = 400 kws. cos. φ 0·59.
6.15.	Current 2,300 A, 280 V, = 365 kws. cos. φ 0·57.

Assuming 300 calories necessary to melt 1 kg. of steel, the thermal efficiency of this melting operation is 55 per cent. and the furnace radiation loss is represented by 180 kw., at this temperature. It was stated that it took about 170 kw. to keep the charge melted, when the furnace was kept up to heat overnight.

The metal was now at a casting temperature, and the total power used was 395 kw. for six hours, equivalent to 790 kw. hours per ton of steel. Other test runs with this 5-ton Hiorth furnace have shown that one ton of steel could be produced in it, with a power consumption of only 700 kw. hours.

During the above heat, 35 kgs. of 30 per cent. ferro-silicon and 8·7 kgs. of 80 per cent. ferro-manganese were added to the bath; while when casting ·15 kg. pure aluminium was added in the ladle. The steel was poured into 20 cm. square ingots and cast well.

The materials used were the purest Swedish Dannemora pig-iron from the middle bed of the Dannemora deposit, and Dannemora Walloon iron, costing, respectively £6 5*s.* 0*d.* (108 kroner) and £15 12*s*. 6*d*. (270 kroner) per metric ton. These are the identical materials used in Sheffield to produce the best quality of crucible steel. Yellowish-white blast-furnace slag, vitreous and glassy, from the Dannemora furnaces, was being used as a flux, mixed with fluorspar when greater fusibility was desired. The contents of the furnace being 5 tons, 3 tons were poured at a time and 2 tons left in to start the next charge, which then consisted of 3 tons of raw materials. The analyses of these raw materials and of some of the steels produced from them, are given below :—

TABLE XXXIV.

—	Carbon.	Silicon.	Manganese.	Sulphur	Phosphorus.
Dannemora, White pig .	3·80	0·310	1·727	0·025	0·020
,, Walloon iron	0·107	0·013	0·068	0·010	0·009
Steel	1·42	0·130	0·322	0·010	0·019
	1·20	0·107	0·269	0·009	0·019
	1·02	0·112	0·301	0·008	0·021
	0·76	0·108	0·253	0·009	0·021
	0·67	0·108	0·288	0·006	0·021

The steel produced is being shipped to Sheffield for use in the steel works, for the manufacture of knives, razors, chisels, etc., and enters into successful competition with the best crucible steel selling at £60 per ton. The capacity of this 5-ton furnace is 12 tons in 24 hours, 3 tons of finished metal being poured every six hours. Under regular conditions of work 700 kw. hours are used per ton of cold metal charged.

Figs. 74 and 75 are sectional elevations of the Hiorth 5-ton furnace installed at Jossingfjord. Figs. 76 and 77 are photographs of the same furnace, showing the external appearance.

The larger 30-ton Hiorth furnace, to which reference has been made, is not yet erected, but a full report of the data upon which its design has been based will be found in a paper contri-

buted by Hiorth to the Toronto (1911) meeting of the American Electro-chemical Society (*Trans.*, Vol. XX, p. 293). From this paper the following details are extracted :—

With regard to the new design the first condition was that the space for the charge must be large enough to hold 30 tons,

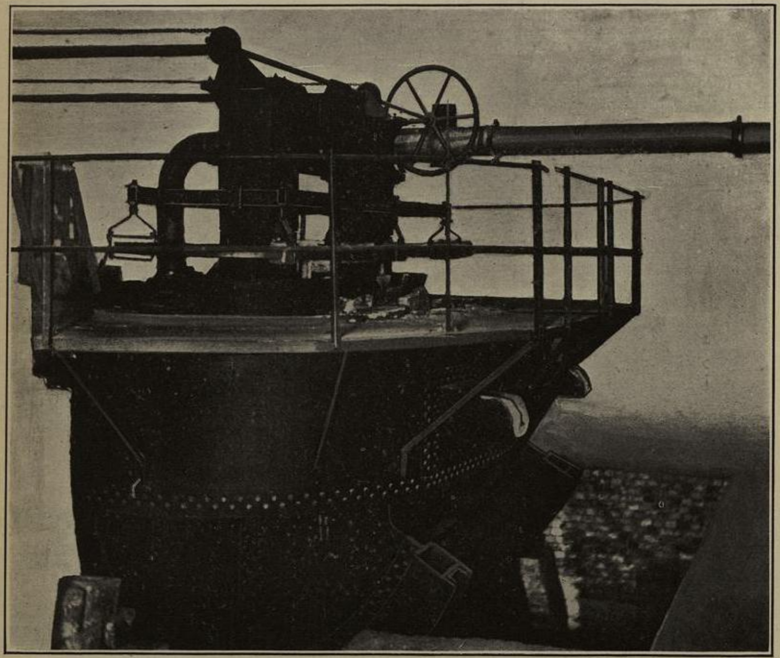

FIG. 76.—External details of Hiorth 5-ton Furnace at Jossingfjord.

but the actual dimensions and shape of the bath must be such as to give the best possible power-factor.

In order to increase the capacity of the furnace, it was necessary to increase the sectional area of the bath more than the length, as otherwise the diameter of the bath, and consequently the dimensions of the furnace, would become too large. The resistance of the bath would thus be considerably decreased, and at the same time the inductance would be increased, owing to the larger diameter, which increased the area of the space between the primary and the secondary windings.

The power-factor would thus in any case be reduced with the increased capacity, and the designer calculated that a 30-ton furnace built on the same lines as the smaller one, for single-phase current, with a two-leg magnet and a current supply with twenty-five alternations, would show a power-factor equal only to 0·25, and that the power-factor even with fifteen alternations per second would still be only 0·38.

It was therefore decided that the 30-ton furnace should be

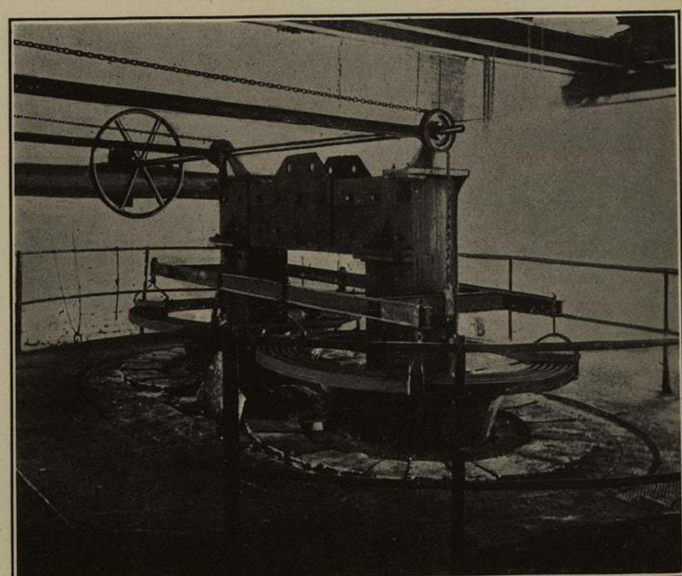

Fig. 77.—Top view of Hiorth 5-ton Furnace at Jossingfjord.

built on the three-phase principle, instead of the single-phase. In this case the weight of the charge per ring was only 10 tons, instead of 15 tons as with a single-phase furnace, and the reduction of the power-factor was not nearly so great. Hiorth states that:—

"In order to facilitate the tilting of the furnace, the three rings were disposed in one row. This arrangement is not strictly symmetrical, and it is to be expected that the load on the middle phase will be somewhat different from the load on the two outer ones, on account of the difference both in the inductance and in the resistance. With a special electric power supply this is, however, not a very serious draw-

back, particularly as the difference between the phases in all probability, will not be very great."

The dimensions finally chosen for the new furnace are shown diagrammatically in Fig. 78, and a comparison of the more important data for the 5-ton and 30-ton furnaces is given in the following table:—

Table XXXV.

Comparative Data of 5-ton and 30-ton Hiorth Furnaces.

—	Old Furnace.	New Furnace.
Total capacity	5 tons	30 tons
Capacity per leg	2·5 tons	10 tons
Diameter of bath	2·1 m.	3 m.
Width of bath	20 cm.	30 cm.
Depth of bath	27 cm.	45 cm.
Total surface of masonry	55 sq. m.	110 sq. m.
Total length of platform	8¼ m.	13 m.
Total width of platform	5¼ m.	6·5 m.
Sectional area of core per leg	1,800 sq. cm.	1,200 sq. cm.
Weight of core	15 tons	23 tons
Number of primary turns per leg	15	13
Sectional area of primary windings	1,000 sq. cm.	4,000 sq. cm.
Weight of copper per leg	0·875 tons	ca. 4·5 tons
Total weight of copper	1·75 tons	ca. 13·5 tons
Energy used	250 kw.	700 kw.
Copper losses	12·3 kw.	40 kw.
Iron losses	18 kw.	18 kw.
Power factor	0·65	0·50
Voltage	250	230
Periodicity (half alternations per second	12½	8
Amperes per phase	1,400	3,540
Kind of current	1 phase	3 phase

The Stobie Heating and Refining Furnaces are the invention of Mr. Victor Stobie of Sheffield, and are of the combined arc and resistance type. They differ, however, in some important details, from the Girod type of furnace construction. As a result of long experience in the Sheffield tool-steel manufacture, the designer of these furnaces has come to the conclusion that for small furnaces arc-heating alone is not economical, and that some portion of the current ought to be employed concurrently for resistance heating, by aid of a conducting lining to the furnace.

In the first experiments, a two-phase furnace was used which was provided with a single electrode embedded in the hearth, connected to the neutral point of the supply system, and with two electrodes above the bath connected to the two phases of the supply. It was found, however, that by this arrangement, the passage of the whole of the return current (which is equal to 70 per cent. of the sum of the currents in the two phases) had too great

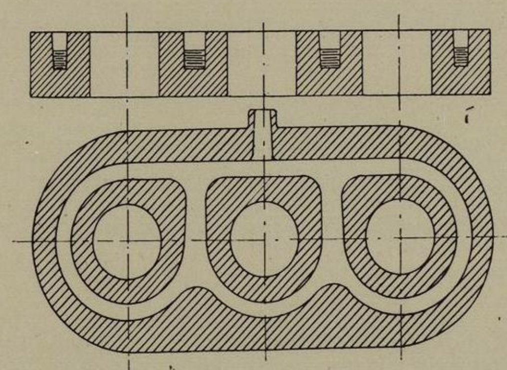

FIG. 78.—Diagram of Hiorth's 30-ton Furnace.

a heating effect on the lining of the furnace, and it was impossible to obtain satisfactory results.

To overcome the difficulty caused by this overheating of the lining, the two phases were kept separate, and *two* electrodes were introduced into the hearth, each having an area three times as large as usual. The top electrodes immediately above these were connected to the same phase of the supply system, the result being that each return current was obliged to travel by a separate conductor and to cross in direction, through the molten metal in the bath. The advantages of this arrangement according to Stobie are:—

(1) The current density through the lining of the furnace is only a portion of what it was in the older type of two-phase

furnace, and the bottom heating is sufficient for the purpose, without disintegrating the furnace lining.

(2) The current travels through a longer path in the bath thus helping the resistance heating.

(3) The crossing of the currents in the bath produces a mixing

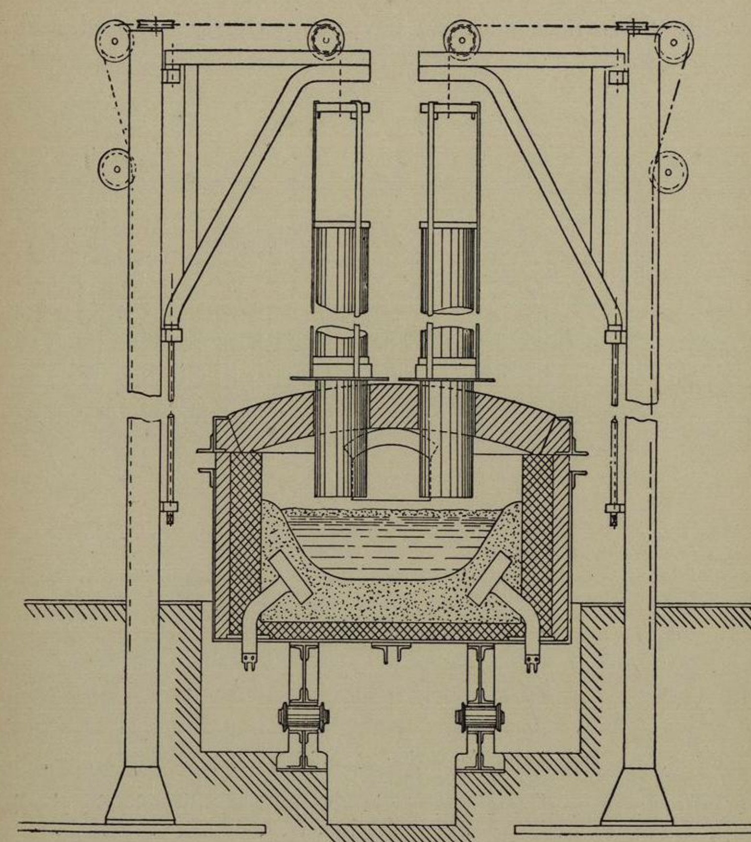

FIG. 79.—Diagrammatic section of Stobie's Two-phase Furnace.

motion which is unobtainable in other designs, except by hard rabbling.

Fig. 79 shows a plan and sectional elevation of the Stobie two-phase furnace.

The three-phase furnace relies only on arc heating, as Stobie admits that in large furnaces there is no necessity to reinforce this by resistance heating. His three-phase current furnace is provided with four carbon electrodes, three of these being connected to the three terminals of a star-connected three-phase current supply, and the fourth is connected to the neutral point of the supply. According to the designer of the furnace, the latter is only required because a three-phase current when used for electric furnace work can never be perfectly balanced, and a

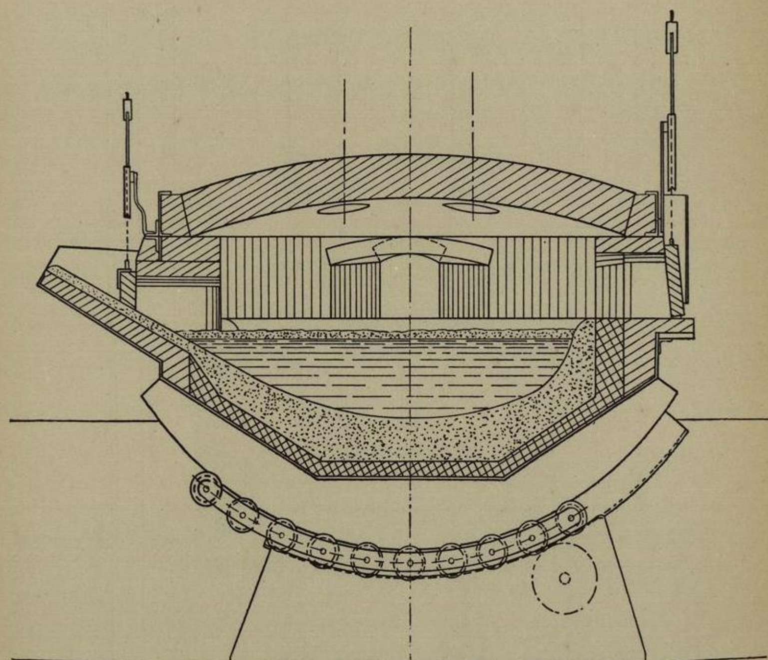

FIG. 80.—Diagrammatic section of Stobie's Three-phase Furnace.

certain portion of the current is always travelling back, via the neutral point within the furnace, at which heat is being developed. Fig. 80 shows a plan and sectional elevation of the three-phase furnace.

No figures are available showing the power consumption or running costs of these furnaces, but the furnaces have been tried experimentally in Sheffield, and the Stobie Steel Co. has been formed to finance and equip a works in Newcastle with furnaces of this type. Two 15-ton furnaces on the three-phase system

and two or more 5-ton two-phase furnaces are now in course of erection, and therefore within a few months one may be able to obtain reliable working figures for the operation of the Stobie type of furnace construction.

A supplementary patent of Stobie's relates to the use of oil or coal-gas for "burning-in" the hearth bottom of the furnace, and also for the preliminary heating and melting of the charge. The advantages claimed for this are:—

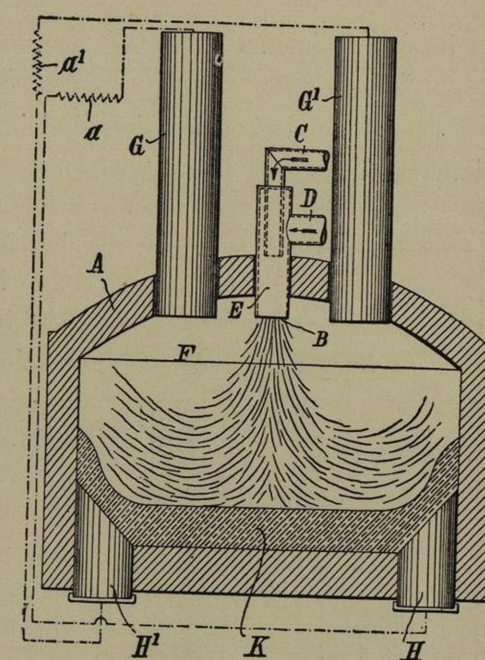

FIG. 81.—Diagrammatic section of Stobie's Combined Electric and Gas or Oil-heated Furnace.

(1) The bottom lining of electric furnaces by this method can be made as solid as in the best open-hearth practice; whereas formerly the lining had to be rammed and was never thoroughly burnt beyond an inch or two from the surface.

(2) The preheating of the charge gives the advantage of a reduced power consumption, which has previously only been obtained by the use of molten steel melted in another furnace, such as an open-hearth or Bessemer installation.

Fig. 81 is a diagrammatic section of this oil- or gas-heated furnace.