

C. HERING.
ELECTRIC FURNACE PROCESS AND ELECTRIC FURNACE.
APPLICATION FILED JULY 16, 1911.

1,105,656.

Patented Aug. 4, 1914.

3 SHEETS-SHEET 1.

FIG. 4.

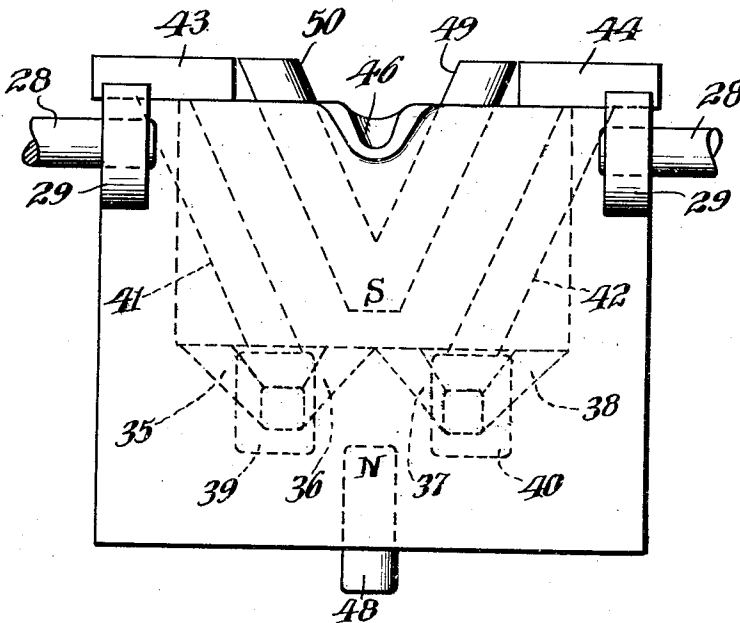
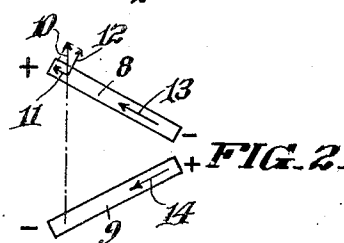
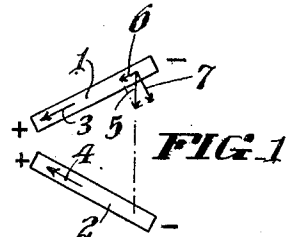
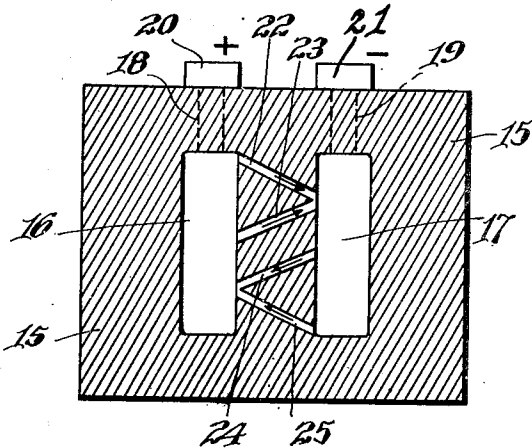


FIG. 3.



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Witnesses

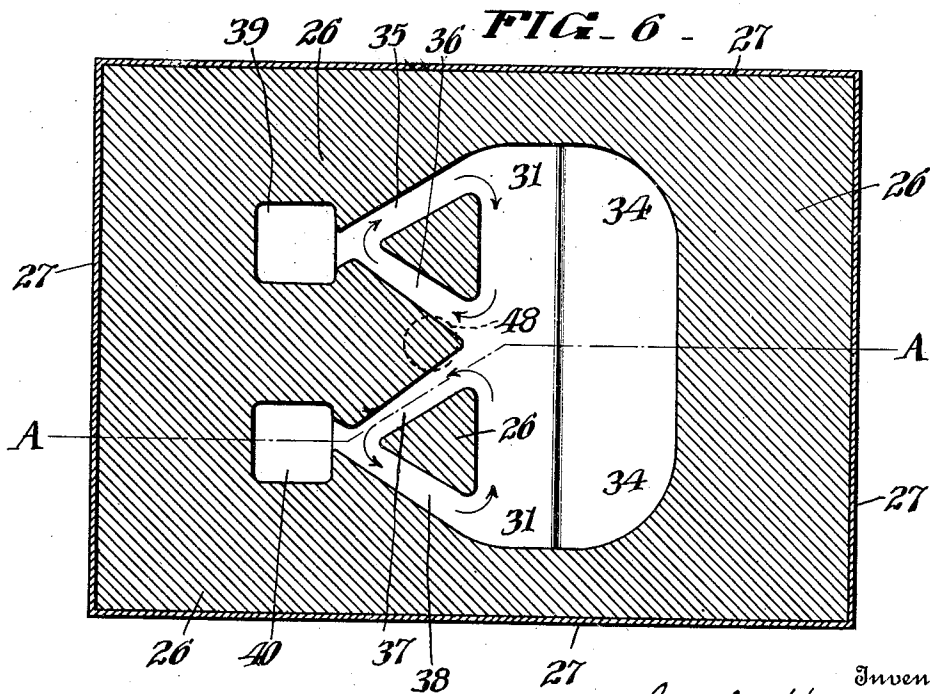
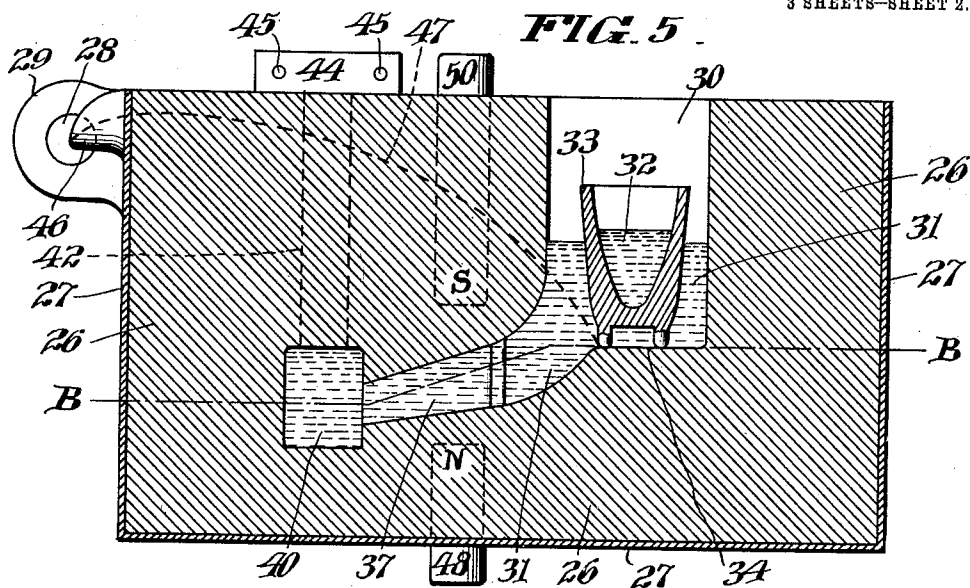
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3 SHEETS-SHEET 2.



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3 SHEETS—SHEET 3.

FIG. 7.

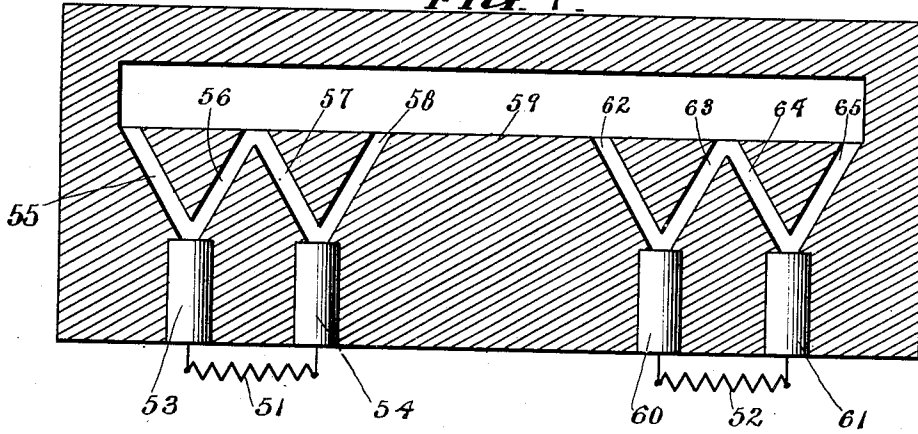


FIG. 8.

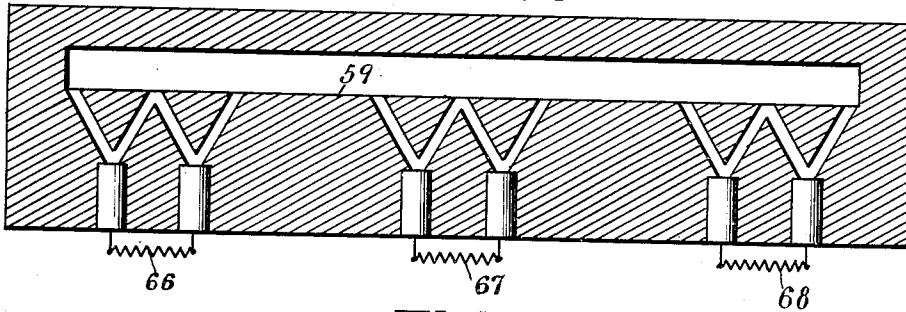
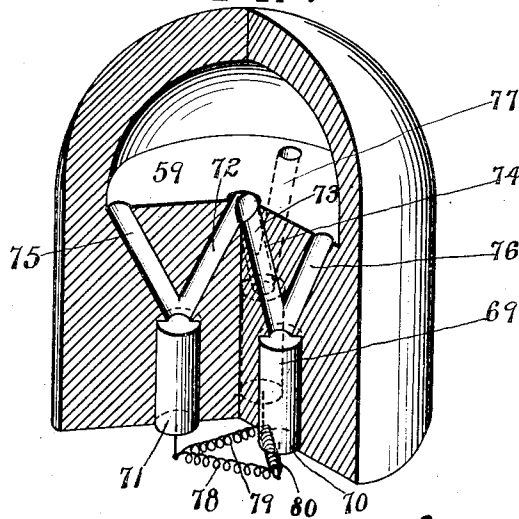


FIG. 9.



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ELECTRIC-FURNACE PROCESS AND ELECTRIC FURNACE.

1,105,656.

Specification of Letters Patent.

Patented Aug. 4, 1914.

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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 certain new and useful Improvements in Electric-Furnace Processes and Electric Furnaces, of which the following is a specification.

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

My invention relates particularly to electric furnaces in which channels or tubes containing molten conducting material are employed, such molten material in the channels constituting a resistor or resistors, in which the heat is generated, or in some cases the molten material outside of the channels constitutes the resistor or resistors, or a portion of same.

My invention resides in part in electric furnaces of the type above referred to in which a plurality of tubes or channels containing molten conducting material communicate with a single electrode, or in which one or more tubes or channels are so arranged as to conduct currents which react upon each other or upon other parts of the circuit like the electrodes, in such manner as to cause a flow of the molten material through a channel or channels or tubes, with resultant automatic circulation, stirring or agitation of the molten material. To this end I construct an electric furnace in such a way that the current in one part of the molten material reacts upon the current in another part of the molten material, so that the resultant forces acting upon the molten material itself cause a flow of such molten material which produces automatic circulation, stirring or agitation which greatly aids in the distribution of the heat within the molten material together with an improvement in the time and effectiveness of treatment of the molten material or of anything heated thereby.

My invention resides in features of construction and the process hereinafter described and claimed.

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

Figure 1 is a diagram illustrating the

mechanical reaction of electric currents upon each other when flowing in like directions through two inclined channels. Fig. 2 is a similar diagram illustrating the mechanical reaction of electric currents upon each other when the currents in the two channels flow in opposite directions with respect to each other. Fig. 3 is an illustration of a simple arrangement of channels in an electric furnace for utilizing these reactions of currents in such channels. Fig. 4 is a front elevational view of a further form of furnace involving my invention. Fig. 5 is a vertical sectional view taken on the broken line A—A of Fig. 6. Fig. 6 is a horizontal sectional view taken on the broken line B—B of Fig. 5, Figs. 5 and 6 being views of the same furnace illustrated in Fig. 4. Fig. 7 is an illustration of the application of two phase current. Fig. 8 is an illustration of an application of three phase current. Fig. 9 is a modified application of three phase current.

For purposes of illustration of the theory of operation of my improved furnace (by which theory I do not wish to be in any way bound) reference may be had to Fig. 1, in which 1 and 2 represent channels containing molten or fluid conducting material, disposed at an angle with respect to each other. Assume currents to flow from + to -, that is, from left to right in both channels; then, since conductors carrying currents flowing in like direction attract each other there will be exerted a force of attraction between the elemental conductors, or particles of the conducting molten material or fluid; that is to say, there will be a force exerted by the material in channel 1 attracting the material in channel 2; and there will be an attractive force exerted by the material in channel 2 upon the material in channel 1. Since the two channels are inclined with respect to each other, the result of these attracting forces will be that the fluid or molten material in the channels will tend to flow toward the left hand ends of these channels as indicated by the arrows 3 and 4. This is apparent from the parallelogram of forces one of which is illustrated in connection with channel 1. Here the force exerted upon a particle of molten material in the channel 1 by another particle in the channel 2 may be represented in quantity and direction by the arrow 5. Resolving this force into its two components, one in the direction of the channel 1 and the other at right angles thereto,

the component forces will be represented by the arrows 6 and 7 respectively. The arrow 6, therefore, represents both as to magnitude and direction the axial force exerted upon a particle of molten material in the channel 1 by the attracting force 5. This shows that the molten material in both channels will flow in the direction of the arrows 3 and 4.

In Fig. 2 the channels 8 and 9 contain conducting molten or fluid material, and are disposed at an angle with respect to each other as shown. The current flows from + to - in each channel, that is, from left to right, in channel 8, and from right to left in channel 9. Here the conductors carry currents flowing in unlike directions, therefore causing a mutual repulsion. This repulsive force upon a particle of the molten material or fluid in channel 8 may be represented in direction and magnitude by the arrow 10. Resolving this into its two component forces, one in the direction of the channel 8 and the other at right angles thereto, by means of the parallelogram of forces, the forces will be represented respectively by the arrows 11 and 12, showing that in channel 8 the fluid will flow from the right toward the left; and the same is true of the material in channel 9, these directions of fluid flow being indicated by the arrows 13 and 14 respectively.

Obviously, in Fig. 1 the channels 1 and 2 may come together at their left ends and the current enter there and divide between the two columns and flow outwardly to some conductor not shown. And likewise, in Fig. 2, the right-hand ends of the channels may come together and the current flow in at the left of channel 8 and out at the left of channel 9. In these cases the forces will be the same as previously described.

While in both Figs. 1 and 2 I have shown conducting fluids in a pair of channels or tubes inclined with respect to each other, it is to be understood that the movement of the fluid in a single tube or channel may be likewise obtained by passing a current there-through and through a solid or gaseous conductor disposed at an angle to the tube or channel, instead of through another mass of fluid in another channel. In such case, the reactions are the same as hereinbefore described, but the movement will take place only in the fluid, though there is probably also exerted an axial force in the solid or gaseous conductor. As the direction of the flow of material produced by these forces will be the same when the electric current is reversed in both the channels, it is evident that the direction of the flow will be the same whether the current is direct or alternating.

It has been denied by some that the attraction and repulsion of neighboring currents can produce any axial forces in the conductors carrying those currents. I have, nevertheless, found, by the actual construc-

tion and operation of apparatus, that such axial forces are in fact produced, and I believe my theory above given explains the production of such axial forces. As an illustration of a simple application of this principle reference may be had to Fig. 3, in which 15 represents the furnace wall of non-conducting material within which are two chambers 16 and 17 containing molten conducting material or conducting fluid, an electrode 18 communicating with the conducting material in the chamber 16 and an electrode 19 communicating with the conducting material in the chamber 17. The outer terminals of these electrodes are represented at 20 and 21 respectively. 22, 23, 24 and 25 are channels connecting the two chambers 16 and 17; these channels may be open at the top or in the form of tubes below the liquid level. Assuming the terminal 20 to be the positive terminal and 21 to be the negative terminal, current enters through electrode 18 and passes through the conducting material in the chamber 16 and thence through the conducting material in the channels 22, 23, 24 and 25 to the conducting material in the chamber 17 and thence outwardly by the electrode 19. The material in the channels 22 and 23 will then flow as indicated by the arrows, in accordance with Fig. 1, from the left toward the right; and similarly the molten material in the channels 24 and 25 will flow in the direction of the arrows, from right to left. It follows, therefore, that there is an automatic and continuous circulation of the molten material from chamber 16 through both channels 22 and 23 into chamber 17 and from chamber 17 through both channels 24 and 25 back into the chamber 16. In actual practice it may be found desirable to have the pair of channels 22 and 23 separated to a greater distance than indicated from the pair of channels 24 and 25. There may also be some reaction between the parallel channels 23 and 24, tending to produce flows in the direction of the arrows, due to the fact that the line joining their centers is oblique to the channels.

For a further form of electric furnace involving this principle, reference is had to Figs. 4, 5 and 6. Here the refractory non-conducting material 26 of the furnace may be inclosed in a metal jacket 27 and the entire furnace supported upon the coaxial pivots 28 engaging in the pivot ears 29 upon the furnace. Within the refractory material 26 is formed a cavity or hearth 30 adapted to contain the molten conducting material or conducting fluid 31 which may be the material under treatment in the furnace, or which may be used to heat the material 32 within a crucible 33 which may rest upon the ledge 34 in the chamber 30; or the crucible may be held down in the position

shown by weights or other means, or may float in the molten material 31, according to the density and depth of the material 32 within the crucible. The crucible 33 is omitted in Figs. 4 and 6 for the purpose of clearness. With the trough 31 communicate the four channels or tubes 35, 36, 37 and 38. These channels are filled with the molten conducting material or conducting fluid and such molten material or fluid extends back into the cavities 39 and 40 filling the same and contacting with the electrodes 41 and 42, respectively. These electrodes extend to the exterior of the furnace and are provided with terminals 43 and 44 respectively, which may have the ducts 45 for conveying a cooling liquid to keep the exterior terminals of the electrodes cool. The current flows in through one electrode, as 41, into the molten material in chamber 39, thence in parallel through the molten material in the channels 35 and 36, thence through the molten material 31, thence through the molten material in the channels 37 and 38 in parallel to the molten material in chamber 40 and thence outwardly by the other electrode 42. And it will be observed that current from the material in chamber 39 flows in series through the pairs of channels into the material in chamber 40, and the same series flow of current occurs through either channel of a pair with either channel of the other pair. Therefore, according to the resultant forces hereinbefore described, the molten material or fluid will flow from the bath 31 toward the chambers 39 and 40 through channels 36 and 37, and will flow from the chambers 39 and 40 through channels 35 and 38 to the bath 31. As to the channels 36 and 37, the currents therein are in opposite directions and produce an action similar to that described in connection with Fig. 2. Furthermore, this action in these two channels 36 and 37 will be the strongest since they are nearest each other. And the mutual actions of the currents in the outside channels 35 and 38 will cause the material to flow from the chambers 39 and 40 to the bath 31. It follows, therefore, that the actions of the currents in the four tubes or channels will be such as to cause the liquid to flow in two streams, one through each pair of tubes or channels, as indicated by the arrows. This will cause a continued circulation of the fluid through the channels, and a stirring or automatic agitation of the main body of the fluid or molten material in the hearth 30. The molten material in these channels 35, 36, 37 and 38 may constitute the furnace resistors in which the C²R heat is mainly produced; and due to the automatic circulation, stirring or agitation described this heat is bodily conveyed, with the moving molten material into the bath 31. It is to be understood, however, that the

bath 31 may be of such proportions as to itself also constitute a furnace resistor or a part thereof; and, of course, more or less C²R heat may be generated in the material in the cavities 39 and 40, as may be desired. 70

One of the chief difficulties in furnaces in which the heat is generated mainly in a relatively small restrained portion of the total charge, is to cause this heated portion to circulate rapidly through the small channels or tubes in which it is restrained while being heated. Unless such circulation is rapid the material will tend to overheat and volatilize, or else the generation of heat in the furnace can be only relatively slow. By a rapid circulation therefore this difficulty is overcome. In the production of this automatic stirring or circulation the currents through the channels 35 and 36 react on each other producing an additional force in the channel 36 in the direction indicated by the arrow, but the force produced in the material in channel or tube 35 will be opposite to the one indicated by the arrow; but as the material flows through these two channels in series, all the forces developed in both of them must be added algebraically and it will then be found that the preponderating force in tube or channel 35 is in the desired direction as indicated by the arrow. 75 80 85 90 95

And the same is true with respect to channels or tubes 37 and 38. But whatever the individual forces may be, or whatever may be the true theory concerning their cause and origin, it is a fact demonstrated by actual practice that the fluid or molten material flow is always decidedly in the directions indicated by the arrows. 100

Communication is afforded from the chamber 30 containing the material 31 to the pouring lip 46 through a passage or channel whose lower surface is indicated in Fig. 5 by the line 47. The pouring lip is coaxial with the pivotal axis of the furnace, thus facilitating the act of pouring the molten material or fluid. The channels 35 to 38 inclusive are inclined downwardly from the lower portion of the chamber 30, away from the bottom of the bath 31, and toward the side from which the metal is poured, so that when the furnace is tilted upon its pivots 28 and the molten material poured out some of the molten material will always remain in the tubes and in the lower part of the bath or puddle in the chamber 30 connecting the right-hand ends of the tubes or channels, as viewed in Figs. 4 and 6, thus making it possible to easily restart another charge in the furnace, and preventing the complete emptying of the channels or tubes, which would interrupt the circuit. These channels or tubes at their juncture with the puddle 31 are undercut, as indicated, to hold a larger body of molten material for starting the next charge. 105 110 115 120 125 130

From Fig. 6 it will be noted that the junctions of the channels 35 to 38 inclusive with the electrodes 41 and 42 are preferably made by means of the enlarged cavities 39 and 40. The purpose is to prevent the melting from extending into the electrodes, and the loss of heat from these cavities through the walls, the increase of cross sections in these enlarged cavities tend to prevent such high temperatures in this vicinity as to cause such melting. It will be noted also that the electrodes 41 and 42 are inclined, and that they are brought out from the top of the furnace, so as to avoid the possibility of leakage of molten material, which might otherwise occur if the electrodes were brought out through the bottom of the furnace, or through the lower parts of the sides of the furnace. Either or both electrodes may be disposed at an angle with one or more of the tubes or channels. The current flowing in an electrode then reacts upon the current in the material in the channel or tube producing in the fluid material in the channel or tube a force having a component which, if the inclination be suitable, and the current in the proper direction, will be cumulative with the other forces produced in the material in the channel or tube, hence will assist in producing the flow. Or in some cases, I may have a single tube or channel so related with the electrode as to produce a flow within the channel or tube, without regard to the flow already set up therein by the influence of another current in another channel or tube, or in another conductor. It will be noted also that the corners and edges are rounded off in all parts of the furnace containing the molten material, so as to secure easy flow of the material. By the employment of a crucible immersed in the heated bath, as shown in Fig. 5, materials which are not conductors may be treated, or where small amounts of material are to be treated, whether conductors or not, the employment of the crucible is advantageous.

Obviously, one terminal of an electric supply circuit is connected to one electrode and the other terminal of the circuit to another electrode of any of the furnaces herein disclosed or employing the principle herein described. The current supplied may be either direct or alternating; and the usual means for controlling the voltage and quantity of such current are to be employed whenever regulation or adjustment is required. Where alternating currents are employed they may, of course, be either single-phase, two-phase, three-phase, or multiphase; for a three-phase current there would be three electrodes with their respective channels.

In Fig. 7, 51 and 52 represent the secondaries of a two phase transformer, or the

secondaries of transformers delivering currents dephased 90 degrees with respect to each other. With the terminals of the secondary 51 communicate the electrodes 53 and 54; with the electrode 53 communicate the two resistors 55 and 56, molten material in channels, as in the preceding figures; and with the electrode 54 communicate similar resistors 57 and 58, the upper ends of all these resistors communicating with the bath of molten material upon the hearth 59. And similarly with the terminals of secondary 52 communicate the electrodes 60, 61. With the electrode 60 communicate the resistors 62 and 63; and with the electrode 61 communicate the resistors 64 and 65, all these resistors communicating at their upper ends with the bath upon the hearth 59.

In Fig. 8 a similar arrangement is shown for three phase currents, where 66, 67 and 68 represent secondaries of the three phase transformer, each secondary having two electrodes, and each electrode having two resistor channels, and the upper ends of all these resistors communicating with the bath upon the hearth 59.

In Fig. 9 only three electrodes 69, 70 and 71 are employed each having two resistor columns communicating at their upper ends with the bath upon the hearth 59. The resistor columns for each electrode are inclined with respect to each other. 75 is a companion resistor to resistor 72 of electrode 71; 76 is the companion to resistor 73 for electrode 70; and 77 is the companion to resistor 74 of electrode 69. To the three electrodes are connected the secondaries 78, 79 and 80 of a three phase transformer, the connection illustrated being in the delta arrangement. It is to be understood however that any other suitable connection may be employed, as for example, the Y connection.

In Figs. 7, 8 and 9 the principle of operation is the same as described in the preceding figures, the reactions of the currents upon each other producing the same effect, the pinch effect also assisting where desired.

The forces may be augmented when employing either direct current or alternating current by recourse to magnetic material, which may be arranged in any suitable position, one arrangement being indicated in Figs. 4, 5 and 6. Here a mass of magnetic material 48 may be inserted from the bottom of the furnace and have its north pole, N, for example, disposed as indicated. Above it may be disposed a south pole, S, of a second mass of magnetizable material 49 which may be inclined, as shown in Fig. 4, so as to come outside of the channel leading to the pouring lip 46. A duplicate mass of magnetizable material 50 may be employed in connection with the mass 49. When direct current is employed in the furnace these

masses of magnetizable material may be permanent magnets, or they may be electro-magnets maintaining north and south poles, for example, as indicated. Or these masses 5 48, 49 and 50 may be simply soft iron. When alternating current is employed these magnetizable masses 48, 49 and 50 may be simply soft iron, preferably laminated, or any of them may be the soft iron, preferably 10 laminated, core of an electro-magnet traversed by alternating current of the same frequency as that passed through the furnace. The winding may be in series in the same circuit with the electrodes 41 and 42, 15 or may be a shunt winding connected in derivation with the furnace electrodes. In fact, the arrangement may be anything desired so long as the magnetism in these masses reverses synchronously with the reversals of current through the conducting 20 molten material. In all cases these masses of magnetizable material are so placed and of such polarity as to increase the effect which produces the forces causing the 25 molten material or fluid to flow.

The cross sections of the tubes or channels of any of the furnaces hereinbefore described, or of any furnace employing the principle hereinbefore set forth, may be so 30 proportioned with respect to the square of the current flowing through the material in such tubes or channels as to produce an axial force due to the "pinch effect" as described in Letters Patent of the United 35 States No. 988,936, granted to me on April 4, 1911. Such "pinch effect" in itself produces a force within a single tube or channel, without regard to any other tube or channel, which will cause a circulation or 40 movement of the molten material. The force exerted by such "pinch effect" may be exercised in either direction through a channel or tube. But when used in connection with the furnaces employing the principle 45 hereinbefore described, the forces hereinbefore described are set up in a definite direction and then the "pinch effect" forces take up the same direction and are cumulative therewith.

50 In Fig. 6 the channel 36 enters the channel 35 through the side of the latter; hence any "pinch effect" produced in channel 36 is added to that in 35, hence the total is equal approximately to their sum, as described in my patent referred to above. It 55 is a feature of my invention, therefore, that in addition to the production of forces as hereinbefore described by the employment of separate tubes or channels, I may augment such forces by recourse to the "pinch effect" 60 which is obtained by making the ratio of the square of the current transmitted through a tube or channel with respect to the cross section of such tube or channel great. Ob-

viously, this same current which produces 65 the forces hereinbefore described, and which may also produce the "pinch effect," may be the current which produces the C²R heat for raising the temperature of the material in the furnace; or this C²R heat may be 70 developed principally within the channels or tubes, or may be outside of them as occasion may require.

While the tubes or channels herein shown are disposed substantially in the same plane, 75 and are substantially straight, it is to be understood that my invention is not limited to such arrangement, because the tubes or channels of a pair or plurality of pairs need not be disposed in the same plane, but may 80 be disposed in different planes and they need not be straight but may be curved or otherwise shaped. For with curved tubes or channels, and with tubes or channels of a pair or plurality of pairs disposed in dif- 85 ferent planes, these forces still act to a greater or less degree, so long as the reactions of the currents in a pair of channels is such as to produce a force which has a component in the direction of the tube or 90 channel.

The furnaces employing the principles herein described have the advantage that, since the flow is in one direction only in each tube or channel, the tube or channel can be 95 made long and small in diameter, thus adapting such furnaces to the treatment of low resistance materials, like copper or its alloys; and this arrangement is adaptable also to furnaces of small size in which the 100 tubes or channels necessarily become small in diameter. It is evident that in such a furnace I may also use various methods of applying auxiliary heat, such as from an electric arc, or from fuel as in the form 105 of a blast flame.

I do not herein lay claim to the specific features of structure illustrated in Fig. 9, but lay claim herein to the employment of three electrodes with a three phase current 110 supply, each electrode having a pair of resistors inclined with respect to each other, as shown, for example, in Figs. 8 and 9. And I reserve for another application the subject matter of Fig. 9 not herein claimed. 115

What I claim is:

1. As an improvement in the art of producing motion in a fluid, the method which consists in dividing the fluid into a plurality of masses in channels or tubes disposed 120 at an angle with respect to each other, each of said channels or tubes being open at both ends, and passing electric current through said fluid in said tubes or channels, whereby forces are exerted upon said fluid causing 125 flow thereof through said tubes or channels.
2. As an improvement in the art of producing motion in a fluid, the method which

consists in passing electric current through fluid disposed in a tube or channel open at both its ends, and passing electric current through a conductor disposed at an angle with respect to said tube or channel, whereby force is exerted upon said fluid causing flow thereof through said tube or channel.

3. The method of treating fluid material in an electric furnace, which consists in passing electric current through said fluid material disposed between masses of fluid comprising with said fluid material a circulatory system, and passing electric current through a conductor disposed at an angle with the longitudinal extent of said fluid material, whereby said fluid material is caused to flow by the force exerted thereon by the current in said conductor.

4. The method of treating molten metal in an electric furnace, which consists in passing electric current through said molten metal disposed between masses of conducting fluid comprising with said molten metal a circulatory system, and passing electric current through a conductor disposed at an angle with the longitudinal extent of said molten metal, whereby said molten metal is automatically circulated by the force exerted thereon by the current in said conductor.

5. The method of treating a mass of molten material in an electric furnace, which consists in passing electric current through a portion of said mass of molten material disposed with the remainder of said mass in a circulatory system, and passing electric current through a conductor disposed at an angle with respect to the longitudinal extent of said portion of molten material, whereby said molten material is automatically circulated by the force exerted thereon by the current in said conductor.

6. The method of treating a mass of molten material in an electric furnace, which consists in passing electric current through the molten material disposed in tubes or channels at an angle with respect to each other, the molten material in each tube or channel disposed in a circulatory system with molten material communicating with both ends of said tube or channel, whereby the molten material in said tubes or channels is caused to flow therethrough by force exerted by said current.

7. The method of treating a mass of molten material in an electric furnace, which consists in passing electric current in multiple through the molten material disposed in tubes or channels at an angle with respect to each other, whereby the molten material in said tubes or channels is caused to flow.

8. The method of treating a mass of molten material in an electric furnace, which consists in passing electric current in series through the molten material disposed in tubes or channels at an angle with respect

to each other, the molten material in each tube or channel disposed in a circulatory system with molten material communicating with both ends of said tube or channel, whereby the molten material in said tubes or channels is caused to flow therethrough by force exerted by said current.

9. The method of treating material in an electric furnace, which consists in passing electric current through fluid disposed in a tube or channel in said furnace, said tube or channel communicating at both its ends with masses of fluid comprising with said fluid in said tube or channel a circulatory system, and passing electric current through an electrode disposed at an angle with respect to said tube or channel, whereby said fluid is caused to flow therethrough by force exerted by said current.

10. The method of treating a mass of fluid conducting material in an electric furnace, which consists in disposing a portion of said material in a tube or channel and in communication therethrough with different portions of said mass of fluid material to constitute a circulatory system, passing an electric current through the fluid disposed in said tube or channel, and passing an electric current through a conductor disposed at an angle with respect to said tube or channel, whereby the reactions of said currents in said conductor and of said fluid in said tube or channel produce forces having components in the direction of the extent of said tube or channel, whereby said fluid is caused to flow through said tube or channel.

11. The method of treating material in an electric furnace, which consists in passing electric current through fluid material in tubes or channels disposed at an angle with each other and each open at both its ends, and passing electric current through an electrode disposed at an angle with one or more of said tubes or channels, whereby said fluid material is caused to flow through said tubes or channels.

12. The method of treating material in an electric furnace, which consists in passing electric current through fluid material in tubes or channels disposed at an angle with each other and each open at both its ends, and passing said electric current through an electrode disposed at an angle with one or more of said tubes or channels, whereby said fluid material is caused to flow through said tubes or channels.

13. As an improvement in the art of producing motion in a fluid, the method which consists in passing electric current through fluid disposed in a tube or channel open at both its ends, the strength of said current being so great with respect to the cross section of said fluid as to produce therein a continued or recurring "pinch effect," and passing electric current through a conductor

disposed at an angle with respect to said tube or channel, whereby said fluid is caused to flow through said tube or channel.

14. The method of treating molten material in an electric furnace, which consists in passing electric current through said molten material disposed in a tube or channel open at both its ends, the strength of said current being so great with respect to the cross section of said molten material as to produce therein a continued or recurring "pinch effect," and passing electric current through a conductor disposed at an angle with said tube or channel, whereby said molten material is caused to flow through said tube or channel.

15. As an improvement in the art of producing motion in a fluid, the method which consists in passing electric current through fluid disposed in a tube or channel open at both its ends, the strength of said current being so great with respect to the cross section of said fluid as to produce therein a continued or recurring "pinch effect," and passing electric current through a fluid conductor disposed in a tube or channel at an angle with respect to said tube or channel, whereby said fluid is caused to flow through said tube or channel.

16. The method of treating fluid material in an electric furnace, which consists in passing electric current through said fluid material disposed in a tube or channel open at both its ends, the strength of said current being so great with respect to the cross section of said fluid as to produce therein a continued or recurring "pinch effect," and passing electric current through a conductor disposed at an angle with said tube or channel, whereby said fluid material flows through said tube or channel, said fluid material constituting a furnace resistor heated by said current.

17. The method of treating fluid material in an electric furnace, which consists in passing electric current through fluid material disposed in tubes or channels at an angle with respect to each other and each open at both its ends, the strength of the current through the fluid material in one or more of said tubes or channels being so great with respect to the cross section of said fluid material that there is produced therein a continued or recurring "pinch effect," whereby the molten material in said tubes or channels is caused to flow there-through.

18. The method of treating fluid material in an electric furnace, which consists in passing electric current through fluid material disposed in tubes or channels at an angle with respect to each other and each open at both its ends, the strength of the current through the fluid material in one or more of said tubes or channels being so

great with respect to the cross section of said fluid material that there is produced therein a continued or recurring "pinch effect," whereby the molten material in said tubes or channels is caused to flow there-through, the fluid material in one or more of said tubes or channels constituting a furnace resistor heated by the current passed therethrough.

19. The method of treating material in an electric furnace, which consists in confining said material in a container, transmitting heat to said material through said container from heated fluid material contacting the walls of said container, heating said fluid material by passing electric current therethrough, and causing a flow of said fluid material by reaction of the current passed therethrough upon current in a conductor disposed at an angle with said fluid material.

20. As an improvement in the art of producing motion in a fluid, the method which consists in passing electric current through fluid disposed in a tube or channel, and passing electric current through a conductor disposed at an angle with respect to said tube or channel, whereby force is exerted upon said fluid in the direction of said tube or channel, and augmenting said force by subjecting said fluid in said tube or channel to a magnetic field.

21. As an improvement in the art of producing motion in a fluid, the method which consists in passing an electric current through fluid disposed in a tube or channel, the strength of said current being so great with respect to the cross section of said fluid that there is produced therein the "pinch effect," and subjecting said fluid in said tube or channel to a magnetic field.

22. The combination with a mass of fluid disposed in a tube or channel open at both its ends, of means for passing an electric current through said fluid, a conductor disposed at an angle with respect to said tube or channel, and means for passing electric current through said conductor, whereby said fluid is caused to flow through said tube or channel.

23. The combination with a mass of fluid disposed in a tube or channel, of means for passing electric current through said fluid, a second mass of fluid in a tube or channel disposed at an angle with respect to said first mentioned tube or channel, each of said tubes or channels being open at both its ends, and means for passing electric current through said second mass of fluid, whereby said fluids flow through their tubes or channels.

24. The combination with a mass of fluid disposed in a tube or channel, of means for passing electric current through said fluid, a second mass of fluid in a tube or channel

disposed at an angle with respect to said first mentioned tube or channel, each of said tubes or channels being open at both its ends and a third mass of fluid with which said masses of fluid communicate and form a circulatory system.

25. The combination with a mass of fluid, of a plurality of masses of fluid in separate tubes or channels disposed at angles with respect to each other and each communicating at both its ends with said first mentioned mass of material, and means for passing electric current through all said masses of fluid, whereby the fluid in said tubes or channels flows.

26. In an electric furnace, a mass of fluid material disposed in a tube or channel open at both its ends, means for passing electric current through said fluid, a conductor disposed at an angle with said tube or channel, means for passing electric current through said conductor, and a mass of fluid adapted to flow into said tube or channel whereby said currents react or cause said fluid material to flow.

27. In an electric furnace, a mass of fluid material disposed in a tube or channel open at both its ends, means for passing electric current through said fluid to heat the same, the resistance of said material to said current producing such heat as to maintain said material fluid, a conductor disposed at an angle with said tube or channel, and means for passing electric current through said conductor, whereby said fluid material is caused to flow through said tube or channel.

28. In an electric furnace, a mass of fluid material disposed in a tube or channel open at both its ends, means for passing electric current through said fluid, the ratio of the square of said current to the cross section of said fluid being such as to produce the "pinch effect", a conductor disposed at an angle with said tube or channel, and means for passing electric current through said conductor, whereby said fluid material is caused to flow through said tube or channel.

29. In an electric furnace, a mass of fluid material disposed in a tube or channel open at both its ends, means for passing electric current through said fluid material, the ratio of the square of said current to the cross section of said fluid being such as to produce a continued or recurring "pinch effect" and to heat said material to a temperature to maintain the same fluid, a conductor disposed at an angle with said tube or channel, and means for passing electric current through said conductor, whereby said fluid material is caused to flow through said tube or channel.

30. In an electric furnace, a plurality of masses of fluid in tubes or channels disposed at angles with respect to each other, fluid ex-

ternal to said tubes or channels and forming with the fluid therein a circulatory system, and means for passing electric current through said masses of fluid in said tubes or channels, whereby the current reactions cause the fluid to flow through said tubes or channels.

31. In an electric furnace, a plurality of masses of fluid in tubes or channels disposed at an angle with respect to each other, and means for passing electric current in multiple through said masses of fluid in said tubes or channels, whereby the fluid in said tubes or channels flows.

32. In an electric furnace, a plurality of masses of fluid in tubes or channels disposed at angles with respect to each other and each open at both its ends, and means for passing electric current in series through said masses of fluid in said tubes or channels, whereby the current reactions cause the fluid to flow through said tubes or channels.

33. In an electric furnace, an electrode, a plurality of masses of fluid in electrical communication with said electrode and contained in tubes or channels disposed at angles with respect to each other and each open at both its ends, whereby the current reactions upon said masses of fluid in said tubes or channels produce forces having components in the direction of extent of said tubes or channels.

34. In an electric furnace, an electrode, a plurality of masses of fluid connected in parallel with each other and connected with said electrode, said masses of fluid contained in tubes or channels disposed at angles with respect to each other.

35. In an electric furnace, a mass of fluid contained in a tube or channel open at both its ends, and an electrode disposed at an angle with respect to said tube or channel.

36. In an electric furnace, a mass of fluid contained in a tube or channel open at both its ends, an electrode disposed at an angle with respect to said tube or channel, and means for passing electric current through said fluid in said tube or channel and said electrode in series.

37. In an electric furnace, a plurality of electrodes, and associated with each of two of said electrodes a plurality of masses of fluid contained in tubes or channels disposed at an angle with respect to each other.

38. In an electric furnace, separated masses of fluid, and means for affording electrical communication between said masses comprising masses of fluid contained in tubes or channels disposed at an angle with respect to each other.

39. In an electric furnace, separated masses of fluid, a plurality of masses of fluid contained in tubes or channels converging toward one of said first mentioned masses of fluid, and another plurality of masses of

fluid contained in tubes or channels converging toward another of said first mentioned masses of fluid, and means for passing current from one of said first mentioned masses of fluid to another through said masses of fluid in said tubes or channels.

40. In an electric furnace, separated masses of fluid, a plurality of masses of fluid contained in tubes or channels converging toward one of said first mentioned masses of fluid, and another plurality of masses of fluid contained in tubes or channels converging toward another of said first mentioned masses of fluid, and means for passing current from one of said first mentioned masses of fluid to another in parallel through said masses of fluid in said tubes or channels.

41. In an electric furnace, an electrode, a mass of fluid in contact therewith, a second mass of fluid, and a plurality of masses of fluid contained in tubes or channels disposed at an angle with respect to each other connecting said first mentioned masses of fluid.

42. In an electric furnace, a mass of fluid disposed in a tube or channel, means for passing electric current through said fluid, a conductor disposed at an angle with respect to said tube or channel, means for passing electric current through said conductor, and magnetic material disposed in the vicinity of said fluid.

43. In an electric furnace, a mass of fluid disposed in a tube or channel, means for passing electric current through said fluid, a conductor disposed at an angle with respect to said tube or channel, means for passing electric current through said conductor, and a magnet disposed in the vicinity of said fluid.

44. The combination with a tilting electric furnace, of a plurality of electrodes, a mass of fluid material within said furnace forming a conducting bridge between said electrodes, said furnace having a chamber for containing said fluid material, said chamber so disposed with respect to said electrodes that when said furnace is tilted said electrodes remain bridged by said fluid material.

45. In an electric furnace, the combination with a solid electrode, of a cavity containing conducting material in contact with said electrode, said conducting material in said cavity having a cross section greater than the cross section of said electrode, a tube or channel containing conducting material in electrical communication with said conducting material in said cavity, the cross section of said conducting material in said tube or channel at its region of contact with said conducting material in said cavity being less than the cross section of said material in said cavity, and the ratio of the square of the current transmitted through said conducting material in said tube or channel to

the cross section of said conducting material in said tube or channel being such that the "pinch effect" is produced.

46. In an electric furnace, the combination with a solid electrode, of a cavity containing conducting material in contact with said electrode, said conducting material in said cavity having a cross section greater than the cross section of said electrode, a tube or channel containing conducting material in electrical communication with said conducting material in said cavity, the cross section of said conducting material in said tube or channel at its region of contact with said conducting material in said cavity being less than the cross section of said material in said cavity, and a current carrying conductor disposed at an angle with respect to said tube or channel whereby the current reactions produce forces upon said conducting material in said tube or channel having components in the direction of said tube or channel.

47. In an electric furnace, the combination with a solid electrode, of a cavity containing conducting material in contact with said electrode, said conducting material in said cavity having a cross section greater than the cross section of said electrode, a tube or channel containing conducting material in electrical communication with said conducting material in said cavity, the cross section of said conducting material in said tube or channel at its region of contact with said conducting material in said cavity being less than the cross section of said material in said cavity, and a current carrying conductor disposed at an angle with respect to said tube or channel whereby the current reactions produce forces upon said conducting material in said tube or channel having components in the direction of said tube or channel, and the ratio of the square of the current transmitted through said conducting material in said tube or channel to the cross section of said conducting material in said tube or channel being great whereby the "pinch effect" is produced.

48. The combination with an electric furnace, of a pouring lip therefor, a hearth, a channel leading from said hearth to said pouring lip, an electrode, a mass of fluid conducting material extending from said electrode through a tube or channel to said hearth, masses of magnetic material disposed on opposite sides of said channel leading to said pouring lip and disposed in proximity to said tube or channel.

49. The combination with a plurality of electrodes, of resistors inclined with respect to each other communicating with each electrode, and means for passing through said electrodes and resistors polyphase current.

50. The combination with a plurality of electrodes, of resistors inclined with respect

to each other communicating with each electrode, means for passing through said electrodes and resistors polyphase current, and a bath of material communicating with all said resistors.

51. In an electric furnace, separated masses of conducting fluid, and means for affording electrical communication between said masses comprising a mass of conducting fluid contained in a circumferentially closed tube or channel filled thereby and open at both ends, said fluid in said tube or channel having a cross section small with respect to the current passed therethrough from one of said masses of fluid to the other, whereby fluid flow due to the "pinch effect" is produced in said tube or channel.

52. The combination with three electrodes, of means for supplying three phase current thereto, a plurality of resistors for each electrode disposed in channels inclined with re-

spect to each other, and a bath communicating with all said resistors.

53. The method of electrically treating molten material, which consists in confining said material in masses in communication with each other through a portion of said material confined in a circumferentially closed channel filled with said material, and passing through the material confined in said channel an electric current whose strength is great with respect to the cross section of said confined material, whereby the "pinch effect" is produced in said confined material, and thereby stirring said masses of material.

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

CARL HERING.

Witnesses:

CHAS. R. RENZ,

ANNA E. STEINBOCK.