CHAPTER X

THE ANDERSON, CHAPLET, COLBY, GREENE, HÄRDEN, HERING, NAU, NATHUSIUS, QUESNAU, REID AND SODERBERG FURNACES

The group of furnaces described in this Chapter are less developed industrially than the furnaces dealt with in the previous Chapters of this book; but for the reasons given in the introductory paragraph of Chapter IX. they are not on that account the less interesting or deserving of attention.

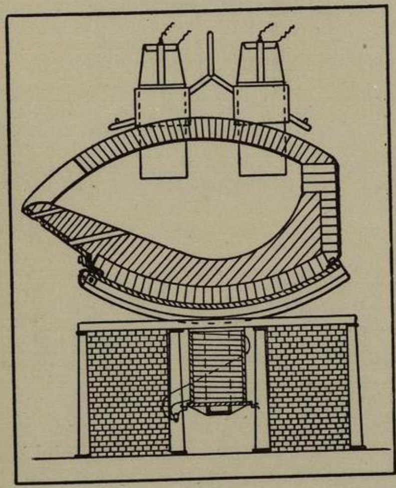
Fig. 82.—Anderson Furnace (sectional elevation).

The Anderson Furnace is the design of T. Scott Anderson, of Sheffield. The furnace is shown in sectional elevation in Fig. 82. In its general appearance and design it resembles closely the refining furnace of Heroult. The furnace is provided with two electrodes capable of vertical movement; these are water jacketed and may be worked either in parallel or series, according to the nature of the work required from the furnace. The special feature of the Anderson furnace is, however, the provision of electro-magnets beneath the base of the furnace, by means of which the arc formed between the two electrodes can be drawn downwards and controlled. It is further claimed for the Anderson furnace that "the concentration of the incandescent gases around the electrode is utilised to the best advantage,"

and that the arrangement of the furnace "tends to efficiency in a very marked degree."

No details of the practical installations of this furnace or of its working costs are available, but according to the patentee, four furnaces, each of 5 tons capacity, have been installed and are now working upon the production of steel from pig-iron.

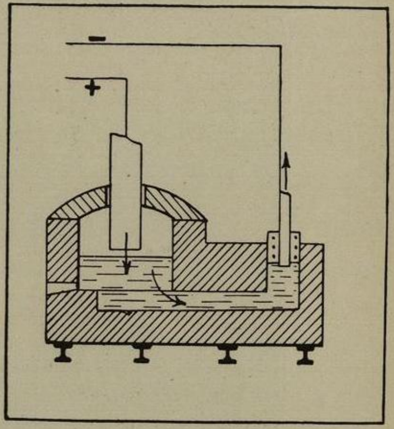

Fig. 83.—Chaplet Furnace in diagrammatic section.

The Chaplet Furnace is shown in sectional elevation in Fig. 83. The two electrodes are seen to be suspended in two different chambers or divisions of the interior of the furnace, which are connected by a lateral canal. The electric current flows from the positive to the negative electrode by means of the metal contained in this canal, as shown by the arrow in Fig. 83.

The metal in the larger chamber of the furnace is therefore melted and purified by combined arc and resistance heating, and the furnace resembles both in principle and in its method of operation the furnaces of Girod and Keller, with conducting hearths. A Chaplet furnace is reported by Keller to be in use at the works of the Aciéries d'Allevard Isére, France, but no details concerning the size or efficiency of this furnace have been published.

The Colby Furnace is of the induction type, and was patented by E. A. Colby, in the U.S.A., in 1905. Fig. 84 is a photograph of a small Colby furnace of 130 kw. capacity, installed for melting tool steel at the works of Messrs. Henry Disston & Sons, at Tacomy, near Philadelphia, in 1907. The general principles of the furnace design resemble those of the more widely-known Kjellin and Frick furnaces, but the following details of the Tacomy furnace may prove of interest. The primary coil of the furnace consisted of twenty-eight turns of copper tube $\frac{3}{8}$ in. inside and $\frac{5}{8}$ in. outside diameter, through which water flowed for cooling purposes. The annular crucible, the molten metal in which formed the secondary circuit of the furnace, measured 24 ins. outside diameter and 15 ins. inside diameter, and was 8 ins. in depth. The trough held 900 lbs. of steel when fully charged, and ingots of 90 lbs. were poured every hour. The fusion of the added metal required half and hour, and the refining and killing process another half an hour. The ingots poured were found to be very dense and homogeneous. The E.M.F. of the single-phase primary current used was 240 volts, and the maximum current employed was 540 amperes with a frequency of 60. The power used per 100 lbs. of metal poured was from 27·5 to 37·5 kw. hours, according to the purity of the charged raw materials and quality of steel desired. This is equivalent to from 605 kw. hours to 825 kw. hours per ton of 2,200 lbs. The Colby Furnace Patents have been purchased by the American Electric Furnace Company, who also have secured the control of the Kjellin and Röchling-Rodenhauser Patents in the U.S.A., and it is stated by this Company that no Colby furnaces are now operating in that country. One may therefore assume that, both in efficiency and operating costs, the Kjellin and Röchling-Rodenhauser types of induction furnace are superior to the Colby furnace. Further details of the Colby furnace erected at Disston will be found in the issue of the journal named below.[1]

FIG. 84.—A Colby Furnace in operation at Chicago.

The Greene Process has been worked out by Albert E. Greene and makes use of any of the ordinary induction types of furnace for producing steel directly from pig-iron. The refining operation is effected, however, by the application of a new principle, namely, the use of producer gas, which is blown into the molten metal that is present in the annular ring or crucible of the induction furnace. The process is called the *Electric Converter Process*, and it is claimed for it that the losses incurred when refining pig-iron by the ordinary Bessemer or open-hearth processes are largely minimised. The following description of the process is taken from a paper contributed by Greene to the New York (1911) meeting of the American Electro-chemical Society:[2]

> The process consists in providing a bath of molten low-phosphorus pig-iron containing the usual proportion of manganese, silicon, and carbon. The charge must contain sufficient manganese and silicon, however, to more than meet the specification for the particular steel required. The temperature of the bath is raised to something over 1,425° C., and is maintained at this temperature by electric heating, while a gaseous mixture containing CO and CO_2 is blown into

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[1] *Electrochemical and Metallurgical Engineering* for June, 1907.
[2] *Transactions*, Vol. XIX., p. 233.

the metal, in much the same way that air is blown into a Bessemer or Tropenas converter. The gaseous mixture may contain 12 to 18 per cent. of CO, and 5 per cent. or more of CO_2.

The rate of elimination of the carbon is a little slower than with the ordinary Bessemer process, for the same rate of blowing. A well-operated side-blown converter requires from twenty-five to thirty-five minutes to make a blow, using about 1,500 cubic feet of air per minute per ton of metal. In the small induction furnace, using about 50 cubic feet of gas per minute per 200 pounds (or about one-third the rate of blowing in the side-blown Bessemer converter just referred to), the carbon can be eliminated in something more than one and a half hours, the exact time depending on how much carbon there was in the raw pig-iron used. Thus, with only one-third as much gas blown per minute per unit weight of metal, the time is a little more than three times as long, as for a similarly blown vessel using air. By increasing the rate of blowing the time can be very greatly cut down. The rate of elimination depends largely on the nature of the contact of the gas with the metal; and when the gas is blown *through* the metal, as in the case of this process, it is most rapid.

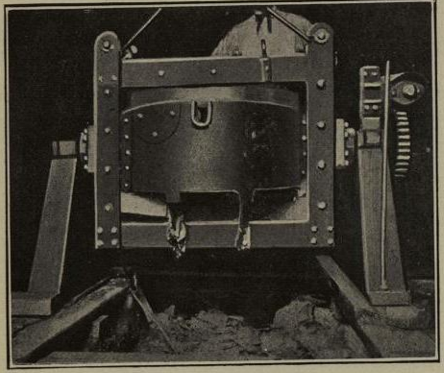

FIG. 85.—A small Induction Furnace for Greene's Process.

It was found that the gas could be blown into the metal without any formation of slag on the surface and without any boiling. The most convincing evidence that oxidation does not take place in the process may be found in connection with the loss of manganese. In converting a 13·4 per cent. speigel-iron into manganese steel, the patentee states that he has dispensed with any additions of any kind, and that he has produced a steel containing over 12·5 per cent. manganese without the use of a slag to prevent vaporisation. The carbon was reduced from over 4 per cent. to 1·20 per cent. In later tests, using a lime slag, the vaporisation loss has been further diminished.

The process described above for oxidising carbon without oxidising iron is similarly applicable to the removal of phosphorus.

The patentee has found that he can eliminate the phosphorus from iron and hold it out by means of lime, and that he can effect this purification with practically no oxidation of iron and manganese. This elimination of the phosphorus has been carried out at temperatures below 1,350° C. without oxidising carbon; and it has also been effected at high temperatures (above 1,500° C. and up to 1,900° C.) after the carbon has been oxidised. In addition to these facts the patentee has found that the sulphur can be taken up and held in the same slag that holds the phosphorus; this action being attributed to the absence of oxide of iron in the slag.

A low-grade pig-iron has been converted into a high quality steel in one continuous operation in this way, taking out first the carbon without oxidation of the iron and manganese, and then, by continuing the blow of the gaseous mixture, with a lime slag on top of the metal, the phosphorus has been oxidised and eliminated. The phosphorus was found combined with the lime as calcium-phosphate, and practically all of the sulphur was found in the slag as calcium-sulphide.

As regards the results obtained, Greene, in the paper referred to, gives the following analysis of the raw material and of the finished steel:—

TABLE XXXVI.

I.	Raw material.	Phosphorus 0·76 per cent.	Sulphur 0·113 per cent.
	Finished steel.	Phosphorus 0·026 per cent.	Sulphur 0·040 per cent.
II.	Raw material.	Phosphorus 0·094 per cent.	Sulphur 0·040 per cent.
	Finished steel.	Phosphorus 0·008 per cent.	Sulphur 0·017 per cent.

Although Greene has stated that the process has been operated in the U.S.A., with the 2-ton induction furnace shown in Fig. 85, and that in larger furnaces of this type a power consumption of only 30 kw. hours per ton of steel would be required to work the same, the electric converter process does not appear to have developed industrially in the U.S.A.; and the writer cannot refer to any existing plant where it is operated at the present moment. As a possible scientific development of the application of the electric induction furnace to steel manufacture, the Greene process is, however, of great interest and is worthy of close study. Greene has pointed out that the provision of a suitable gas for working the process in large iron works would not be a difficult matter, as the substitution of a gas containing carbon monoxide and carbon-dioxide, for the air used in the ordinary Bessemer process, does not involve any change in present methods. A suitable gas for carrying out this process is available from cupolas or blast-furnaces, or may be made in a very simple gas-producer. Blast-furnace gas should be diluted by admixture with stack gas, since the percentage of carbon monoxide in blast-furnace gas is usually much higher than is required. The process itself (in so far as the elimination of carbon is concerned) is a gas-producer process, the evolved gas being richer in CO and lower in CO_2 than that blown into the metal. This fact opens the possibility of using the gas over and over again, by burning a part of it in order to maintain the desired composition.

The Härden Furnace is of the combined arc and resistance type, and is designed to remove the defect attaching to the original type of Kjellin furnace, namely, that the temperature is too low and the slag surface too small, to permit the proper elimination of the phosphorus and sulphur from the charged metal. The new furnace has been termed by its designer the "Paragon" furnace, and is shown in section and plan in Figs. 86 and 87. The following description of it is given by J. Härden in a paper read before the Faraday Society in October, 1911.[1]

In this furnace the bath of metal is heated, not only from the surface of the slag by means of suitably arranged arcs, but also at the same time from the sides and beneath the bath, by means of side plates of second-class conductors, similar to those which have been used for some four or five years in the Röchling-Rodenhauser furnace. In this manner the metallurgist is able to apply the maximum heat exactly where he wishes to have it, since both circuits can be regulated at will. Thus, during desulphurisation and dephosphorisation, the slag is heated to a temperature higher than that of the steel; while during the period of degasifying, the greater portion of the power is conveyed to the bath through the bottom and sides.

This design brings in other important improvements. For example, it is quite easy to start the cold furnace by means of the arcs, thus dispensing with the necessity of filling in a liquid charge. Further, the electrode question in simple arc furnaces may in many cases become a serious one, as large electrodes for furnaces of great capacities are exceedingly difficult to obtain, and are always very expensive. Owing to the nature of the "Paragon" furnace, where only a smaller portion of the power enters the furnace through the electrodes, this drawback is considerably reduced. If, for instance, the upper limit of a simple arc-furnace is 20 tons, on account of the difficulty in obtaining sufficiently large electrodes, it will be found that this capacity can be doubled with the "Paragon" type.

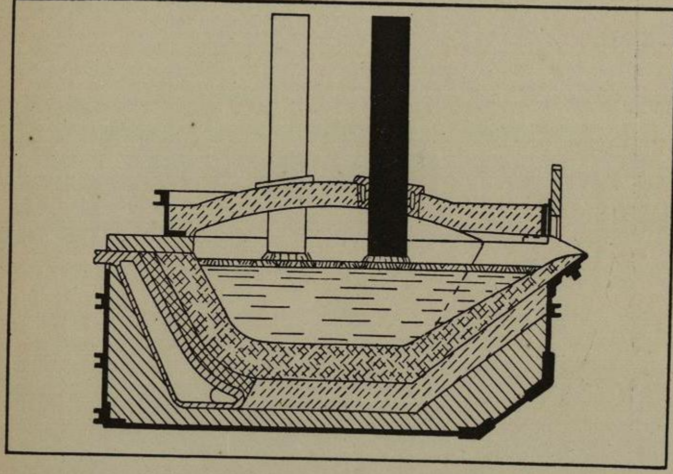

FIG. 86.—Härden's Paragon Furnace in sectional elevation.

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[1] *Transactions of the Faraday Society*, Vol. VII., p. 183.

The electrodes for a 30-ton three-phase "Paragon" furnace would have a cross-section of 16 ins., or 256 sq. ins. only, and in a 50-ton furnace the electrodes would measure 24 ins. by 24 ins., or 576 sq. ins. This would still only give a maximum current density of 24·5 to 26 amperes per square inch, which, as experience has proved, is well within reasonable limits, both from an electrical and manufacturing point of view. These sizes of carbons correspond to simple arc-furnaces having capacities of only 12 to 14 tons and 18 to 22 tons respectively.

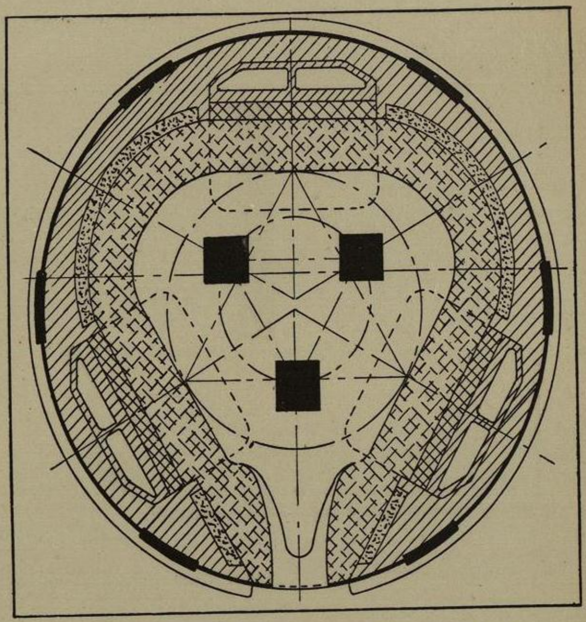

Fig. 87.—Härden's Paragon Furnace (plan).

A further advantage claimed for this design is the greater durability of the roof. It is well known that the roof is that portion of an ordinary furnace which is most rapidly destroyed by the action of the hot gases. In the "Paragon" furnace the destructive action is minimised, as only a small portion of the power is acting on the slag.

The "Paragon" furnace has been patented by J. Härden and the Gröndal Kjellin Company, Ltd., and an experimental furnace of the new type has been erected in Germany, at the Röchling Iron and Steel Works. No constructional details of this furnace have yet been published and no figures are available showing the working results; but it is expected that the "Paragon" furnace will prove more economical and more generally useful than any of the existing types, and that the special features of the design will permit larger furnaces, up to 50 tons capacity, to be operated with success.

The Hering "Pinch Effect" Furnace.

The "pinch effect," upon which C. Hering's patent is based, was discovered by the patentee when working with an electric furnace, in which this effect was disadvantageous and not desired.

The phenomenon is an electro-magnetic one, and is due to the physical contraction of the cross-section of any liquid conductor through which a current is passing, this contraction or "pinch effect" being sufficient under certain conditions to rupture the conductor and break the current. Mr. Carl Hering, impressed with the practical possibilities of this phenomenon, has designed both an electric furnace and a valveless electro-magnetic pump upon the "pinch effect." Fig. 88 shows a diagrammatic cross-section of the Hering furnace, and Fig. 89 shows a tilting furnace based on this principle. The following descriptions are taken from a paper read by E. K. Scott before the Faraday Society in October, 1911.[1]

Fig. 88 represents the cross-section of two liquid conductors (AA) surrounded by non-conducting material (BB). The current enters and leaves by water-cooled electrodes (CC); (D) being the transformer. Assuming for the moment that each liquid conductor is made up of a number of elemental conductors, it is clear that these will be attracted together in accordance with the law that "like currents attract." Circulation of the liquid is therefore set up as shown by

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[1] *Transactions*, Vol. VII., p. 202.

the arrows, by the liquid moving from the circumference to the centre. As one end of the hole is stopped up by the electrode, any pressure set up can only be relieved by the liquid moving upwards as in a fountain, and that is what actually happens.

The furnace may be a tilting one (as shown in Fig. 89), or there may be a tapping-hole just above the top of the resistor tubes. In any case the resistor tubes must not be emptied, and sufficient metal must be left in the bottom of the furnace to connect them across. Fig. 89 is drawn to scale, and it shows very clearly how small the two electrodes are, compared with the bulk of the furnaces. It also shows how the electrodes are inclined, this being done in order to reduce the back pressure on the surface of the electrode.

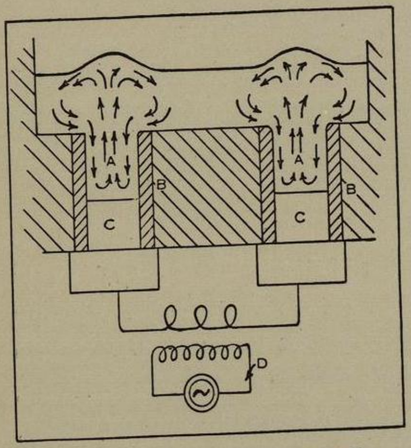

FIG. 88.—Hering Furnace in diagrammatic sectional elevation.

Looking at the top of the charge, its appearance is somewhat similar to that of water in rapid ebullition at two spots where heat is localised, but of course there is no noise and the bubbles are few.

In some cases the agitation at the top of the metal charge is so great that the surface is inclined at 45 degrees. The suction down into the bottom of the resistor tubes is also considerable.

It should be noted that the heating is entirely effected at the bottom of the charge, and the circulation from there is in a natural direction upwards. Heat is thus transferred to the whole of the charge by a vigorous stirring and not by mere suction. The electrodes are usually made of the metal that is being melted. The sections of the electrodes and the current that passes are so proportioned, that the ends of the electrodes are raised to a temperature as nearly as possible equal to the temperature of the molten charge.

Of the various materials used for electrodes, Hering's experience has proved that metal electrodes are distinctly cheaper and more economical in energy. Copper is the best and iron nearly as good; gas-carbon is the worst, graphite being only slightly better than gas-carbon.

As the hottest metal flows up the centre of the "resistor tubes" the lining does not have to withstand the greatest heat. Again, there is very little eroding action due to friction on the wall; for the pinch effect tends to pull the metal away from the lining, and tends to form a vacuum there. This is just the opposite of the effect in other furnaces, where the circulation of the molten metal has given trouble by its digging into the lining. Alundum has been used for the lining, but as it had a tendency to crack magnesite powder is now employed. It is packed in whilst in plastic condition, and after being heated forms an extremely hard and smooth glossy surface.

The rapid circulation obtained in the furnace allows chemical changes to take place rapidly; this means great economy in time. The maximum temperature at any point does not need to be much above the normal. In other furnaces where circulation is sluggish, the temperatures in the charge vary a good deal. To allow for effective action of the slag it is important that the hottest metal should impinge directly upon it. This is exactly what takes place in the Hering furnace; for when it leaves the centre of the tube, the heated metal is forced up against the blanket of slag.

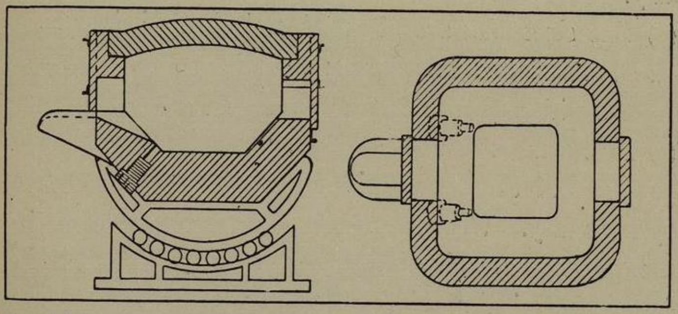

FIG. 89.—Hering Furnace (sectional elevation and plan).

The furnace can be worked with either direct or alternating current; three-phase current may also be employed. With alternating current, the power factor can be raised to practically unity; the frequency need not be low, and may be chosen to suit the ordinary generating machinery. If the electrodes are made of the same metal or material as the charge, the furnace tends to be self-regulating as to temperature. The advantages claimed for the Hering pinch effect furnace are the following:—

(a) It is simple and cheap, consisting merely of two holes (or three with three-phase current) in an ordinary furnace hearth, a simple electrode being fixed at the bottom of each hole.

(b) The heat is generated by resistance in the charge itself, and the heating takes place at the bottom of the bath, just where it can be most effective.

(c) The circulation of the hot charge is entirely automatic, and in a most effective direction, namely, from the bottom of the bath up to the underside of the blanket of slag.

(d) The speed at which the mixing takes place is such that the charge is treated more rapidly than by other methods. Therefore, for a given size of furnace hearth, and given amount of electric energy, a larger amount of material can be dealt with per day.

(e) The electrodes are of metal and cheap, being usually of the same material as the charge; they do not consume away, as is the case with carbon and graphite electrodes.

(f) In furnaces using carbon or graphite electrodes, the temperature of the furnace is quite frequently higher than is really necessary. With the Hering furnace, on the other hand, the temperature and circulation of metal may be exactly adjusted to the metallurgical requirements.

(g) Heat from gaseous fuel can be applied to the top of the bath, without affecting any of the electrical gear. The current can be switched on all the time, or only for the refining part of the process.

(h) All the electrical gear is out of the way on the underside, and if the furnace is required to tilt, a transformer can be attached to it, so that the flexible leads for the high-tension current can be of small section.

In his Patent Specification, Hering claims that with slight modification, the pinch effect furnace might be applied to making steel direct from the ore. For this purpose a double furnace would be employed, and the carbon monoxide gas given off by the one furnace would be employed to preheat the ore. In one section of the furnace carbon would be dissolved in the iron—in the other, iron oxide—and by the reaction of the two solutions the carbon would be eliminated.

Since the above description of the furnace was published, it has been stated by the inventor that if (when melting steel) a carbon rod be held in front of one of the squirting tubes it dissolves like a stick of candy in hot water; on the other hand, iron ore placed on this carbonised iron gave off large volumes of gas, showing that the ore was being reduced by the carbon in the iron, just as in the open-hearth process. With this combination, Hering therefore proposes to use the furnace for the reduction of iron ores.

The material to be employed for the construction of the resistor-tubes is of considerable importance in its bearing upon the working costs of the furnace. Magnesite and alundum have so far been employed, and good results have been obtained with both, but the use of other materials is now being considered, and electrically calcined magnesite is to be used for the next furnace constructed. The lining of the resistor-tubes is tamped in around a mould when in a plastic condition; it thus forms part of the general refractory lining of the furnace.

No data are yet available showing the actual working results obtained with this new type of refining furnace, and in view of the criticisms that have been expressed with regard to the wear and tear on the resistor-tubes, some little time must elapse before any trustworthy opinion as to the commercial and industrial possibilities of the furnace can be formed.

As regards the capacity of the furnaces of this type with which the trials have been conducted, only small experimental furnaces have yet been used. The Ajax Metal Company of Philadelphia, however, have purchased the patent rights, and intend to develop the industrial applications of the Hering furnace, both for steel-refining and for melting brass and other non-ferrous metals. This company hopes to have four or five of these furnaces at work, on a commercial basis, in 1913. They have demonstrated in their own preliminary trials that sulphur can be more easily eliminated in this type of furnace than in the arc furnace. A recent test made in the presence of American steel experts is stated to have shown a reduction in sulphur contents of the steel from ·066 per cent. to ·012 per cent. in 50 minutes, using a slag composed of lime and fluorspar. This rapid elimination of the sulphur is stated to be due to the active circulation of the metal under the slag blanket.

The Nau Furnace and Process have been designed for the preliminary refining of phosphoretic pig-iron, too high in its silicon contents for treatment directly in the open-hearth furnace. The process is protected by U.S.A. Patent No. 786048 of 1905, and depends upon running liquid pig-iron through a column of heated iron ore, and in allowing a bath of molten metal to accumulate at the bottom of the ore column. The intimate contact between the molten pig-iron and the ore maintained at a high temperature leads to a chemical reaction between the silicon and the iron-oxide of the ore; and the temperature attained is found to remain sufficiently high to produce both a fluid slag and a molten pig that can be run easily from the melting furnace. The silicon and portion of the phosphorus and manganese are eliminated by this process, and are found in the slag. The patentee of the process has also designed a special form of electric furnace which allows easy immersion of the ore in the metal that is to be refined. This furnace, according to the description given by the designer in the journal named below,[1] is capped by a water-cooled roof and is surmounted by an ore-shaft, with a lateral inlet for the liquid pig-iron that is to be refined. Vertical electrodes penetrating the roof are placed around the shaft. The bottom is made of carbon paste, and the electric current passing between the electrodes and the carbon bottom traverses the liquid metal and slag.

The furnace is so arranged, and the operations are so conducted, that the ore required as refining medium is kept immersed to any desired depth in the molten pig-iron. As soon as the ore

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[1] *Metall. and Chem. Engineering*, March, 1911.

in the bath is consumed and has to be replaced by new ore, the latter can be immersed without any trouble in the liquid bath.

The patentee has calculated that the removal of the silicon, phosphorus and manganese will demand 44,724 calories per ton of metal treated, and that in order to supply this loss of heat, and to maintain the metal and slag at a temperature of 1,200° to 1,400° C., 2,100 e.h.p. hours will be required. Under more favourable conditions, the chemical reactions, however, might supply sufficient heat to keep the process working without any external heat supply; and at times, no doubt, the process could be worked as a self-supporting one.

No data relating to this process, beyond those given by Nau in the article referred to above, are available, and it would appear, therefore, that both the process and furnace are still in the experimental stage of their development.

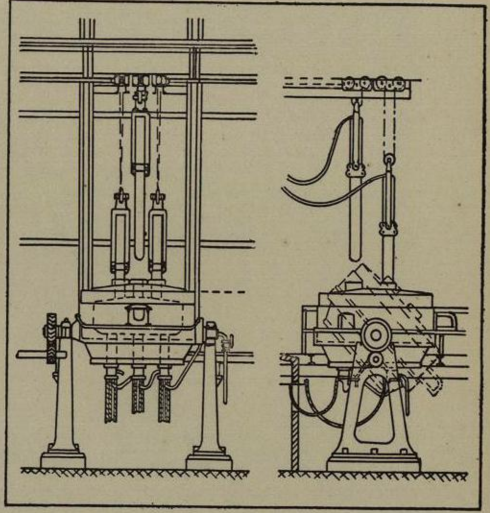

Fig. 90.—Nathusius Furnace (sectional elevations).

The Nathusius Furnace is a design which seeks to combine the advantages, and to escape the disadvantages, of the Heroult and Girod types of furnace.

The furnace is of the combined arc and resistance type, and is shown in section in Fig. 90, and in operation in Fig. 91. The furnace is seen to be provided with three carbon vertical electrodes, arranged symmetrically *above*, and with three extra steel electrodes, arranged *below* (*or in the bottom of*) the crucible. These six electrodes are connected to the inner and outer terminals of a three-phase generator; the molten metal in the crucible itself forming the neutral point of the system. As both the upper and lower electrodes are of mutually alternating polarity, the metal in the bath is subject to a great variety of heating currents, and the thermal efficiency of the furnace is stated to be high. Further advantages claimed for this furnace are:—(1) Excellent mixing of the metal and the production of a uniform melt, results due to the rotary fields set up by the vertical currents that traverse the molten bath. (2) Rapid heating, due to the presence of three arcs, and of three fields of heat activity. (3) The convenience and economy of a three-phase current supply.

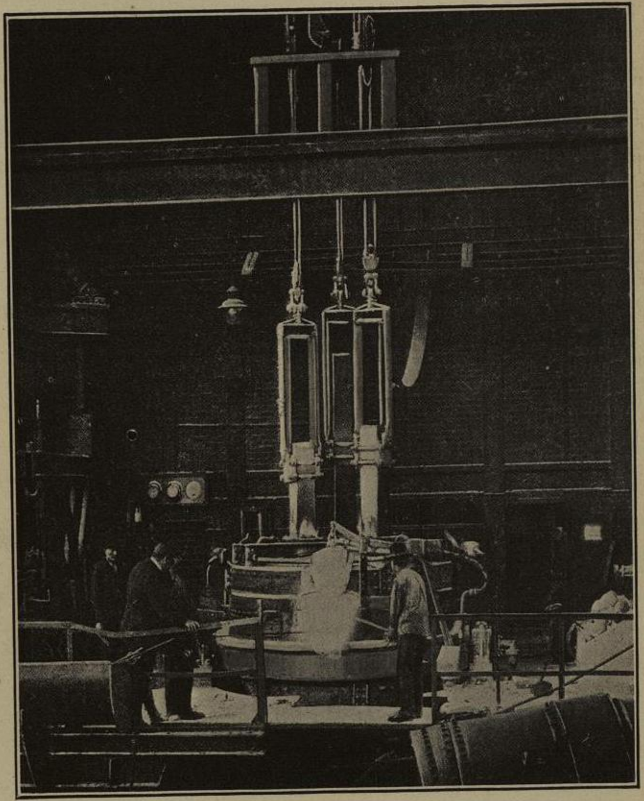

FIG. 91.—General external view of Nathusius Furnace in operation.

(4) Easy regulation by means of a booster transformer, or by a special generator with an adjustable neutral conductor. (5) The heat effect can be concentrated where it is most desired; namely, in the slag during the earlier stage of the refining process, and in the molten bath during the later stages, when the slag has finished its work and the "rest" or quiescent period of the refining process has been entered upon.

The furnace is of the tilting type. Fig. 91 shows the external appearance of the furnace, the electrodes being suspended from ordinary cables by means of pulleys, and operated by means of high-speed motors. Some further details of the Nathusius furnace will be found in the issue of the journal[1] named below. No figures for the power consumption and running costs of this furnace have yet been published.

The Queneau Furnace is similar to that of Hering, both in principle and design, the "pinch effect" of powerful electric currents being made use of to produce a series of regular pulsations in a bath of molten metal, heated by ordinary resistance. One or more steel electrodes are fixed in the bottom of the furnace. The upper ends of these are molten, and are in direct contact with the molten furnace charge. These columns of molten steel which form the electrodes are enclosed in cavities lined with magnesite bricks set in tar, and the continual make and break of the electric current caused by the "pinch effect" creates a series of regular pulsations throughout the molten charge. Further particulars of this furnace will be found in the papers referred to below.[2] No data based on the actual operation of this furnace have been published.

The Reid Refining Furnace, as shown in Fig. 92, is a simple arc furnace, with carbon electrodes. It is protected by U.S.A. Patent No. 947849, granted to J. H. Reid in February, 1910, and it forms only one portion of the "Reid system of electric smelting and refining." No efficiency or costs data relating to this furnace

[1] *Electrical Review*, London, April 5, 1912.
[2] *Metallurgical and Chemical Engineering*, March and June, 1910.

are available for publication, and it does not appear to have been applied to steel refining on a commercial scale of operation.

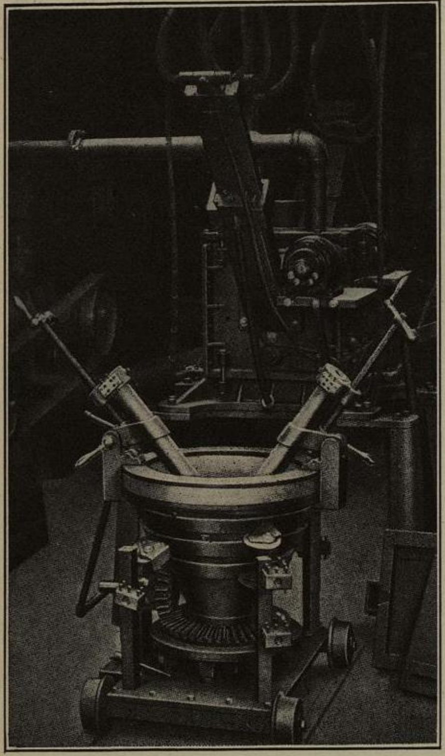

FIG. 92.—Experimental type of Reid Furnace.

The Soderberg Furnace is of the combined arc and resistance type, and is similar in principle and design to that of Nathusius (see p. 169). Richards, in the *Transactions of the American Electro-chemical Society*,[1] has given details of a furnace of this type which is being erected at the works of the Jossingfjord Manufacturing Company in Norway. The furnace is circular, and will hold 2·5 tons of metal. The three electrodes passing through the roof are connected to a three-phase generator by a "star" connection. Six small electrodes, each $\frac{3}{4}$ in. in diameter, are embedded in the hearth, and serve as connection to the bath. This latter acts as the neutral point of the system. Little or no current passes through these embedded electrodes; consequently the arcs from the upper electrodes pass in one direction only, namely from the electrodes to the bath, and are not in series with one another.

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[1] Vol. XX., p. 413.

CHAPTER XI

COMPARATIVE POWER CONSUMPTION AND RUNNING COSTS

THE preceding Chapters have contained a very large number of figures relating to the power consumption and running costs of the various furnaces and processes described. It is the author's purpose in this, the final Chapter of the book, to reduce this mass of data to a form in which the results may be more easily compared. It is necessary to note, however, that when all the values of power, weight, and value have been reduced to one common form of expression, there will still remain the differences due, (1) to the greater or less impurity of the pig-iron and steel used for the refining process; and (2) to the extent to which the electric refining operation is varied in the production of a pure product; and (3) to the varying rates of wages and costs of materials in the different countries. For these reasons, comparative power and costs data require most careful investigation and study before they can be used as guides to the relative efficiency of competing electric steel-refining furnaces and processes. In those cases where no chemical analyses of the raw materials and finished steel are given, the data are, for comparative purposes, practically worthless. Even when full details of the chemical and physical tests have been presented, only a practical steel-maker and metallurgist can judge of the comparative efficiencies of the refining processes.

The author proposes, therefore, in this Chapter merely to present all the available data in the form in which it can be most easily made use of, in order to arrive at an independent and reliable judgment upon the various furnaces and processes of electric steel refining; and each steel-maker will be expected