C. HERING.

ELECTRIC FURNACE PROCESS AND ELECTRIC FURNACE.

APPLICATION FILED JULY 6, 1909.

988,936. Patented Apr. 4, 1911.

2 SHEETS—SHEET 1.

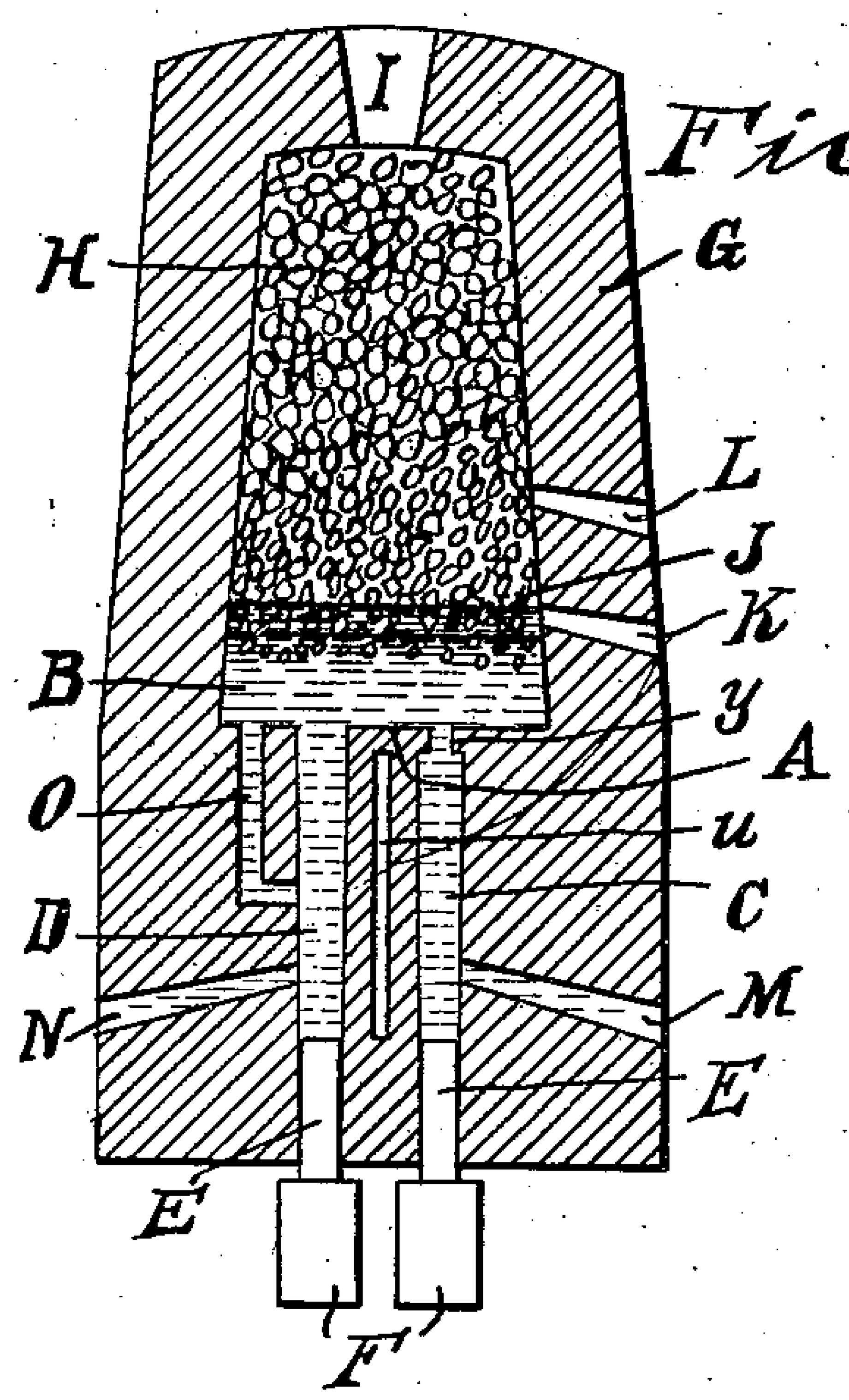

Fig. 1.

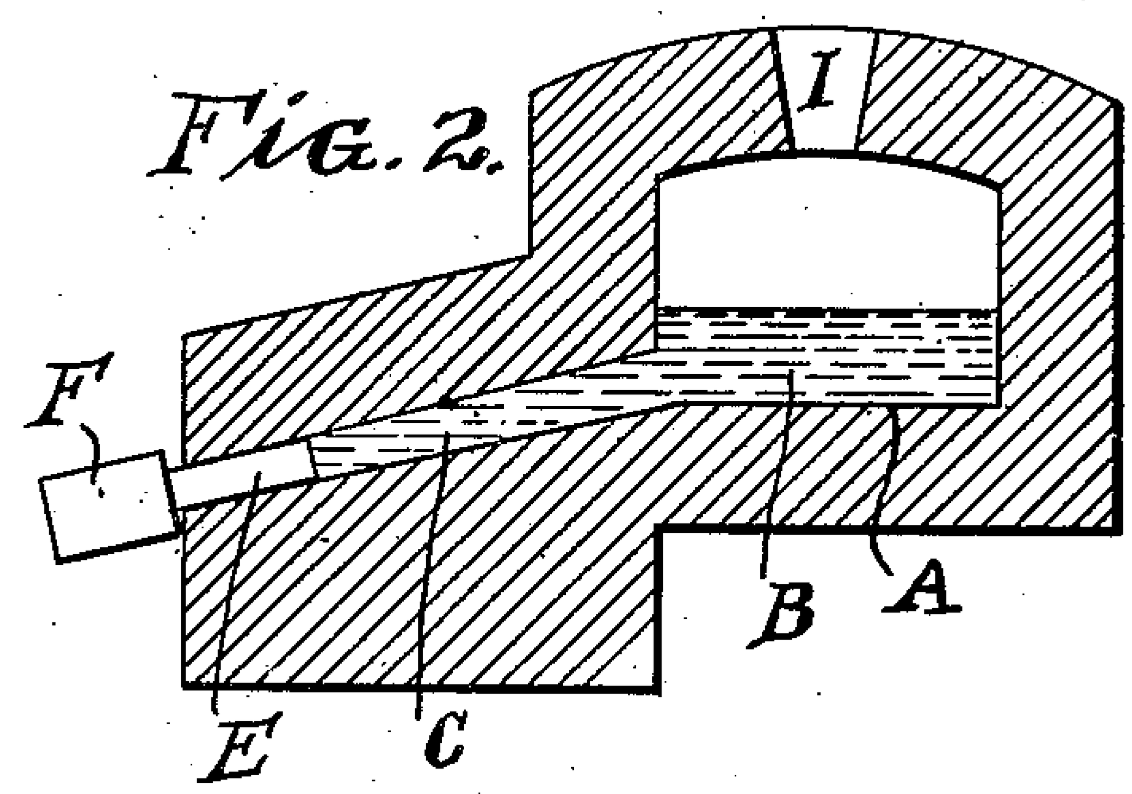

Fig. 2.

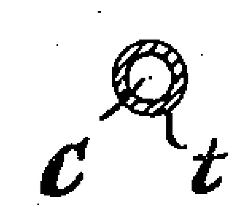

Fig. 1a

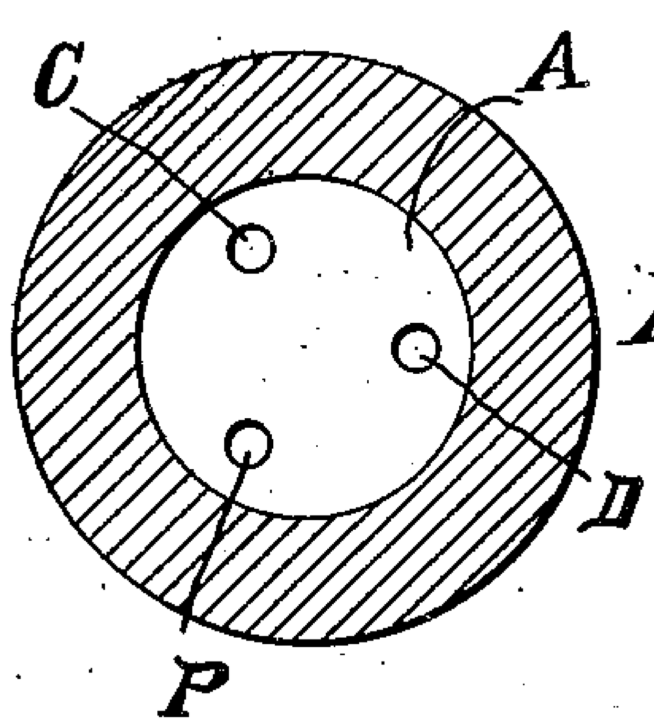

Fig. 3.

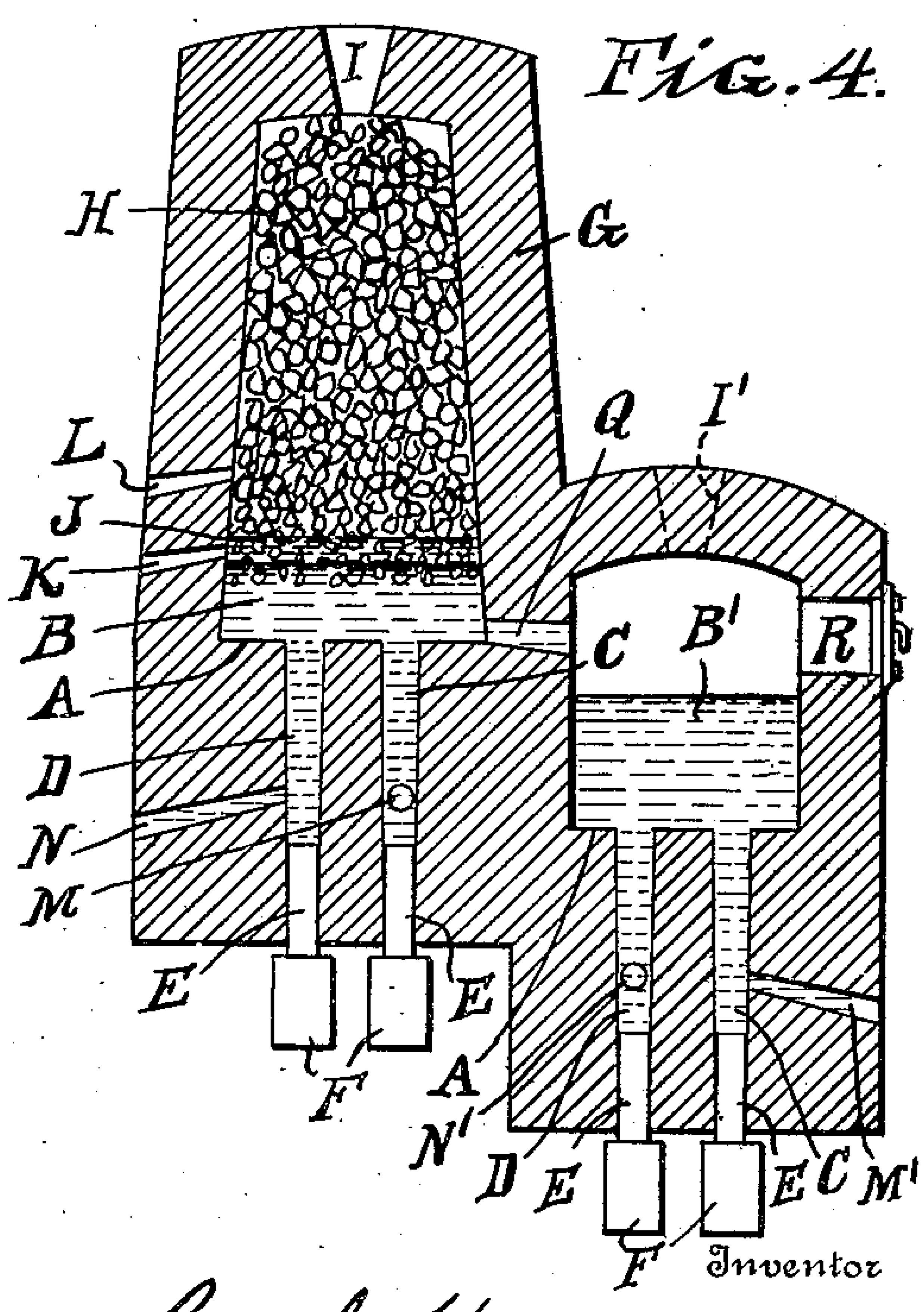

Fig. 4.

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2 SHEETS—SHEET 2.

FIG. 5.

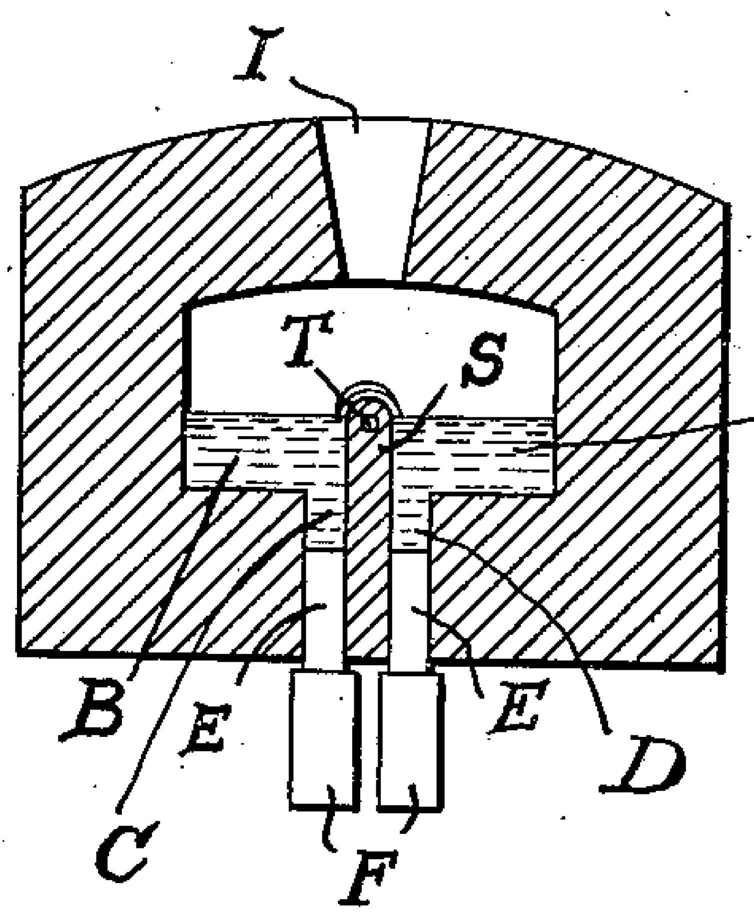
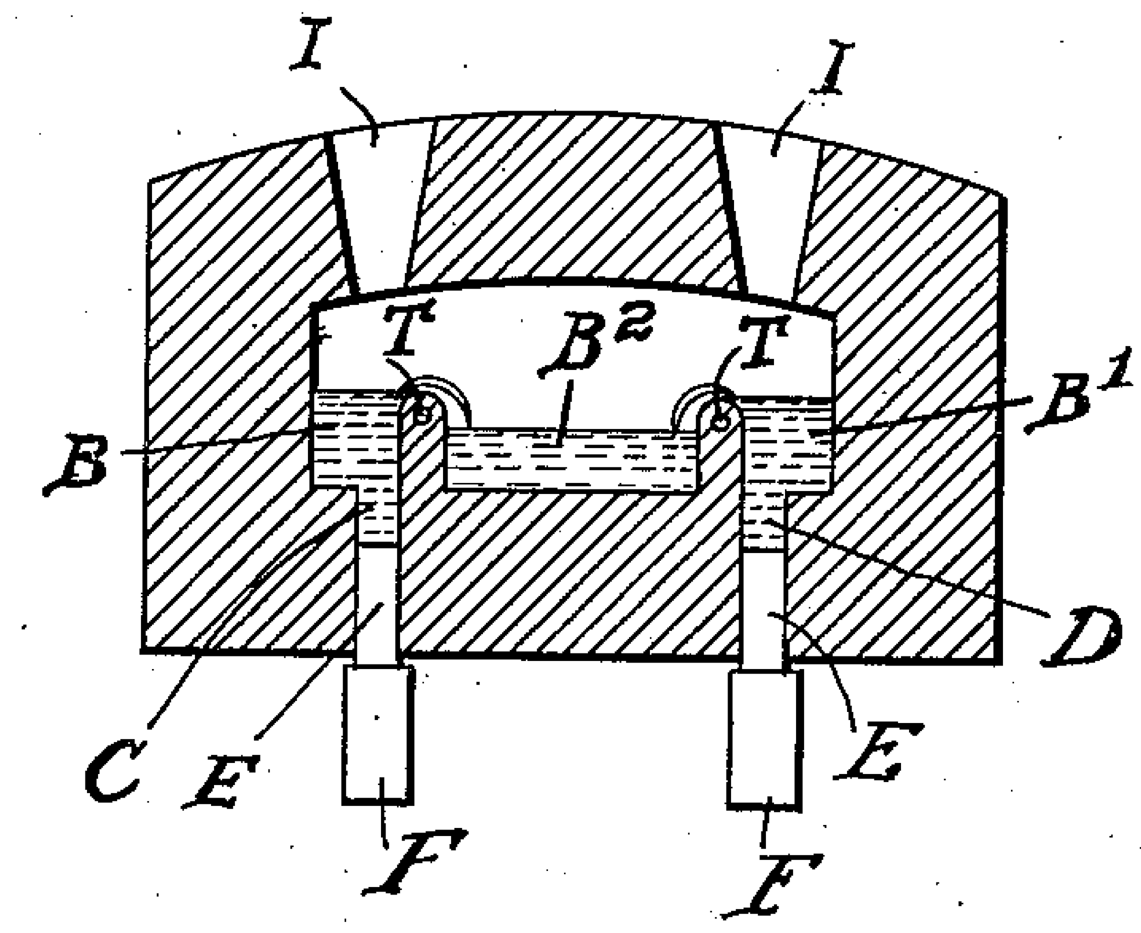


FIG. 7.



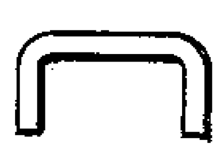


FIG. 6.

FIG. 9.

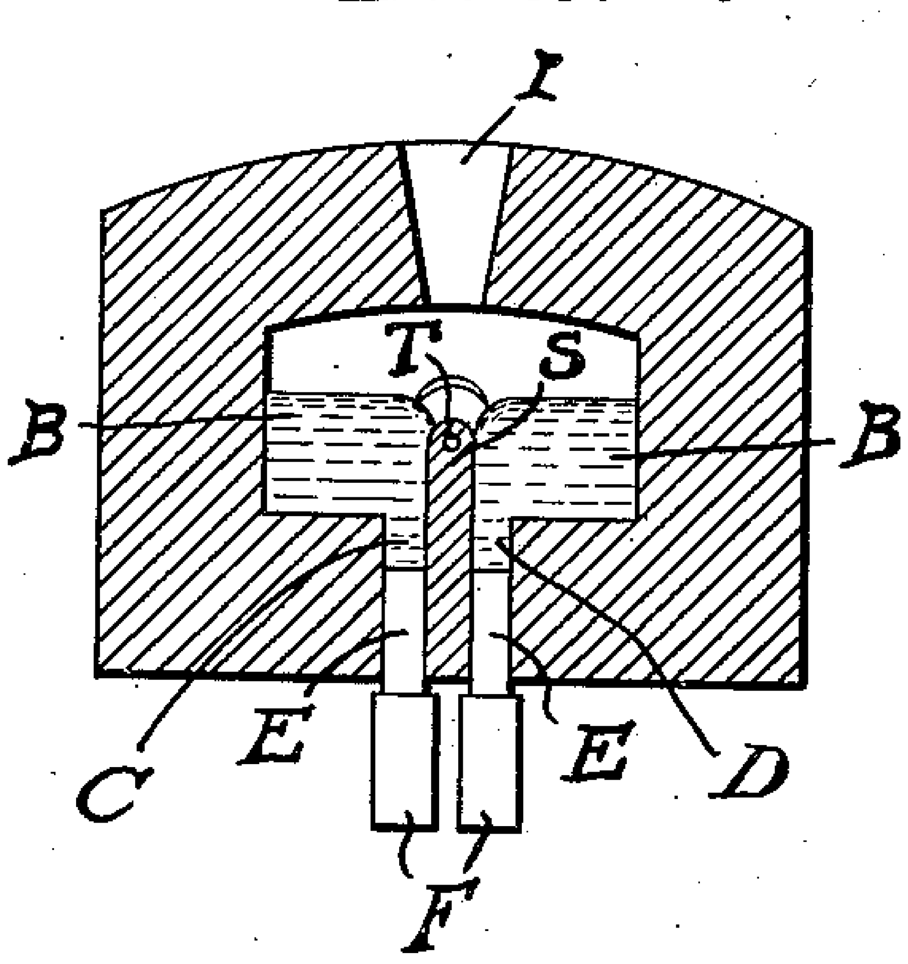
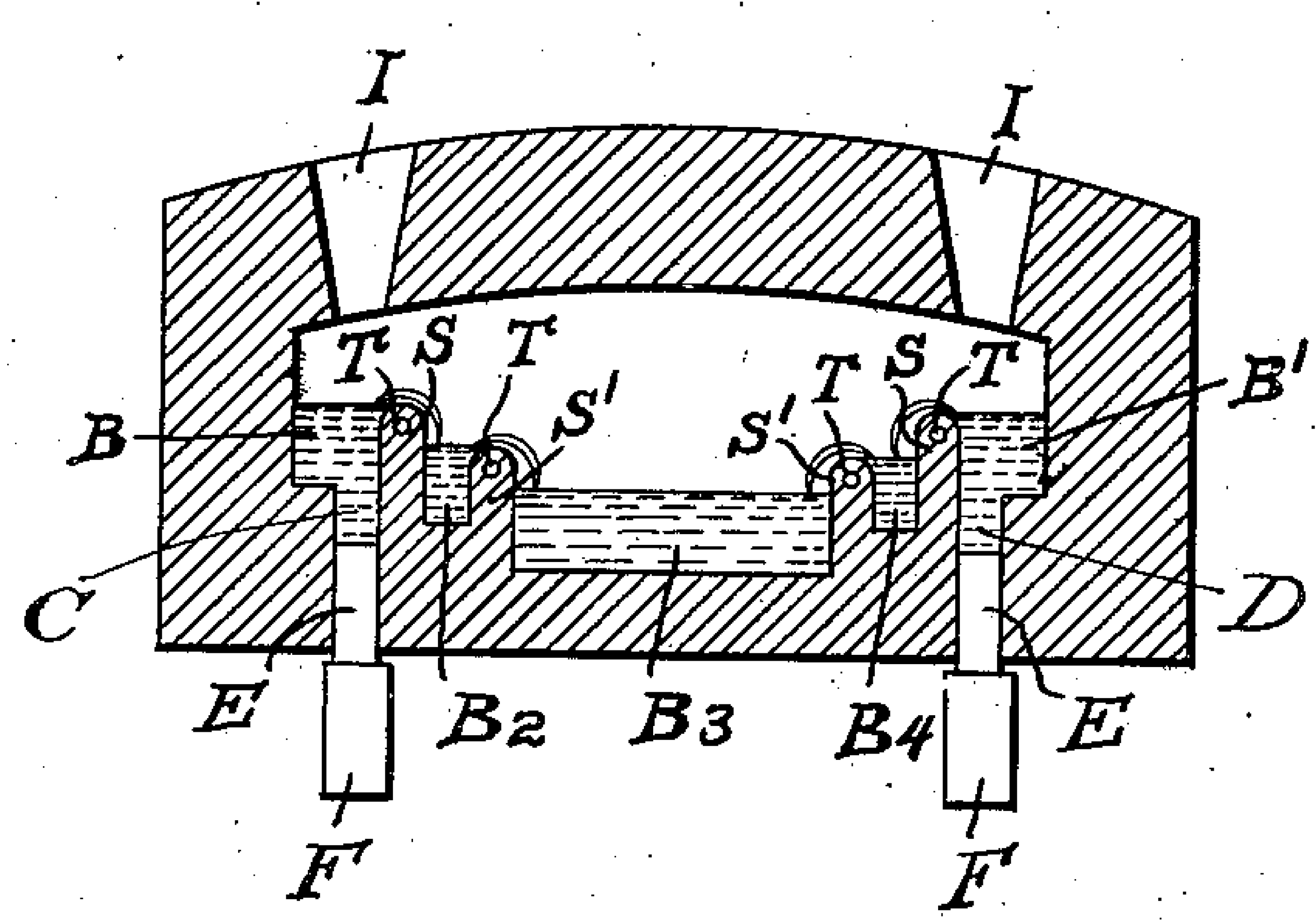


FIG. 8.



Witnesses

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UNITED STATES PATENT OFFICE.

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ELECTRIC-FURNACE PROCESS AND ELECTRIC FURNACE.

988,936. Specification of Letters Patent. **Patented Apr. 4, 1911.**

Application filed July 6, 1909. Serial No. 505,963.

To all whom it may concern:

Be it known that I, Carl Hering, a citizen of the United States, residing in the city of Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented a new and useful Electric-Furnace Process and Electric Furnace, of which the following is a specification.

My invention relates to electric furnaces and furnace processes, and resides in features of construction, proportionment, mode of operation, and other matters.

My invention resides in an electric furnace wherein the resister comprises a column or columns of molten material, electrodes furnishing communication with said columns, the heat in the column resister being communicated to the main body or mass of molten or other material under treatment by conduction from such resister and chiefly by convection and rapid circulation; and it is a further feature of my invention that I so construct and proportion the column resister that the "pinch effect" in such column is usefully availed of for causing more or less violent circulation and movement of the heated material from the columns into the mass of molten material under treatment.

My invention resides also in other forms of electric furnace in which the "pinch effect", above referred to, is usefully availed of for causing stirring or agitation of material under treatment.

My invention resides also in other modified forms of this type of furnace hereinafter described.

My invention resides also in the use with such furnaces of furnace electrodes, which, if made in accordance with my invention, are far smaller and cheaper as compared with former general practice and which greatly reduce the electrode losses, whereby the efficiency of the furnace is considerably increased.

My invention resides also in the improved processes of electrically treating materials as hereinafter described.

My invention resides in other features hereinafter pointed out and claimed.

For an illustration of some of the forms my invention may take, reference is to be had to the accompanying drawings, in which:

Figure 1 is a vertical sectional view of an electric furnace in which the resister is in the form of a column or columns of molten material contacting with the electrodes and communicating with the main mass of molten material above it. Fig. 1[a] is a cross sectional view of a modified form of conductor column or channel. Fig. 2 is a vertical sectional view of a similar furnace in which, however, the resister column is inclined, whereby there will be less hydrostatic pressure in the resister column. Fig. 3 is a horizontal sectional view of a furnace similar to the type shown in Fig. 1 and adapted for the use of three phase alternating currents. Fig. 4 is a vertical sectional view of a plural furnace, such as may be used, for example, in the production of steel directly from iron ore. Fig. 5 is a vertical sectional view of an arc furnace, the arc being struck between two baths of fused metal, the furnace involving also other features herein described. Fig. 6 is a side elevational view of a metallic or conducting starter. Figs. 7 and 8 are vertical sectional views of combined arc and resister furnaces wherein a plurality of arcs are employed in series. Fig. 9 is a vertical sectional view of an arc furnace in which the arc is started by the "pinch effect."

Referring to Fig. 1, an electric furnace is shown in vertical section and having a broad flat hearth A, which is especially suitable for the treatment of iron, or other materials when a large exposed surface is required; the hearth may take any suitable or desired form, as the heat producing resister is practically independent of the proportions of this hearth or of the amount of material in it. Upon the hearth A is a mass B of molten iron or other conducting material under treatment, the molten material extending also downwardly into the columns C and D, the molten material in these columns making electrical contact with the furnace electrodes E, E which extend through the bottom or wall of the furnace, and may terminate outside in conducting enlargements F, F which may be cooled, if desired, as by a water jacket. The furnace extends upwardly in the form of a dome G, preferably enlarging toward the bottom, such dome being preferably filled with the charging material H, as iron ore or other material, which may be introduced through the opening I at the top, and which is thereby preheated. The furnace may be started by a charge of molten material by a casting preferably of the same material as that to be treated, extending downwardly in the columns C and D into contact with the electrodes E, E, such casting being continuous and bridging the columns C and D at the top. When the current is turned on, it flows from one electrode through one of the columns and out through the other column and other electrode, the casting becoming hotter and hotter until finally melted. Then the usual mixture of ore, carbon and flux is introduced, it being preferably in sufficient quantity above the hearth to force masses of it into the molten mass, whereupon the heat of the molten mass B is rapidly conveyed to it, thereby hastening the chemical action such as the combination of iron and carbon on the one hand, and the combination of the carbid, thus formed, with the iron oxid, on the other hand, as is well understood in the art. J represents the slag. And a further opening L may be provided for the introduction of air, as by a blast, for burning any possible unburned gases which may be formed, like carbon monoxid, thus preheating the ore and thereby increasing the economy of heat of the furnace. In fact, the part of the furnace above the mass B may be an ordinary blast furnace where the necessary heat is procured by ordinary combustion. The reduced metal then collects as the mass B in the hearth A where it is further heated electrically and where, by the introduction of more ore, it can be directly oxidized into steel. By this arrangement, cooling and reheating in a separate chamber or furnace is avoided with resultant increased economy.

M is a tap hole communicating with the column C for drawing off the reduced iron or other material, and a similar tap hole N may be provided for communicating with the other column D for the same purpose, if desired. Or the tap hole may communicate with the bottom of the hearth A, if desired, or tap holes may be placed at both places.

In operation, the heat is produced by the current in the columns C and D, the molten masses in these columns constituting the resister. This heat is then conducted to the mass B through the columns C and D, and the delivery of the heat to the mass B is further procured, and chiefly, if desired, by the "pinch effect" caused in the columns C and D by the current flowing through them, this "pinch effect" causing the molten metal to flow up through the central axis of the columns and the hydrostatic pressure will then cause it at the same time to flow downwardly at the circumference of the columns. This pinch effect may be made so great, if desired, as to cause an actual squirting of the molten material up through the mass B into contact with the lower layers of the ore and slag. This pinch effect may be secured by properly proportioning the cross section of the columns C and D with respect to the current traversing them. The pressure developed by the current flowing in such a column of liquid conductor may be expressed by the following formula:

$$p=\frac{cC^2}{S}$$

where p represents the pressure in pounds per square inch at the central axis, c is a constant, C the current in amperes and S the cross section of the liquid column in square inches. It is apparent, therfore, that to secure a strong pinch effect the ratio of the square of the current to the cross section of the column should be large. The greater this ratio the greater will be the pinch effect, and, as above stated, this effect may be made so great as to actually squirt the molten material upwardly through the mass B in the hearth A into contact with the lower layers of the ore or other material to be reduced or otherwise treated, whereby effective stirring or agitation is procured, and the heat generated in the resisters is rapidly conveyed to the mass above them.

A side column O communicating with the mass B and with a column, as D, at a distance below the mass B may be provided for further stimulating the circulation of the molten mass. The section of the column O may be so chosen that, with the current passing through it, a different pressure is produced by the current within it from that produced in the column, as D, with which it communicates, so that this difference in pressure in the two columns will cause a circulation. However, such side column O may be omitted and the pinch effects in the main columns themselves may be availed of for securing the circulation and rapid transfer of heat to the mass above.

The columns C and D are preferably made slightly conical with the greatest diameter at the end nearest the bath B in order that when the metal solidifies in the bath and columns the columns will not break due to the contraction of the solidifying metal. And as shown at y one or more of the columns may be contracted just below the molten mass B in order to have a greater pinch effect in the region of the contraction.

As shown in Fig. 1[a] in cross section, the columns C and D may be entirely surrounded by a tube or partially surrounded by a rod or plate *t*, the tube, rod, or plate extending substantially the entire length of the column and being of a material which conducts at high temperatures so that if the column is ruptured, due either to the pinch effect or any other cause, the circuit will not be broken and the conduction through the columns may be again started. Carborundum, siloxicon, or other suitable material conducting at high temperatures may be used for the tube, rod, or plate. And in the furnace wall or in the furnace material lying between the columns C and D may be provided an air space *u* to insure that current will not pass directly from one column to another through the furnace wall material in case such material should be conducting at high temperatures.

In Fig. 2 the arrangement and construction are substantially the same as shown in Fig. 1, except that the columns are inclined, in place of vertical, so that less hydro-static pressure is developed in the columns. By this means, the pinch effect developed is required to overcome a smaller hydro-static pressure of the molten material, and the angle through which the furnace must be tilted in order to completely empty it, becomes much less.

Since by this construction of the furnace, the current flows through a resister column and then through the mass of molten material in the hearth, alternating current of three phases, or other number of phases, may be readily employed. As shown in Fig. 3, in horizontal section, there communicate with the hearth A three columns C, D, and P, one for each of the three currents, the connection being then a Y connection, the mass of molten metal in the hearth A forming the common junction for the three legs or columns of the three phase circuit.

In Fig. 4 I have shown in vertical section a plural furnace, the left hand unit being substantially the same as shown in Fig. 1. In this left hand unit the ore may be reduced or otherwise treated to form a molten mass B, as heretofore described. From time to time the tap hole Q may be opened, access to such tap hole being provided by the opening R in the opposite side of the second unit. In this second unit the refining is done by treatment by the usual slags, oxids, or other materials which may be introduced through the top opening I′, the molten mass B′ being drawn from the mass B in the first unit. Here again the liquid columns C and D, communicating with the electrodes E, E, are provided with tap holes M′ and N′ for drawing off the refined material.

By a furnace of this construction steel may be made directly from iron ore. The reduction or treatment of the ore occurs in the left hand unit and the refining in the right hand unit. By this process, steel may be made from the ore without cooling and reheating the unrefined iron. The ore is reduced by electrically produced heat in part or wholly, and with a minimum loss of heat, and therefore with a maximum efficiency.

In a furnace for making and refining steel, it is important to have a moderately large surface of molten metal for the slag and other ingredients to act upon, as some of the refining action takes place only at this surface of contact. In my furnace this surface can be made as large as one desires without changing the electrical constants, because the electrical resistance is always practically entirely in the columns, as C, D, and is not materially changed by increasing the surface or depth of the mass B in the hearth A. And the stirring action due to the "pinch effect" may be made as great as one desires even to the extent of a violent squirting of the material through the slag and material above it, thus exposing a very large surface to the slag and other materials. I may, therefore, use the furnace as shown in Fig. 1 for the direct production of steel from the ore by feeding the mixture of ore, carbon and flux in at I, which will cause the solids to be forced into the bath B of molten material, thereby coming into direct and intimate contact with it. The heated gases will give off their heat to the descending raw material, thereby also utilizing it and in addition the combustion heat of the carbon monoxid may be utilized, if burned with a blast of air, introduced at L. The reduced cast iron may then be oxidized or otherwise treated to form steel, and refined. Or the reduced molten cast iron may be drawn off into a second furnace as shown in Fig. 4 where it is oxidized into steel and refined. In either case this may be done by the well known methods of adding oxid of iron, or ore, to the pig iron to reduce the carbon, and the various slags may be added to reduce the sulfur, phosphorus, etc. All this becomes very simple and rapid in a furnace in which the heat is generated in the material of good conductivity and transferred from it by rapid agitation to the other ingredients. And as described in connection with Fig. 1, the first unit of the plural furnace shown in Fig. 4 may be replaced by an ordinary blast furnace wherein the necessary heat is secured by combustion, the molten material then being drawn off to the second unit, as above described, for further treatment.

It is possible, of course, to use this type of furnace for many other metallurgical processes besides the reduction, oxidation and refining of iron and steel. It can be used in other operations in which the heat can be transmitted from the liquid resister to the mass to be heated, like ore, slag, glass, or mixtures of materials, as for instance, in the reduction of zinc, production of arsenic either as metal or oxid from its ores, also the production of calcium carbid, ferro alloys, etc., whenever the temperature required is less than the volatilization temperature of the liquid resister. The specific gravity of the resister should then be greater than that of the material to be treated and the two materials should preferably not be miscible.

I have found that the energy loss in the furnace electrodes may be reduced greatly below what has heretofore been common practice. I have discovered the law of the electrode losses and from it I have found that for a minimum amount of loss in the electrodes, such electrodes must be so proportioned that the C^2R loss (heat generated by current in the resistance of the electrodes) shall be equal substantially or approximately to twice the heat conduction loss of the electrodes. By heat conduction loss I mean the loss of heat from the interior of the furnace through the electrodes by heat conduction, when no current is flowing. I have found that for any other relation between these two losses the combined loss becomes greater. As a result of proportioning the electrodes so that this relation shall hold, the losses of energy in and through the electrodes become very small as compared with prior practice. The total loss in the electrodes will then be equal to the electrical resistance loss only, (C^2R loss), as there will then be no heat lost by conduction, because the temperature of the hot end of the electrode will then be equal to that of the furnace, and the electrode will therefore be the equivalent of a perfect heat insulator, allowing no heat to pass through it from the furnace, although the electrode remains a very good electrical conductor. No material is known which has these two qualities combined, namely, heat insulation and electrical conductivity; but by proportioning the electrodes according to the laws which I have discovered, the practical equivalent of these two properties can nevertheless be realized. From these laws I find that the minimum loss is generally least for the metals, and that it is very considerably less than for the usual materials carbon and graphite. It is a part of my invention, therefore, that metal electrodes are employed, preferably of the same metal as is melted in the furnace, or of metal or material which does not contaminate the material or metal fused in the furnace, and thereby I can greatly reduce the electrode losses. To obtain this advantage of a lower minimum loss for metal electrodes they must be proportioned so that the heat conduction loss, with no current flowing, will be equal to half the C^2R loss approximately or substantially. But my improvement is not limited to metal electrodes, for, by observing the novel proportions herein described, carbon and graphite electrodes, giving minimum losses for those materials, may be employed, and the loss will be found to be much smaller than for the carbon and graphite electrodes as heretofore used. From the laws which I have discovered it follows that this economy of material will be greatest, that is, for any given length the cross section will be least, when the square root of the product of the electrical and the thermal conductivities is greatest. Hence, I find that as far as economy of material is concerned, those materials are best in which this product is greatest. From the conductivities of different materials as far as they are known, I find, from the law which I have discovered, that the square root of these quotients and products are as a rule greatest for the metals as distinguished from the usual electrode materials, carbon and graphite. The difference is great. Hence, I have found it much more economical to use metal electrodes whenever possible.

When metal electrodes are used and proportioned in accordance with the laws which I have discovered, they will remain solid at the external ends although they will be at the temperature of fusion at the inside or furnace ends. The reason is that when so proportioned there will be no heat conducted by the electrodes from the interior of the furnace, and all the heat generated in them by the current will be led off at the cool or outside end just as fast as it is generated in it; hence their temperature will not increase and they will remain unfused except at their extreme inside ends. If continuously covered with fused metal at their inside or hot ends they will not be consumed and if made of the same metal as that fused in the furnace, or of one which is non-miscible with the fused material, they will not contaminate the latter. This state, as I have found, is also the state of least total loss in the electrodes.

From the laws above stated I have deduced the following formula:

$$X = 2.894\, C\sqrt{krT}$$

in which X is the total minimum loss in watts in or through the electrodes, 2.894 is a constant involving no physical properties, C is the current in amperes, k is the heat conductivity in gram calories per second, cubic inch units, r the electrical resistivity in ohms, cubic inch units, and T the temperature difference between the inside and outside ends of the electrode in centigrade degrees. And I have deduced the following formula for determining the condition of proper proportions of the electrodes for minimum loss:

$$\frac{S}{L}=0.3456\ C\sqrt{\frac{r}{kT}}$$

in which S is the cross section of the electrodes in square inches, L their length in inches, C the current in amperes, r, k and T being the same as above. The electrodes must have this proportion in order to obtain the minimum loss given in the first formula.

When the thermal conductivity k in the above formulæ is expressed in watts in place of in calories per second, the numerical constants in these formulæ, namely, 2.894 and 0.3456, disappear, and a factor 2 accompanies the factor k, so that these formulæ take the form, respectively, as follows:

$$X=C\sqrt{2krT}$$

$$\frac{S}{L}=C\sqrt{\frac{r}{2kT}}$$

This second formula gives the ratio of the section to the length of the electrodes and therefore leaves a choice of either, but not of both. The length should be made as short as possible; it is usually determined by the general design and thickness of the furnace walls or other considerations. The quantity of electrode material increases as the square of the length. It follows, therefore, that in accordance with my discoveries and invention, I may greatly reduce the size of, and therefore cheapen, the electrodes heretofore used in the art and at the same time secure a minimum loss of energy in the electrodes, thus leaving greater amounts of energy for useful work within the furnace and, in consequence, increasing the efficiency of the furnace. And in a furnace involving the "pinch effect" as herein described, with a certain amount of energy available, there remains, because of this electrode efficiency, a greater amount of energy and current available within the furnace, and the greater current thus available not only produces greater heating effect, but also materially increases the "pinch effect", since that effect is dependent upon the square of the current.

If by the electrode efficiency is meant the ratio of the energy set free in the interior of the furnace, that is, between the hot ends of the two electrodes, divided by the total energy between the two cold ends, then for a given minimum loss in the electrodes, this efficiency will evidently be higher the greater the drop of voltage between the hot ends, as compared with the drop of voltage in one of the electrodes. By my invention the latter may be made very small, much smaller than heretofore, hence for a given current and voltage of a furnace there will be more useful heat generated in the furnace. But to increase this efficiency still more the drop of voltage between the two hot ends should be made as great as possible. To do this with a liquid resister may require this resister to be made long and small in section, hence I may in those cases prefer to use the arc as this has a relatively high drop of potential in a small space. Or still better I may use several arcs in series.

In Figs. 5, 7, 8 and 9 I have disclosed furnaces involving an electric arc or arcs, in certain relations, and the electrodes E, E may be such as those hereinbefore described, and the columns of molten material with which they are in direct contact may be the "pinch effect" columns hereinbefore described.

In Fig. 5 I have shown an arc furnace having the metallic electrodes E, E communicating with the separated baths B, B′ of molten material, a dividing wall or member S being provided. The arc may be started by a bridge piece such as shown in Fig. 6 made of the same metal as that in the baths B, B′, by placing the same over the dividing member S; the member then melts and an arc is formed between the two baths B and B′. Or the arc may be started by granular conducting material extending over the member S into contact with the two baths, or the baths may be agitated to come momentarily into contact with each other above the member S, or any other means may be employed. The dividing member S may be kept from fusing by a circulation of water or other cooling material through the opening or tube T. Or the magnetic blow-out principle may be used to keep the arc farther from the dividing member S. Or the member S may be made of a conductor of the second-class which will conduct after being heated by the arc.

If desired, two or more arcs may be used as shown in Figs. 7 and 8, thereby obtaining a higher heat efficiency and a single large hearth surface. It will be noted from Figs. 7 and 8 that the openings I in the cover or roof of the furnace are disposed opposite the columns and the electrodes in communication with these columns, whereby the columns or channels are readily accessible through the roof or covering of the furnace. Or the arc may be automatically started by the "pinch effect" as shown in Fig. 9, and in which the metal level is higher than the top of the dividing member S. The current passing through the constricted portion over the dividing member S will, when properly proportioned, part the metal and form an arc.

In all of the forms of furnaces herein shown, it will be noticed that the two terminals or electrodes may be brought out close together, thereby facilitating the connections to the transformer and thus increasing the power factor, since the area inclosed by the conducting loop formed within the furnace is greatly reduced. Also that the electrodes are not consumed and therefore do not contaminate the fused product and do not have to be advanced into the furnace. In consequence, the construction of the furnace is greatly simplified and cheapened. Unless proportioned as I have shown, the losses through metal electrodes may become very large due to their high heat conductivity.

By the construction and mode of operation of the furnaces I have herein described, I am enabled to heat the molten metal to so high a temperature that there is a rapid and great transfer of heat from the mass of molten metal to the slag or other treating material through their surface of contact, whereby the slag treating process or other treating process is greatly facilitated, as distinguished from those cases where the slag or other material above the molten metal is heated for the same purpose. Because of this rapidity of transfer of heat from the molten metal to the slags or other materials, a given amount of metal may be treated in a smaller furnace.

While I have herein disclosed improvements in the electrodes themselves of application to electric furnaces generally, I herein claim such electrodes only in combination with other features, and reserve for a divisional application the subject matter relating to these electrodes themselves, or their employment in other combinations.

What I claim is:

1. In an electric furnace, a hearth for containing a mass of molten material, columns or channels communicating with said hearth and adapted to be filled with molten material in communication with said molten mass to constitute the furnace resister, and electrodes in end on communication with said columns or channels, the square of the current transmitted through said electrodes to the molten material in said columns or channels with relation to the cross section of said columns or channels being great, whereby said mass of molten material is automatically stirred.

2. In an electric furnace, a molten mass, and a column of molten conducting material in communication with said mass, the ratio of the square of the furnace current transmitted through said column to the cross section of said column being great, whereby the molten material is automatically agitated by the resulting "pinch effect."

3. In an electric furnace, a mass of molten material, and a column of molten conducting material in communication with said molten mass and serving as a furnace resister, said column being of such cross section compared with the furnace current transmitted that the "pinch effect" is produced, whereby said molten material circulates.

4. In an electric furnace, a plurality of molten resisters, a molten mass forming a common connection for said resisters, whereby the currents in the different phases of a polyphase Y connected system may be transmitted through said resisters, the ratio of the square of the furnace current transmitted through each resister to the cross-section of said resister being great, whereby the molten material is automatically agitated.

5. In an electric furnace employing alternating current, a mass of molten material through which alternating current is passed, the ratio of the square of said current to the cross section of said mass being great, whereby the molten material is automatically agitated, and in contact with said molten mass electrodes proportioned for minimum electrode loss, whereby the distance between said electrodes is small and the power factor of the furnace is great.

6. In an electric furnace, the combination with a hearth adapted to hold a molten mass, of a channel adapted to contain a column of molten conducting material in communication with said molten mass, and a side or branch channel forming a communication between said first named channel and said hearth, the ratio of the square of the furnace current transmitted through the column in said first mentioned channel to the cross section of said column being great, whereby the molten material is automatically agitated.

7. In an electric furnace, the combination with a hearth adapted to hold a molten mass, of a channel adapted to contain a column of molten conducting material in communication with said molten mass, and a side or branch channel forming a communication between said first named channel and said hearth, the ratios of the squares of the furnace currents transmitted through the columns in said channels to the cross sections of said columns being great, whereby the molten material is automatically agitated.

8. In an electric furnace, a column of conducting material serving as a resister, the ratio of the square of the furnace current transmitted through said column to the cross section of said column being great, whereby the molten material is automatically agitated, and an electrode of substantially the same cross section as said column in electrical communication with said column of molten material, said electrode being so proportioned that the furnace current passing therethrough to said column raises said electrode at its furnace end by its own

resistance to a temperature substantially equal to furnace temperature.

9. In an electric furnace, the combination with a hearth adapted to hold a molten mass, an electrode, a plurality of channels adapted to contain molten conducting material in communication with said electrode and with said molten mass, the ratios of the squares of the furnace currents transmitted through the conducting material in said channels to the cross sections of said channels being great, whereby the molten material is automatically agitated.

10. In an electric furnace, a hearth adapted to hold a mass of molten material, and a channel communicating with said hearth and adapted to contain a column of molten material in communication with said mass of molten material, and a contraction in said channel near its communication with said hearth.

11. An electric furnace provided with a hearth for containing a bath of molten conducting material, a molten column in communication with said bath, the ratio of the square of the furnace current transmitted through said column to the cross section of said column being great, whereby the molten material is automatically agitated by the resulting "pinch effect."

12. In an electric furnace, the combination with a mass of molten material, of a molten mass in communication therewith serving as resister, the ratio of the square of the current through said resister to its cross section being great, whereby circulation of molten metal is produced, and an electrode in communication with said resister having such dimensions that the C^2R heat developed in said electrode by the current traversing said resister shall be equal to substantially twice the heat conduction loss through said electrode when no current is flowing.

13. In an electric furnace, a mass of molten conducting material, means for passing an electric current through said molten material, and means for giving to said molten material through which said current is passed a predetermined cross section, the ratio of the square of said current transmitted through said material to said cross section of said material being great, whereby the molten material is automatically agitated by the resulting "pinch effect."

14. In an electric furnace, a mass of molten conducting material, means for passing an electric current through said molten material, and means for giving to said molten material through which said current is passed a predetermined cross section, the ratio of the square of said current transmitted through said molten material to said cross section of said molten material being great, whereby the "pinch effect" caused in said material and the hydro-static pressure due to said material causes circulation or agitation of said molten material.

15. In an electric furnace, a molten conducting mass, means for passing an electric current therethrough, and means for giving to said mass through which said current is passed a predetermined cross section, the ratio of the square of the current transmitted through said mass to said cross section of said mass being great, whereby the "pinch effect" is produced in said mass to cause a continued circulation of said molten mass.

16. The method of treating a mass of molten material in an electric furnace, which consists in passing through said molten material an electric current so proportioned to the cross section of said material as to produce the pinch effect, whereby said molten material is automatically agitated.

17. The method of treating a mass of molten material in an electric furnace, which consists in passing through said molten material an electric current so proportioned to the cross section of said material as to produce the pinch effect, whereby said molten material is automatically continuously stirred.

18. The method of treating a bath of molten material in an electric furnace, which consists in passing an electric current through a mass of molten material in communication with said bath, said electric current so proportioned with respect to the cross section of said mass as to produce the pinch effect, whereby the molten material is automatically agitated.

19. The method of treating a bath of molten material in an electric furnace, which consists in passing an electric current through a mass of molten material in communication with said bath, said electric current so proportioned with respect to the cross section of said mass as to produce the pinch effect, whereby the molten material is automatically continuously stirred.

20. The method of treating a mass of molten material, which consists in passing through said molten material an electric current so proportioned with respect to the cross section of said material as to produce the pinch effect, said pinch effect and the hydrostatic pressure due to said molten material causing a continued circulation of said molten material.

21. The method of treating a mass of molten material, which consists in passing through a portion of the entire mass an electric current so proportioned with respect to the cross section of said portion that the pinch effect is produced, whereby continued automatic circulation of the molten material is produced.

22. The furnace process of treating a mass

of molten material, which consists in passing through a portion of the mass of molten material an electric current, the current strength compared with the cross section of said portion of the molten material being so great that the "pinch effect" is produced, whereby automatic circulation of the molten material is produced.

23. In an electric furnace, a mass of molten material, means for passing an electric current through said molten material, and means for giving to said molten material through which said current is passed a predetermined cross section, said current passing through said cross section of said material electrically heating said mass of molten material, and the strength of said heating current compared with said cross section of said molten material being great, whereby said molten material is automatically agitated by the resulting "pinch effect."

24. The method of treating a mass of molten material in an electric furnace, which consists in passing through said molten material an electric current sufficient to produce a recurring or continued "pinch effect".

25. The method of treating a mass of molten material in an electric furnace, which consists in passing through a portion of said mass of molten material an electric current sufficient to produce in said portion a recurring or continued "pinch effect", whereby said molten material is automatically agitated.

26. The method of treating a mass of molten material in an electric furnace, which consists in passing through said molten material a heating current, said heating current causing in said material a recurring or continued "pinch effect", whereby said heating current automatically stirs said molten material.

27. The method of treating a mass of molten material in an electric furnace, which consists in passing a heating current through a register, said heating current being sufficient to cause a recurring or continued "pinch effect", whereby said heating current automatically stirs said molten material.

28. As an improvement in the art of operating an electric furnace, the process which consists in passing through a mass of molten material a current sufficient to produce a "pinch effect" to divide the mass of molten material, and drawing an arc between the parts of said mass so divided.

29. The process of treating a mass of molten material in an electric furnace, which consists in passing through said material a current to cause a recurring or continued "pinch effect", and subjecting said molten material to the effects of an electric arc.

30. The process of treating a mass of molten material in an electric furnace, which consists in passing through said molten material a current causing a recurring or continued "pinch effect", producing an electric arc, and subjecting said molten material to heat derived from said arc.

31. The electric furnace process which consists in bringing raw material into contact with a bath of molten material, passing an electric current through said molten material to produce the "pinch effect", whereby said molten material is automatically stirred, liberating combustible gases from said raw material, and burning said gases in contact with said raw material within said furnace to preheat said raw material.

32. The electric furnace process which consists in bringing raw material into contact with a bath of molten material, and passing an electric current through said molten material to produce a "pinch effect", whereby said molten material is projected against said raw material to transfer heat thereto.

33. The process of reducing oxid ores, which consists in producing a bath of molten metal reduced from the oxid ore, passing a current through said molten metal to produce therein the "pinch effect", whereby said molten metal is brought into intimate contact with the oxid ore, and dissolving carbon and the oxid ore in said molten metal, whereby the dissolved carbon and dissolved oxid ore react upon each other to reduce said oxid ore to metal.

34. The process of reducing oxid ores, which consists in producing molten metal, bringing the oxid ore and carbon into contact with said molten metal, passing an electric current through said molten metal to produce the "pinch effect", whereby said molten metal is brought into intimate contact with said carbon and oxid ore, dissolving carbon and the oxid ore in said molten metal, liberating combustible gases, and burning said combustible gases and adding resulting heat to the raw material.

35. The process of reducing oxid ores, which consists in producing molten metal reduced from the oxid ore, passing current through said molten metal to produce the "pinch effect", whereby said molten metal is automatically stirred, dissolving carbon and oxid ore in said molten metal, liberating carbon monoxid, and burning said carbon monoxid and adding resulting heat to the raw material.

36. An electric furnace comprising a hearth and a cover therefor, a channel in communication with said hearth, and an opening in said cover in substantial alinement with said channel.

37. The electric furnace process which consists in passing a current through molten

material, said current producing heat in said molten material sufficient to maintain the same molten, and the ratio of the square of said current to the cross section of the path of said current through said molten material being great, whereby said molten material is automatically stirred by the resulting "pinch effect".

In testimony whereof I have hereunto affixed my signature in the presence of the two subscribing witnesses.

CARL HERING.

Witnesses:
MAY E. GILL,
A. E. STEINBOCK.

Corrections in Letters Patent No. 988,936.

It is hereby certified that in Letters Patent No. 988,936, granted April 4, 1911, upon the application of Carl Hering, of Philadelphia, Pennsylvania, for an improvement in "Electric-Furnace Processes and Electric Furnaces," errors appear in the printed specification requiring correction as follows: Throughout the specification and claims the word "resister" should read *resistor* and the word "resisters" should read *resistors;* page 2, line 12, after the word "material" the word *or* should be inserted; page 7, line 37, the word "metal" should read *material;* page 8, line 48, the word "register" should read *resistor;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 9th day of May, A. D., 1911.

[SEAL.]

C. C. BILLINGS,
Acting Commissioner of Patents.