

to in the first claim, of hydraulic cylinders for effecting the tipping thereof, substantially as described.

1901, No. 24234. Granted to *Charles Albert Keller*, of Paris, for "*Improvements in the Obtainment of Metals and Alloys and in Furnaces to be Employed Therein.*"

Having now particularly described and ascertained the nature of this invention and in what manner the same is performed I declare that what I claim is:—

1. An electric furnace arranged or constructed substantially as hereinbefore described and illustrated by the accompanying drawings.

2. In electric furnaces two groups of electrodes, the electrodes of each group being in parallel, while the two groups of electrodes work in series, the number of electric foci thus formed being equal to the number of electrodes and the arrangement of the foci being such that the substances being treated act as intermediate conductors between the two groups of conductors, the said substances being charged between the electrodes all substantially as hereinbefore described.

3. In electric furnaces the arrangement of the electrodes at the angles, or sides, of a figure, circumscribing the section of the charging column, so as to leave between the foci of the electrodes a space into which the substances to be treated are introduced, these substances being thus capable of being supplied and subjected to the action of the foci without the proportion of the said substances being altered by the carburation caused by the electrodes and therefore so that the verifying of these components after a trial-tapping of the furnace is reliable, substantially as hereinbefore described.

4. In electric furnaces, a passage around the wall of the column containing the substances to be treated, a communicating passage over the roof of the furnace proper and communications such that the reaction gases from the furnaces pass through these passages and are heated therein substantially as hereinbefore described and illustrated by the accompanying drawings.

5. In electric furnaces a chamber at the bottom of the furnace and means for introducing the reaction gases and air thereto for effecting the combustion of the reaction gases and assisting in the heating of the said furnace and thereby increasing the thermic efficiency of the apparatus; substantially as hereinbefore described and illustrated in the accompanying drawings.

6. In electric furnaces the hereinbefore described arrangement and mode of working permitting when tapping-off the molten metal, of causing said metal to be acted upon by long electric arcs having a

powerful stirring effect and a high calorific action, so as to obtain simultaneously, a reheating of the molten mass, volatilization of the impurities, and elimination of the carbon substantially as hereinbefore described.

7. In electric furnaces, the combination of two electric furnaces one at a higher level than the other, for the treatment of ores and metals, metals or alloys; the upper furnace serving to produce the metal, or alloy, and the lower furnace serving for its refining, or further treatment, substantially as hereinbefore explained.

1902, No. 3912. Granted to *Paul Louis Toussaint Heroult*, of La Praz, France, for "*Improvements in Electric Furnaces.*"

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. An electric furnace comprising a well of refractory material in which is effected reduction of the ore fed into the furnace at a high temperature, the furnace having at the bottom a carbon crucible, and at the top a carbon block, the electric current being conducted to the crucible and to the block above, so as to pass through the coke or other fuel which fills the well of the furnace below the upper block and is being constantly fed through a passage above, substantially as described.

2. In combination with an electric furnace such as is above described, an adjacent preparatory furnace into which pass the hot gases produced by the reduction, which gases heat the ore, which in this hot condition is then fed into the mass of fuel in the well of the electric furnace, substantially as described.

3. The block of carbon at the lower end of the inclined floor of the preparatory furnace, arranged to produce a short circuit between itself and the carbon block which forms the upper side of the mouth of the preparatory furnace, substantially as and for the purpose set forth.

4. The modification in which the passage through which the coke is fed opens through the centre of a broad carbon plate to which is connected one of the conductors, and which forms the top of the well of the electric furnace, the other conductor being connected to the carbon crucible, substantially as described.

1902, No. 15271. Granted to *Charles Albert Keller*, of Paris, for "*New or Improved Process for the Electric Heating of Metals and Other Substances.*"

I, CHARLES ALBERT KELLER of 3, Rue Vignon, Paris, in the Republic of France, engineer, do hereby declare the nature of my invention and in

what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The object of the present application is an electric process for heating and refining metals and other substances, particularly iron, cast-iron and steel, by allowing of various metallurgic operations, for instance.

1. The introduction into one chamber or space of one or several tappings coming from one or several smelting apparatus and there maintaining them at a temperature produced by electric current.

2. The refining of the material, or the mixing thereof with other materials at any moment.

3. The melting and the mixture of metallic waste particularly of iron and steel.

4. Refining of the metal in an auxiliary chamber of the cupola itself after melting.

The process is based on the employment of an auxiliary chamber generally of a casting ladle, the contents of which can be easily and rapidly inserted in an electric circuit or be subjected to the action of the latter.

The casting ladle rests by means of pivots or trunnions on one end of a beam, the other end of which carries a counter weight intended for balancing the ladle and its charge; this beam is carried by a truck, which can be moved on rails. This arrangement allows of bringing the ladle to the proximity of a smelting furnace to receive the successive tappings or to the proximity of each of the furnaces of a battery to receive from them the successive tappings; it also permits of bringing the ladle under an apparatus comprising vertical electrodes supported by chain tackle so as to raise or lower them into the ladle for the requirements of the operation as hereinafter described.

The cupola is provided with a basin to receive the casting and above which is arranged a group of vertically movable electrodes similar to those previously described.

The ladle is provided with a refractory jacket and does not form part of the electric circuit; the current enters and leaves through vertical electrodes arranged above it, these electrodes can be regulated and each set belongs to a distinct furnace, and in practice I employ more than one electrode for each pole, this permits of always being able to replace an electrode at work without interrupting or disturbing the course of the operation.

If only two electrodes were provided, the removal of one of these would cause the breakage of the circuit. On the other hand if each pole carries a minimum of two electrodes it will be possible to remove one of them and this would only result in an increase of tension in the remaining electrodes.

As an example the manufacture of iron or of steel will be described.

The metal contained in the ladle can be easily put into the electric circuit through the suitable lowering of the electrode into the bath. The ladle is carried on a truck adapted to be moved so as to be brought successively under the tapping orifices of furnaces of the same battery. This arrangement will be particularly useful if used with a group of electric furnaces since the individual output of this kind of furnace is less than that of blast furnaces of the ordinary kind.

After each tapping, or set of tappings, the cast substance in the ladle is introduced into the electric circuit and the re-heating is effected by a current of suitable strength, regulatable as required. By these means the metal is maintained at the required temperature: the quantity of heat necessary for this purpose will simply replace the quantity lost by radiation.

The slag which will have probably been tapped with the metal from the furnaces is removed in convenient quantities from the ladle so as not to be superfluously re-heated. This removal is effected by simply tilting the ladle.

The electric current is interrupted when the ladle has again to be placed under the openings of the smelting furnace or furnaces, to receive a further tapping or tappings and the re-heating if required then takes place as described above.

By this process a new method of working is realized; very large castings can be made with furnaces the actual capacity of which is much less than the weight or size of the castings. The temperature of the melted metal can be easily regulated and the metal remaining in the ladle after tapping will not be wasted as often happens, as it can be kept hot until mixed with other tappings; the founder can therefore estimate the amount of metal required for the filling up of large moulds without fear of waste resulting from too high an estimate which leads him sometimes to under estimate and to spoil castings through insufficiency of metal in the ladle.

To refine or mix the metal collected in the ladle, it is introduced into the electric circuit, and the removal of slag proceeded with if required, as already described; the current is then regulated so as to considerably re-heat the metal to be refined and the necessary additions are then made to obtain the required quality. For example, steel can be manufactured with the tappings of ordinary cupolas by refining this tapping by the addition of oxide and as with the Martin furnace, desulphuration dephosphoration and deoxidation can be adopted.

This process therefore permits of transforming an ordinary foundry into a steel foundry.

This process of refining or mixing can also be employed for the metal coming from ordinary furnaces as well as from electrical furnaces.

The process can also be easily applied to the melting and mixture of steel and iron waste which it may be required to re-cast, owing to the extreme facility it offers of taking samples, by the continuous access it permits to the metal in the ladle. For this purpose a certain quantity of metal (iron, steel or cast-iron) is first introduced into the ladle and a certain quantity of mineral which covers over the metal. The electric current is then passed into the ladle and the operation having thus commenced, pieces of metal to be re-cast and mixed are introduced into the liquid layer.

These pieces of metal could not be placed in circuit in the empty ladle on account of their weak electrical resistance or an electric current of a strength inadmissible in practice would have to be used and which would cause large fluctuations in the operation.

With this process which utilizes the usual strengths of current employed in electric melting, the operation is rendered normal and effective by throwing the respective pieces of metal to be cast into the metal bath formed in the ladle as described.

Under these conditions, the electric working of the apparatus is in no way disturbed when the melting is complete; the additions can be made and the operation is effected according to the usual method of mixing and refining of metals. In the case of iron the second melting effected as described corresponds to the actual manufacture in the crucible.

The process above described also permits of transforming the ordinary second melting cupolas into mixed furnaces for obtaining cast iron or steel. As known, some cupolas have a front basin into which the meltings arrive; it is this basin which will replace the ladle, which permits of manufacturing steel with existing apparatus for the manufacture of cast-iron.

In this form of application above the existing or specially constructed basin or auxiliary chamber the group of vertical electrodes are arranged so as to descend into it, after receiving the tapping and the refining is effected as previously described, after removal of slag. During tapping the electrodes can be removed or not and the process is otherwise proceeded with as usual. It is evident that for the refining operations in the case of ladles as well as in cupolas acid resisting linings are employed.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed I declare that what I claim is:

1. A process for the electric melting or refining of metals and other substances, consisting in the employment with electric or other smelting

furnaces, of an auxiliary fixed or movable feed chamber into which a group of vertical electrodes is adapted to be plunged, the said electrodes being allowed to descend into the melted material coming from the furnace or furnaces, in order to cause the electric current to pass through the said material, for maintaining the latter at the temperature necessary for performing in said auxiliary chamber the operation of mixing, or refining or for subsequent casting.

2. In the process as described in Claim 1, the employment of a tapping ladle mounted on a movable truck, and adapted to be conducted close to a furnace or to each furnace of a battery, to receive the successive tappings of said furnace or furnaces, and to be passed under a group of vertical electrodes which are plunged into the fused material in order to place the latter in the electric circuit and maintain it at the required temperature for subsequent casting into moulds, permitting of accumulating in the ladle a much larger quantity of melted material than could be obtained for immediate casting and thus making large castings with a small quantity of material from each.

3. In the process as described in Claim 1, the arrangement above the front basin of a cupola, of vertically movable vertical electrodes, adapted to descend into the fused material coming from the cupola so as to place it into the electric circuit and maintain it at the temperature required for refining the casting and its direct transformation into steel on coming out of the cupola.

4. In the process as described in Claim 1, the second melting and the refining of waste iron or steel consisting in introducing the waste material into a preliminary bath of suitable composition contained in a ladle provided with movable electrodes to permit of melting with currents of the usual strength without sudden fluctuations.

5. In the process as described in Claim 1, a method of electrical heating, consisting in the arrangement above the auxiliary chamber or appliance receiving the fused material to be treated, of a group or groups of vertical electrodes each group comprising two or more positive and negative electrodes respectively and each group belonging to a separate regulatable furnace, for the purpose of replacing an electrode at will without stopping the operation.

IV. ABSTRACTS OF PAPERS AND NOTES ON ELECTRIC STEEL REFINING.

A. *The Function of the Slag in Electric Steel Refining.*

An exceedingly interesting and valuable paper upon this subject was presented by Richard Amberg to the Eighth Inter-

national Congress of Applied Chemistry, held in New York in September, 1912 (see *Transactions*. Sections 3 and 10, also *Metall. and Chem. Engineering*, September 12, 1912).

From the report of this paper, and of the discussion upon it, which appeared in the Journal named above, the following extracts have been taken :—

The function of the slag depends upon the work which the furnace is required to perform. In localities where power is cheap, the electric furnace may be used for carrying out reactions which, in other places, with more expensive power, would be carried out more cheaply in an oxidizing furnace like the open-hearth.

Where cheap power is available, electric steel melting begins with the widely-known open-hearth process, of melting pig and scrap. Assuming a basic-lined bottom and hearth, heated by one or more electric arcs, the charge melts down, slag is formed by lime, silica, and iron-oxide in the form of ore or scale,—and the refining by oxidation takes place in the form of heterogeneous reactions of different kinds. After the ferric oxide dissolved in the slag has been reduced to the ferrous oxide, it partly acts directly on those parts of the metallic solution which come in immediate contact with it, and partly dissolves in the metal, according to the temperatures and coefficient of division of FeO between the two liquid phases (metal and slag). If the slag is saturated with FeO, the latter can assume its full concentration in the metal bath, according to the solubility curve. Its action there on manganese and the metalloids is much the same as in the open-hearth. It can be more energetic, however, if the operator avails himself of the facility of a higher temperature and of a higher concentration of FeO which is a special feature of the electric furnace.

There is one essential difference from the reactions of an open-hearth slag. In a well-built electric furnace, practically all the oxygen required has to be supplied in solid oxide form, while the open-hearth furnace has an unlimited supply of oxygen in the air supply. At this period of oxidation, the basic slags of an arc furnace, and of an induction furnace, show a material difference. The dephosphorisation, being a process which reaches its maximum velocity at a temperature somewhat below the melting point of soft iron, is accomplished more quickly with the comparatively colder slag of the induction furnace, than under the higher heat of the arc. The technical significance of this fact, however, is small. This dephosphorisation period may be carried out in an ordinary non-electric furnace. When it is finished, there begins an entirely new operation—the deoxidation of the metal.

This involves a slag process, which none of the other furnaces can perform. Carbon is the chief deoxidising agent, and is bound to act in both phases.

Electric heating, as described in the patents of Humbert, offers the possibility of heating the slag, with the addition of carbon, in a reducing atmosphere so quickly that it forms a high endothermic compound of calcium and phosphorus (probably Ca_3P_2) which is not absorbed by the steel phase; hence the opportunity to dephosphorise without skimming the slag. How sensitive this reaction is, with regard to temperature, is shown by the fact, that without very accurate control of the temperature, a rephosphorisation of the metal has been found. Since in the reducing atmosphere, when carried on far enough, the partial pressure of oxygen is very low, the oxygen can be removed to a considerable extent from both phases without disturbing the equilibrium at the contact surface, while the opposite would be the case with an open-hearth furnace. In fact the amount of FeO present in the final slag is easily brought down in everyday practice to between 1 per cent. and 0.5 per cent., and with a little attention considerably lower. The reaction, by which this is performed, is a true heterogeneous one (that is, a reaction between the metal and the slag at the points of contact), and consequently does not come to an equilibrium in the original phase. FeO, as a base of the silicates, or as dissolved in the slag, is freed from oxygen, and the metal joins the other phase. Manganese is practically removed from the slag in a similar way. Even silica is partly reduced, when the basicity of the slag and the temperature are both high enough.

The desulphurisation process has been the subject of many experiments and discussions. In the oxidising period, where sulphur is being removed only to a small extent in the open-hearth, the electric furnace is much more efficient, especially when manganese ore is used. It is likely that a large portion of the sulphur forms SO_2 and disappears with the gases. As the partial pressure of O and SO_2 , in the atmosphere of the electric furnace, is smaller than in the open-hearth, the reaction takes place more easily. In the reducing period a new desulphurising action takes place, according to Dr. Amberg, as follows :—

(1) $\text{FeS} + \text{CaO} + \text{C} = \text{Fe} + \text{CaS} + \text{CO}$ at the high temperatures of the arc furnace.

(2) $2\text{CaO} + 3\text{FeS} + \text{CaC}_2 = 3\text{Fe} + 3\text{CaS} + 2\text{CO}$ at still higher temperatures, where calcium-carbide can be formed.

(3) $2\text{FeS} + 2\text{CaO} + \text{Si} = 2\text{Fe} + 2\text{CaS} + \text{SiO}_2$ at the lower slag temperatures of the induction furnace.

(4) $\text{CaS} + \text{FeO} = \text{FeS} + \text{CaO}$. This equation occurs from left to

right for comparatively small amounts of oxygen, while from right to left it is the underlying principle of the three reactions, 1 to 3.

In all the foregoing reactions, one feature deserves the most important consideration, that is, the high basicity of the slag. This is made possible by the high temperature attainable, especially in the arc furnaces. The elements which in the present electric furnace practice act as reducing agents for the oxides are chiefly carbon in the arc furnace, and silicon in the induction furnace. The manganese is practically eliminated altogether. The FeO is easily removed down to 0.5 per cent. Nickel is reduced with great ease, chromium, tungsten, and vanadium (according to their inherent amount of free energy) with a larger consumption of power.

To explain the mechanism of the reactions, it is best to consider them as reactions in a system of different phases, two liquid—metal and slag—the third gaseous—and the fourth (the hearth of the furnace) solid. It is of great importance for the advancement of general metallurgical knowledge, to determine the melting points of the pure compounds, and to give the complete diagram of the melting point of their mutual solutions over as wide a range of concentration as possible. Much remains to be done in this field. Some important melting points are as follows: FeSO₃, 1050° C.; MnSiO₃, 1150° C.; CaSiO₃, 1220° to 1225° C.; MgSiO₄, 1400° C.

The carbon thrown into the furnace and the carbon derived from the electrodes can produce several compounds. Among these are silicon carbide, calcium silicide, and calcium carbide. This latter seems to be the most permanent under operating conditions, and is recognised by the liberation of acetylene from a cooled-off sample. It is only after this carbide has been formed that the deoxidation of the charge can be looked upon as completed.

When this condition of the bath has been attained, the electric furnace represents the nearest approach to the ideal heterogeneous equilibrium, between the different phases, which has hitherto been accomplished in large-scale metallurgy. The converter and open-hearth are under the action of air and gas—the crucible metal takes carbon and silicon up—whereas in the electric furnace the action of the metal on the basic lining is almost nil, and there is no exchange of elements between metal and slag. However, a slight evaporation of the constituents of the slag does take place, and in this respect the induction furnace, with its cold slag, has a slight advantage over the arc furnace.

The author then discusses the physical aspect of the fact, that there is by no means an ideal two-dimensional contact surface

between slag and metal, and that both phases penetrate each other to a considerable extent. The prevailing notion that slag and metal behave like oil and water is only relatively true. The slag swims on the metal, but where small portions of the one are caught in larger masses of the other, they have to overcome an enormous friction in order to be separated, and the smaller the slag particles the more difficult is their separation from the metal bath. It is therefore very important to keep the finished charge quiet, and at a sufficiently high temperature, to allow it to settle. Proper precautions have also to be taken afterwards while teaming and pouring in order that the painstaking results of refining may not be reversed.

This slow physical action may furnish a new explanation for the slow progress of the desulphurisation, according to Equation 2. The microscope shows that siliceous and sulphidic products are sometimes contained down to two-thirds, and even lower, from the top of an ingot.

These non-metallic products appear as balls in the ingot structure, and are elongated into a cigar-like shape, after rolling or forging the metal. Although their melting point is lower than that of steel, they have not succeeded in uniting with the bulk of the slag in proper time.

The author concludes with a brief discussion of the acid-lined electric steel furnace. An acid lining requires an acid slag, to keep the hearth in good condition. This acid slag will be much the same as the slag of an acid open-hearth furnace so long as the charge is treated with an excess of oxides, and the heat is not exaggerated. If necessary, it can be made to contain a higher percentage of SiO₂ for the same reasons which hold good for highly basic slags. The great difference from the basic electric furnace in this case is that all four phases are in lively reaction with each other, and that conditions approaching a status of equilibrium cannot be reached; the metal, therefore, must be "caught," at a certain moment of teaming.

The solid and the metal phases react in this way, that carbon of the bath reduces Si from the hearth, the amount of Si present being regulated by a reaction between the two liquid phases, namely, by keeping a sufficient stock of oxides in the slag to hold the Si within the required limits. The slag will therefore be a thoroughly black one, particularly during the beginning of the run. Thallner ascribes a specific beneficent effect to this exchange of Si and to the low heat conductivity of the silica lining. Towards the finishing of the acid heat, the colour of the slag clears up, and its reduction finally reaches a point

where the glassy masses become light grey and green coloured. Sulphur, as in the acid open-hearth, will remain unaltered in quantity—while phosphorus may be slightly decreased, by phosphoric acid being thrown out of solution by the stronger SiO_2 and then reduced to phosphide of iron. This has yet to be confirmed, however, and it has to be explained how such a reaction can take place. Nothing definite can be said about this reaction at the present time.

It may be that some of the advantages of this method are due to the mechanical property of the acid slag of agglomerating more easily than the basic slag particles to larger globules, which in turn force their way up and combine with the bulk of the slag.

The paper produced quite an extended Discussion. Dr. Richards called attention to the discussion at the Congress for Testing Materials, on the effect of slag enclosures on steel, and urged that the contribution presented at this Congress, by those who used and tested the steel, should be carefully considered by the manufacturers of steel.

As to the control of microscopically disseminated particles of slag in steel, Dr. Richards made the following suggestions:—First, to regulate the composition of the slag carefully; and, secondly, to heat the metal in the furnace for some time after the furnace reaction is over, in order to let the emulsion separate. Dr. Richards referred in this connection to the practice of a Bessemer works in Germany, where the metal is permitted to rest after the blow is concluded, for a considerable time. The cost of this is high, and in his opinion the final solution will be to let the metal from oxidising furnaces rest in an electric furnace for a definite length of time. The electric furnace in such treatment would do nothing else but keep the metal at a high temperature, and permit the slag particles to separate from the metal.

Mr. Rogers agreed with Dr. Richards that by heating the metal in the furnace and in the ladle, as long as permissible, a marked influence would be effected on the slag enclosures; but this delay would mean an enormous expense. To his former remark, that electric steel seemed more suitable for rails than for wire, and that they did not feel justified in substituting electric steel for open-hearth steel for wire-making, he added two reasons for this distinction. Firstly, the increased cost; and, secondly, the difference in the working of the open-hearth steel and the electric steel. The difficulties in working, he admitted, might possibly be due to their inexperience with electric steel.

Dr. Richards replied that the additional cost of heating the metal long enough for it to rest, and to allow the slag to separate was not so important, if a "holding" electric furnace was used. The cost would lie between 25 and 50 cents a ton. The tests of the engineers have shown that the enclosures of slag are very important.

Mr. E. R. Taylor referred to the use of a pig-iron mixer, and thought that an electric steel-mixer, for letting the metal rest, might be the final solution of the difficulty.

Mr. Speller urged that the time required for letting the metal rest would be a serious objection. He thought they had found a partial solution, in controlling the condition of the slag when the metal leaves the furnace, and in a subsequent circulation of the metal in the ladle.

B. *The Use of Titanium in Foundry Practice with Electric Steel.*

Titanium alloys have been used recently in the manufacture of steel for casting purposes, with beneficial results.

The following extracts give valuable information upon this subject:—

I.

Recently a very important improvement has been realised by introducing into electric steel for castings, special titanium alloys of approximately the following compositions:—

1. Si : 56 per cent.	Ti : 36 per cent.
2. Si : 21 per cent.	Ti : 28 per cent.
3. Si : 10 per cent.	Ti : 10 per cent.

Very small additions of these alloys render the steel perfectly quiet, and the castings very dense and free from any blow-holes. The number of lost heats is also greatly diminished by this use of titanium alloys.—From article by Paul Girod in *Metallurgical and Chemical Engineering*, October, 1912.

II.

The writer early in 1908 was using titanium alloys for steel made in electric furnaces of from 2 to 5 tons capacity, recognising the fact that by such treatment only was it possible to obtain a uniform and thoroughly deoxidised product.

Deoxidation is only accomplished in the presence of carbide of calcium slag, and every one experienced in the use of the electric furnace knows how difficult it is sometimes to form this carbide slag.

A great feature of the addition of titanium is that this metal by oxidation is transformed into titanous acid, which fluxes all the slag held in suspension in the steel after it has been tapped into the ladle. The proportion of slag so held in the steel is very large when the calcium carbide slag has once been formed, the latter being very pasty. While ferro-alloys of titanium and silicon combined may be a new way of

placing titanium on the market, their use will prove a much more complicated operation than separate additions of ferro-titanium and ferro-silicon. Ferro-titanium alone is very useful, but when an equal quantity of silicon is combined with the alloy the silicon is oxidised last, if the deoxidation of the bath has not been completed by the titanium. If it has, the silicon will be dissolved in the steel, thus raising the silicon content to a point very often over the limit imposed by the specifications.

In the case of steel made in the electric furnace, it will very often be found that the silicon is too high, a condition brought about either by these additions of ferro-silicon during the deoxidation period, or more often by the melting of the roof of the furnace, which introduces silica into the slag, this silica being in turn reduced by the calcium carbide present.—From letter by N. Petinot in *Metall. and Chem. Engineering*, November, 1912.

C. *Extracts from an Annual Review Article upon "Progress in Electric Furnaces."*

The inventor points out the possible combinations of elements; the engineer determines which of them are practicable. Ideas which during one period of development may be classed as freaks, may at another survive those which were at first thought to be more sound. The enclosed arc lamp is a good illustration. When shown at the Philadelphia Exhibition in 1884 it was classed as a freak, now it is fast replacing its early competitor. The frail Welsbach mantle, wireless telegraphy and telephony, are other illustrations. So-called freak ideas should therefore not be ignored on general principles; sometimes they are worthy of consideration.

Fortunately for the development of the electric furnace there are no controlling basic patents; the field is wide open. Improvements in the form of inventions, as distinguished from designing and proportioning, are therefore to be looked for in details rather than in any radically new way of converting electric energy into heat, other than by means of resistance, although other ways may be possible.

Aside from the furnace itself, there is of course a very wide field open to inventors in devising new thermochemical processes for treating materials with the aid of the electric furnace, and it is in this direction that valuable improvements may be looked for.

Considering now the second branch of the development, namely, that in which the engineer and scientist are concerned, as distinguished

from the inventor, it is probable that it is in this branch that the most important progress will be made in the immediate future. It is a simple matter to produce an arc between two carbons, thereby getting instantaneously, probably the highest temperature which can be produced artificially on a commercial scale to day; but such a device cannot or should not be dignified with the title of furnace, nor should it be called so when the arc is simply enlarged in scale. The same is true of a wire carrying a current by means of which the volatilisation temperature of the conductor can be produced in a very short time. To be a commercial furnace it is necessary that it operate continuously, with reasonable certainty, and with as few stoppages as possible; also with the least possible losses, and with as little expert attendance as possible. It is here that the work of the engineer becomes important; it is for him to determine how to design, proportion, and construct a furnace, so that it may deserve to be classed among engineering structures.

It is therefore in the careful study of the proper designing and proportioning and operation of furnaces that the greatest and most important progress is to be looked for to-day. And it may be said that development in these directions has only just begun.

To calculate proportions requires a knowledge of the physical constants of materials such as their thermal and often also their electrical conductivities, more particularly at high temperatures; also their specific heats, their melting and often their volatilisation points; the combination energy when compounds are formed or decomposed; the laws governing the various thermal phenomena, including the flow, convection and radiation of heat. Much, if not most, of this fundamental knowledge does not yet exist, or it is only crudely known, or perhaps even worse, as it has already been found in some cases, that what we thought was known was actually wrong, and had been misleading us.

These few-illustrations (and many more could be cited) show that what might be termed our knowledge of the science of electric furnaces is still in a somewhat crude and undeveloped state. Heat is a low form of energy to which all other forms tend naturally to degenerate; hence to simply produce heat from energy of the very high state of availability of electric energy is no difficult task, as nature tends to do it for us. But to do it commercially, without undue waste, and so that it will produce the desired product, involves no small amount of knowledge and skill on the part of the engineer, and it is in

the acquiring of this knowledge that the development in electric furnaces is to be looked for at the present time.

It is when the engineer can predetermine whether a desired furnace operation is possible or not, and if so, whether it is commercial, that much progress and fewer failures by the cut-and-try method are to be expected. Calculations, when it is possible to make them with reasonable certainty, are generally far cheaper than blind cut-and-try methods.

The cost of heat by fuel per degree of temperature increases as the temperature rises; in fact a temperature is reached when the efficiency is zero; that is, where the material no longer gets hotter, the gases (including the very large amount of the useless nitrogen) carrying away all the heat generated. With electricity generated heat, however, it costs no more to produce a high-temperature calorie than one at a low temperature. Hence a point must necessarily be reached up to which it would pay best to heat with fuel, and beyond which it would be cheapest to use electric heat, even though generated by coal, not to mention the sometimes very valuable advantage of the possibility of a neutral atmosphere in the electric furnace.—From "Electric Furnaces," by Carl Hering, in *The Electrical Review and Western Electrician*, (Chicago) January 7, 1911.

D. *Notes on work of Stassano Furnaces installed at Newcastle, England.*

The Stassano Rotary furnaces of the Electro-Flex Steel Co. at Dunston-on-Tyne are used in the production of mild steel castings of all descriptions used in the engineering trades, ranging in weight from a few ounces to one ton.

The furnaces are lined with magnesite. A lining generally lasts three weeks, and will work eighty-five charges of an average of one ton before being dismantled for renewal. The average time of working per charge is four hours, and the current consumption lies between 1,100 and 1,200 k.w. hours.

The charge while in the furnace is under absolute control. Steel scrap is charged into the furnace, and a highly basic oxidising slag is formed by the addition of iron-ore and lime. This slag being very hot and fluid, takes up practically all impurities from the steel, and on being raked off it leaves a bath of almost pure iron. At this point carbon, manganese, silicon, &c., are added, to produce a resulting metal to meet any given specification.

The metal is sound, of a high degree of purity, and very ductile.

Owing to the great heat obtainable and the consequent fluidity of the steel, intricate castings of very thin sections can be produced. A peculiarity of the steel made by this process is the excellent physical properties it possesses in the unannealed state. Tests taken from a side-frame for an electric car gave the following results, unannealed:—

Chemical Composition.

Carbon	0.26 per cent.
Manganese	0.50 "

Physical Tests.

Breaking stress	28.9 tons per sq. in.
Elongation on 2 ins.	30.0 per cent.
Reduction of area	31.6 "

The test piece ultimately broke with a fibrous fracture.

A typical charge taken from the furnace last in commission gave the following results of tests:—

Chemical Analysis.

Carbon	0.23 per cent.
Silicon	0.25 "
Manganese	0.76 "
Phosphorus	0.015 "
Sulphur	0.016 "

Physical Tests.

Elastic limit	16.0 tons per sq. in.
Breaking stress	29.0 " "
Elongation	30.0 per cent. on 2 ins.
Fracture	Fibrous.
Bending test	180°

From article by Kershaw in *Electrical Times*, July 9th, 1913.