Jan. 16, 1934. E. F. NORTHRUP 1,943,802

ELECTRIC INDUCTION FURNACE

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Fig. 1.

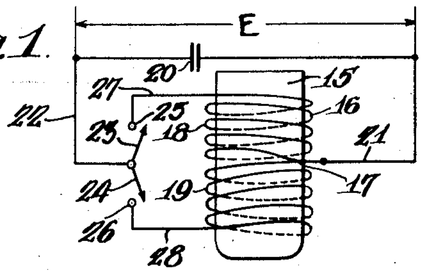



Fig. 2.

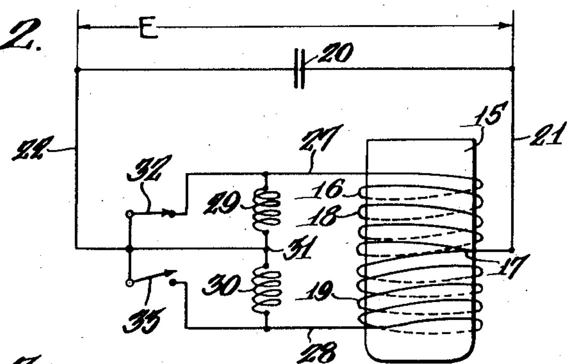



Fig. 3.

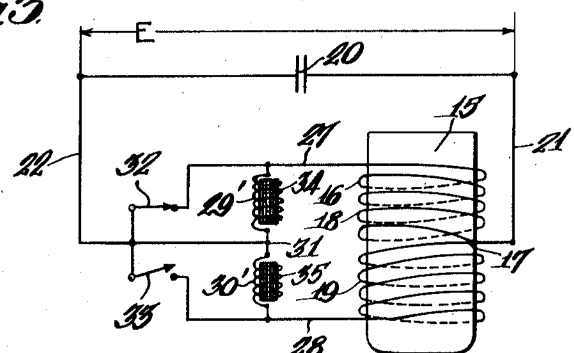
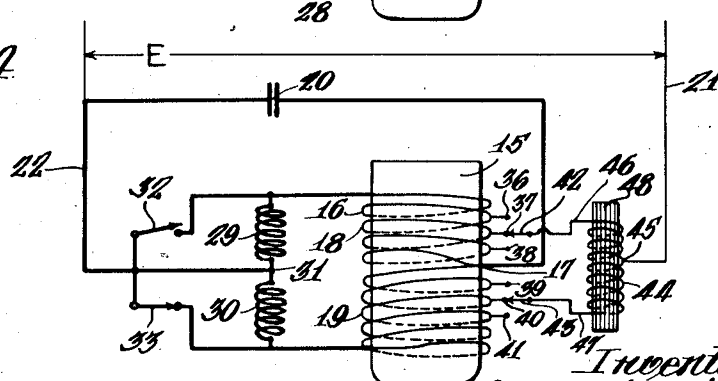



Fig. 4.

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ELECTRIC INDUCTION FURNACE

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Fig.5.

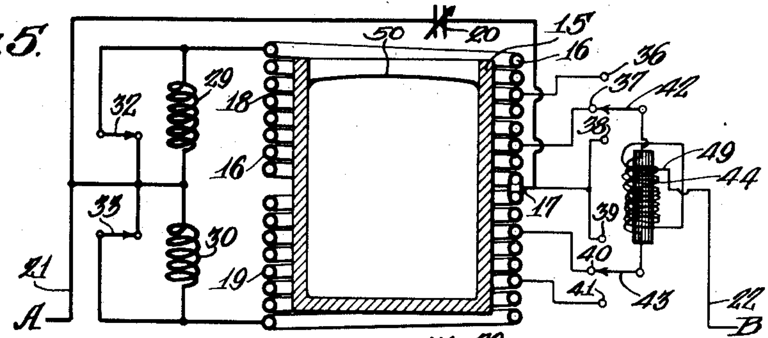


Fig.6.

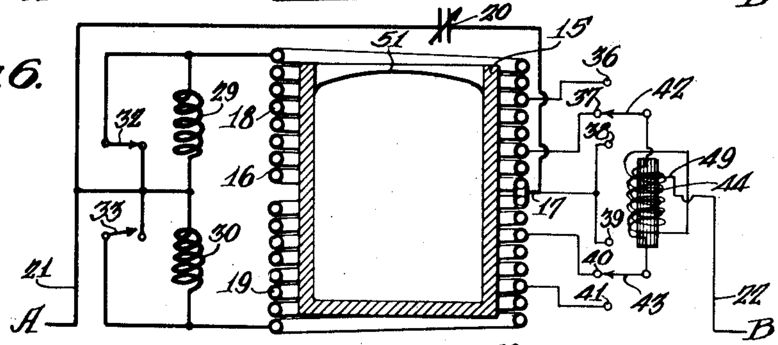
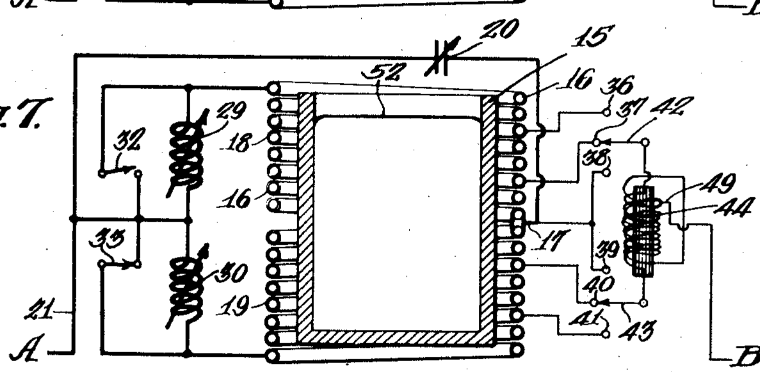


Fig.7.



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ELECTRIC INDUCTION FURNACE

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Fig. 8.

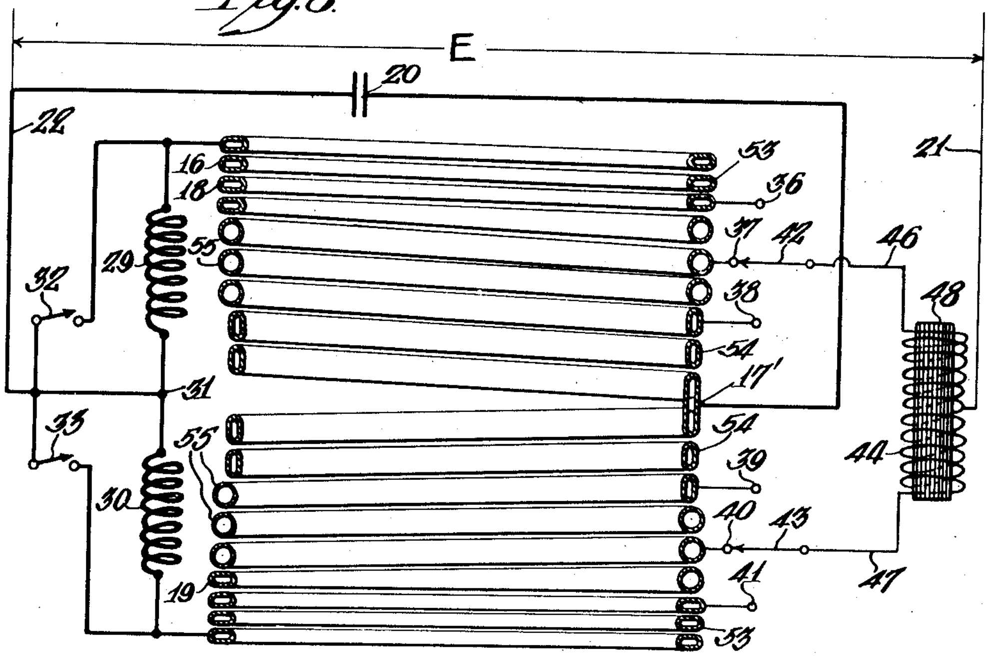
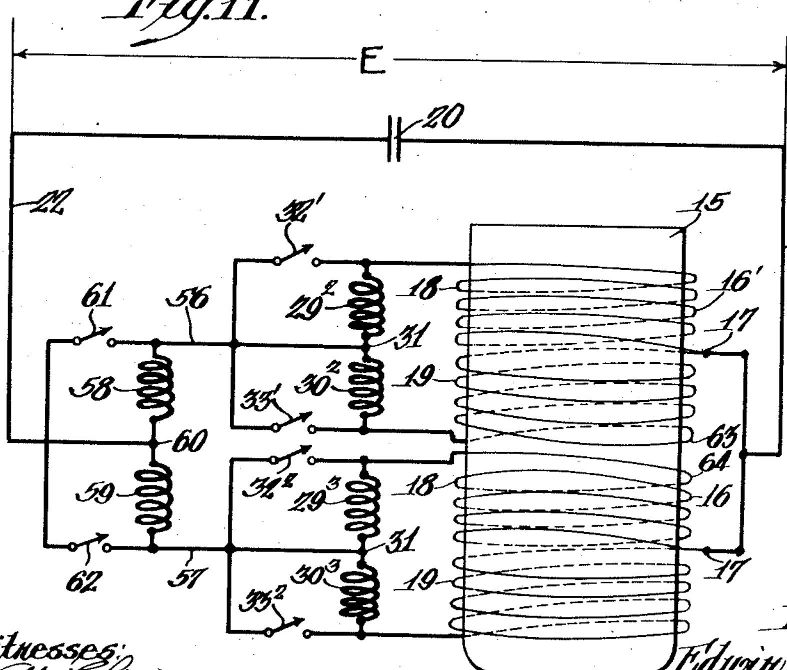



Fig. 11.

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ELECTRIC INDUCTION FURNACE

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Fig. 9.

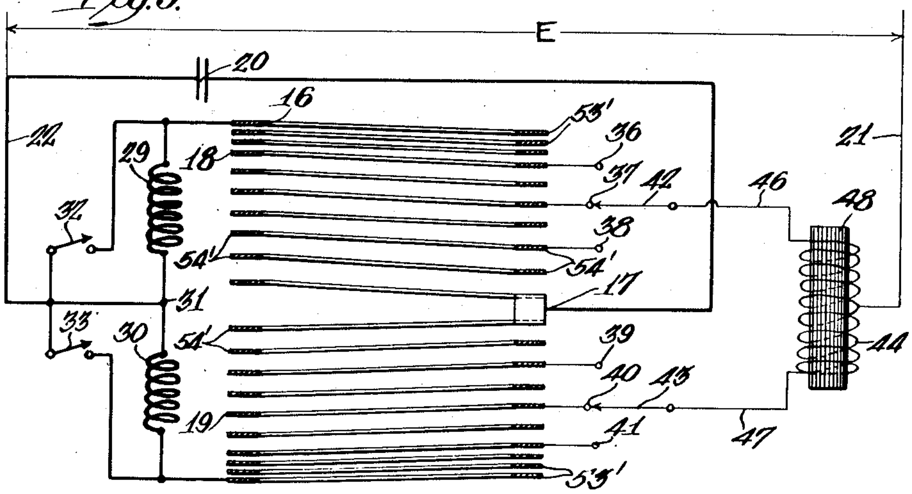
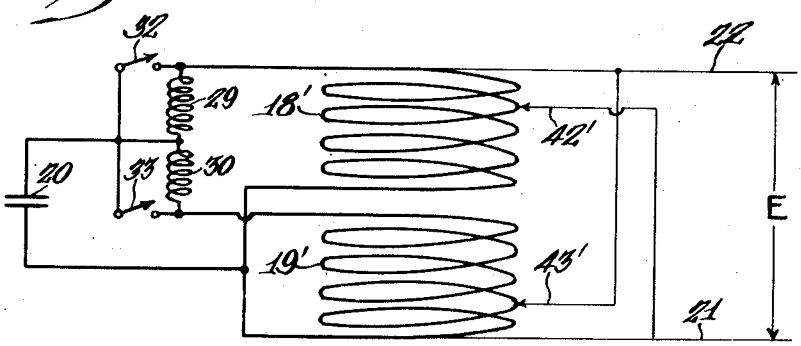



Fig. 10.

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# UNITED STATES PATENT OFFICE

1,943,802

## ELECTRIC INDUCTION FURNACE

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Application March 18, 1930. Serial No. 436,847

32 Claims. (Cl. 13—27)

My invention relates to methods and apparatus for controlling the stirring in a coreless induction furnace.

A purpose of my invention is to pass current through an inductor coil between points along its height, and to control the stirring produced by the inductor coil by varying the amount of current flowing in the inductor coil between any such points or the ratio of the amounts of current flowing between respective groups of such points as desired.

A further purpose is to control the stirring in an induction furnace by varying the ratio of the number of ampere turns surrounding the charge above its center of gravity to the number below its center of gravity.

A further purpose is to control the stirring in a coreless induction furnace by moving the point of maximum flux density at the axis of the inductor coil, while retaining the inductor coil stationary.

A further purpose is to divide an inductor coil into upper and lower sections oppositely wound, one with respect to the other, and to apply current to the sections from a common terminal at their point of union, simultaneously or successively, and in variant proportions, to regulate the stirring effect produced by the inductor coil upon the charge.

A further purpose is to apply a plurality of such pairs of oppositely wound coil sections with suitable circuit connections about the same furnace.

A further purpose is to use an inductor coil formed of oppositely wound sections in which the number of ampere turns per unit axial length is increased at the extremities of the coil with respect to the intermediate portion.

A further purpose is to introduce inductance in the oscillation circuit of a portion of an inductor coil in order to reduce the stirring effect attributable to that portion, and, if desired, to introduce capacity to correct the power factor in that portion of the inductor.

A further purpose is to connect the physical extremities of an inductor coil to two separate inductances of which the other terminals are joined to one side of a current source, to connect the other side of the current source to the physical center of the coil or to points intermediate between the extremities and the center, and to regulate the stirring in the furnace by switching means shunting either or both of the inductances in whole or in part.

In an induction furnace in which one side of the power source is connected to the inductor coil at points intermediate between the coil extremities, and the other side of the power source is connected to the extremities of the inductor coil, whether through inductance or not, a further purpose is to avoid building up excessive currents outside the inductor by inserting inductance between one side of the current source and the power application to the coil intermediate between the extremities of the coil, which shall be only slightly inductive to current flowing from the source and very highly inductive to current tending to flow from either intermediate connection to the other.

A further purpose is to apply taps for varying the power application at points intermediate between the extremities of the coil so as to change the voltage across the extremities of the coil by autotransformer effect.

A further purpose is to apply water cooling to a coil in which the upper portion is oppositely wound with respect to the lower portion.

Further purposes will appear in the specification and in the claims.

Many users of the coreless induction furnace have found the electrodynamic stirring in particular furnaces or for special operations to be excessive for the intended uses and so disadvantageous. Others have wished to increase the stirring effect during certain phases of the furnace operation without appreciably changing the power input. It has previously been recognized that the stirring effect may be altered by mechanically lifting or lowering the inductor coil with respect to the charge, or by providing the inductor coil with a series of taps at variant heights so that the current can be made to traverse one portion only of the coil between the chosen taps at any height desired.

These prior methods of stirring control have limited utility because of the complicated construction required to physically lift or lower the coil in the first case, and because of the small portion of the inductor coil which can be used at any one time and the excessive heating of the idle coil portions in the second case. By my method in its best form I propose to utilize the entire coil at all times, but to vary the amount of current traversing selected portions of the coil.

Among quite a number of forms of my invention I have preferred to show a few only, selecting forms which are practical and effective and which at the same time well illustrate the principles involved.

Figures 1, 2, 3 and 4 are diagrammatic views illustrating various circuit connections for carrying out my method.

Figures 5, 6 and 7 are diagrammatic sections illustrating various phases in the operation of the furnace according to my method.

Figure 8 is a section of a graded coil formed of hollow water-cooled tubing, with diagrammatic connections, the crucible and charge being omitted to show the coil more clearly.

Figure 9 corresponds generally to Figure 8, and has the same circuit connections as Figure 8, but shows the inductor coil formed somewhat differently.

Figure 10 shows diagrammatically a different form of my invention.

Figure 11 is a diagrammatic view of a furnace having a plurality of coils and suitable connections thereto.

Like numerals refer to like parts throughout.

Referring to Figure 1, the crucible 15 is shown as surrounded by the inductor coil 16. From some point 17, preferably at the center of the coil, the upper portion 18 of the inductor coil is shown oppositely wound with respect to the lower portion 19.

In Figures 1 to 4 the upper portion is wound counterclockwise and the lower portion clockwise, but this is merely for the purpose of illustration, and my invention could equally well be carried out by reversing the direction of winding of each portion. Current is supplied at E and the power factor may very desirably be corrected as by the condenser 20.

In Figure 1, one side of the supply line is attached through the connection 21 to the inductor coil at 17, while the other side of the line is connected through 22 to the switches 23 and 24. The switch terminals 25 and 26 are connected by leads 27 and 28 to the respective extremities of the inductor coil. When the switches 23 and 24 are closed in Figure 1, it will be seen that current which, for example, may at one instant enter through the line 21, will divide, one portion flowing through the upper part 18 of the inductor coil, and the other portion flowing through the lower part 19. Since, however, the parts 18 and 19 are oppositely wound, the flux passing through the charge within the inductor coil will all flow in the same direction, and, of course, this condition will prevail during each reversal of the current.

With my invention, therefore, it is important that the branches of the inductor coil be oppositely wound, as otherwise the flux produced in one branch would tend to oppose that produced in the other.

When both switches are closed in Figure 1, the oscillation circuit will comprise two branches, the one extending from the point 17 through the inductor section 18, over the connection 27 to the switch 23, along the connection 22, across the condenser 20, and back over the connection 21 to the point 17, and the other extending from the point 17 through the coil section 19, the connection 28, the switch 24, the connection 22, across the condenser 20 and back along the connection 21 to the point 17. Either of these branches may be used selectively.

In the operation of the furnace of Figure 1, no selective control of the stirring is possible while both switches 23 and 24 are closed. If, however, it be desired to reduce the stirring, I may open the switch 23 so that the stirring will be confined to the lower part of the furnace charge where primary-on-secondary motor effect will combine with pinch effect to produce a composite stirring movement. For certain purposes, I may desire to obtain a high degree of stirring near the top of the charge, as for the oxidation of impurities for example, and in this case I will open the switch 24 and close the switch 23, allowing the current to traverse the upper branch 18 only of the coil. This will give a corresponding composite stirring effect, but, because it is produced in the upper part of the charge, it will stir and crown the upper surface as stirring within the lower part of the pool will not.

The form of Figure 2 is more advantageous than that shown in Figure 1 because I may regulate the stirring in the furnace without the necessity of cutting off the current entirely from any part of the inductor coil. The structure of the inductor coil and furnace, the source of current supply and the power factor correction are here the same as those seen in Figure 1. Instead of the switches 23 and 24 adapted to cut out portions of the inductor coil, I have placed inductances 29 and 30 in the oscillation circuit between the line 22 from the power source and the connections 27 and 28 to the respective physical extremities of the inductor coil. The inductances are each connected to the lead 22 at the point 31. In order to permit me to place the inductances in the circuit or to cut them out at will, I have provided switches 32 and 33 capable when closed of shortcircuiting the inductances.

Thus when both of the switches 32 and 33 are closed the furnace will operate with a general stirring throughout. This will be the normal mode of operation in many cases. When the switch 32 is opened the current in the upper portion 18 of the inductor coil will have to flow through the inductance 29 in completing the oscillation circuit. It will therefore be reduced, but not entirely cut off, because some current will pass through the inductance 29. With the switch in this position, therefore, the stirring in the upper portion of the charge will be much reduced, and only a submerged stirring will occur. It will therefore be seen that the effect of opening the switch 32 is to reduce the ratio between the current in the upper portion of the inductor and the current in the lower portion.

If the switch 33 be now opened, and the switch 32 closed, a violent stirring near the surface will be caused, as the bulk of the current will then pass through the upper portion 18 of the inductor.

Figure 3 is generally similar to Figure 2 except that the inductances 29′ and 30′ are provided with cores 34 and 35 of magnetic material. This will tend to make the inductances still further effective in reducing the current when they are thrown into the oscillation circuits of the respective branches of the inductor coil. By moving the cores axially the current passing through the inductances may be regulated.

In the circuits previously discussed, the voltage across either branch of the inductor coil has always been equal to or less than the line voltage.

In Figure 4 I take advantage of the autotransformer effect to impress a voltage across the respective branches of the inductor coil greater than the line voltage. As seen in Figure 4, the inductor coil is provided with a plurality of taps 36, 37, 38, 39, 40 and 41, to which connections may be made from one of the switches 42 and 43. The inductances 29 and 30 and the switches provided to cut them in or out are similar to those seen in Figure 2.

Power factor correction for both branches of the inductor coil is provided by the condenser 20 as before, connected across from the line 22 to the point 17 where the branches of the inductor coil join. For convenience in reading the drawings, the connections in the oscillation circuit have been drawn with somewhat heavier lines than the connections carrying power current only, in order to indicate that higher current values obtain in the oscillation circuit.

The voltage across the inductor coil and hence the power input to the furnace may be regulated according to the well understood principles of autotransformer operation. Thus if the switches 42 and 43 be moved to make contact with the respective taps 36 and 41, the power input will be greatest because the number of turns of the autotransformer spanned by the power supply is least and the transformation ratio is greatest. On the other hand, if the switches 42 and 43 be moved into contact with the respective taps 38 and 39, the power input will be decreased to a minimum because the number of turns on the low voltage side of the autotransformer will be greatest and the transformation ratio least. Infinite variation in the voltage impressed may be obtained by providing a great variety of taps to the inductor coil or switching means to change the transformation ratio. It is not important to my invention whether the change be accomplished by varying the number of turns on the high voltage or low voltage side.

I provide the choke coil 44 to protect the switches and lines from excessive currents. The coil is connected at 45 near its center to the power line through the connection 21 and at 46 and 47 to the respective switches 42 and 43. A core 48 is located within the coil. Current which for example at any instant may enter through the line 21 will divide through the branches of the choke coil and encounter very little inductance because the magnetic effects are opposed. However, a current seeking to flow from one end of the choke coil to another, as for example from the connection 46 to the connection 47, would encounter very high indutance so that the current could not reach a high value.

In Figures 5, 6 and 7 I show the same circuit as in Figure 4 except that the taps 38 and 39 are together connected to the point 17 at the center of the coil. Power is supplied through the leads A and B. It will be understood that 17 is intended to be the point at which the direction of winding changes in the indicator coil. The connections to the inductances and switches 32 and 33 might not be made at the exact extremities of the inductor for structural reasons, although they would ordinarily be made there.

The choke coil 44 I show wound in the form which I prefer to employ in practice. The coil is made by winding once from end to end and then making a second winding in the same direction beside the first winding. The connection to the coil from the lead 21 is made at the point 49. The inductor coil 15 is shown conventionally, as formed of hollow tubing preferably water-cooled from water connections not shown. As seen, the entire coil can be made of continuous tubing wound above the point 17 in a direction opposite to the winding below that point.

The same structure and the same power connections are shown in all of Figures 5, 6 and 7. The positions of the switches 32 and 33 are different to suit the stirring for various phases of operation. For convenience the power switches 42 and 43 are seen in the positions 37 and 40 for medium input into the charge in all the figures.

In Figure 5 the switches 32 and 33 are both closed, and the charge is undergoing a moderate stirring throughout as indicated by the slightly elevated meniscus 50 on the top of the bath. The power is equal in both portions 18 and 19 of the inductor coil.

In Figure 6 the switch 33 has been opened, while the switch 32 is still closed. The power is here greater on the upper section 18 of the inductor coil, because the current in the lower portion of the inductor coil has been reduced on account of the inclusion of inductance 30 in the oscillation circuit of the lower portion of the inductor coil. The charge is undergoing concentrated stirring in the upper portion as shown by the elevated meniscus 51.

I show in Figure 7 a condition of greater current and greater power input in the lower section 19 of the coil, due to the fact that the switch 32 has been opened and the switch 33 closed. In this condition the stirring will be much decreased and will take place almost entirely in the lower portion of the bath as indicated by the comparative flatness of the meniscus 52 on the charge.

It is important to note that the power input to the charge with the conditions seen in Figures 6 and 7 may be made substantially the same as that in Figure 5 by shifting the switches 42 and 43 into contact with the proper taps or by changing the applied voltage.

I may, of course, still further vary the stirring action by using variable inductances instead of fixed inductances at 29 and 30. In Figure 7 I have conventionally illustrated my inductances as being variable.

In practice I find that the capacity required to correct the power factor of my furnace differs only slightly, whether the inductances 29 and 30 or either of them are in or out of the circuit. Therefore, except as it is affected by change in the inductance of the charge, my power-factor-correcting capacity may be fixed as shown in Figures 1 to 4 or variable as shown in Figures 5 to 7, with only a slight advantage in favor of the variable form.

In operating upon an actual charge the power input can be regulated as desired by shifting the switches 42 and 43. Since stirring can do no harm previous to the melting of the charge, the switches 32 and 33 may desirably be closed. If the material be magnetic a change of power will be desirable when it reaches the point of decalescence. This is taken care of by shifting switches 42 and 43, thus changing the voltage across the inductor coil. When the charge is completely melted, or if a molten charge be supplied at the start, I may desire to stop the stirring at the surface, which in some cases will be sufficiently accomplished by opening the switch 32 as seen in Figure 7. Moderate or mean stirring may be secured by closing both switches 32 and 33.

In Figure 8 I show a form of inductor coil embodying my invention which I have found to give very good results in practice. Other aspects of the use of this type of coil are claimed in other applications filed by me and copending herewith. The circuit connections in Figure 8 are identical with those seen in Figure 4. The two oppositely wound portions 18 and 19 of the inductor coil are specially constructed so as to concentrate the ampere turns per unit axial length at the extremities of the coil.

The concentration of the ampere turns at the extremities is accomplished in the form of Figure 8 by forming the inductor of hollow water cooled tubing, and by pinching the tubing in its axial dimension near the extremities as at 53 and transversely to its axial dimension near the center as at 54. At some point 17′ the direction of winding is reversed. Between the center and the extremities certain of the intermediate turns are not pinched, as seen at 55. Thus the number of ampere turns per unit axial length increases progressively from a minimum at the center to a maximum at each extremity.

It will be understood that any other form of coil having the desirable concentration of ampere turns at the extremities could be used, as for example a coil in which the turns are of uniform cross-section, spaced close together at the extremities and wide apart in the center. In Figure 9 I show this type of inductor coil, similar in all of its other characteristics to that of Figure 8. Copending applications describe and claim other phases of the use of this method of grading. See my applications, Serial Number 438,966, for Electric induction furnace, and Serial Number 438,967, for Electric induction furnace, both filed March 26, 1930.

This progressive increase in ampere turns toward the extremities, called grading, produces a high flux concentration at the extremities, and is very desirable in accomplishing stirring control by my invention. Thus, if the switch 32 be open, placing the inductance 29 in the oscillation circuit, and the switch 33 be closed, the point of maximum flux density in the charge is lowered much more with an inductor coil of the type of Figure 8 than would be the case with a coil of the type of Figures 5–7. There would therefore be less stirring with this switch position than with the similar switch position in Figure 7.

On the other hand, with the switch 33 open, placing the inductance 30 in the oscillation circuit, and with the switch 32 closed, the point of maximum flux density is raised much higher in Figure 8 than would be the case in Figure 6, because, in addition to the fact that the bulk of the current transverses the upper section 18 of the inductor coil, the bulk of the ampere turns of this upper section is near the top.

It will thus be evident that the form of Figure 8 accentuates the difference between the maximum and minimum stirring conditions, making the minimum lower and the maximum higher by displacing the point of maximum flux density further from the center of gravity of the charge in each case. For this reason I prefer to use the form of Figure 8 where the conditions of use will permit.

The above advantages also apply to the form of Figure 9.

In Figure 9 the turns of the inductor coil winding are close together at the extremities, as at 53′, and relatively far apart near the center, as at 54′. The intermediate turns are desirably progressively graded from the center toward the extremities. The chief advantage of the form of Figure 8 over that shown in Figure 9 is the water cooling and the structural solidarity of the inductor coil of Figure 8, without the need for using insulating material of variant thickness between all adjacent turns.

Because of the importance of having an instantaneous unidirectional flux in the charge, I have shown the inductor coil oppositely wound above and below an intermediate point on the coil in my previous figures. By Figure 10 I intend to indicate that my invention may be used with a plurality of inductor coil sections wound in the same direction. Thus current from the source is carried by the leads 21 and 22 to the respective inductor coil sections 18′ and 19′, through which it passes in parallel. Suitable switching means 42′ and 43′ make it possible to vary the voltage across the inductor coil sections by autotransformer effect. At any instant the current in both sections will travel in the same direction.

In the oscillation circuit for each inductor coil section is placed one of the inductances 29 or 30, shunted by a switch 32 or 33, as well as the condenser 20. The number of inductor coil sections connected according to the method here shown may of course be greatly multiplied, with a corresponding increase in the number of inductances and shunting switching means.

In Figure 11 I intend to indicate that more elaborate circuits may readily be devised, using the broad principles of my invention. The comparison of Figure 11 with Figure 2 will show that in Figure 11 I have merely connected two inductor coils, with their inductance and switches, in parallel, adding suitable other inductance and switches for better control of the stirring.

In very large furnaces it is sometimes desirable to use only a few turns in the inductor coil. Where this is done, each turn must be ordinarily very wide in order that the inductor may surround the whole charge. By my invention I make it possible to employ a plurality of inductor coil units, each section of each unit consisting of the desired small number of turns, which will be of much smaller size than would be the case if the inductor coil were formed of only one such set of turns.

In Figure 11 the inductor coil consists of two units 16′ and $16^2$, electrically separate from one another. Each inductor coil unit is formed of two oppositely wound sections 18 and 19 as shown in Figure 2. The upper section 18 of the lower unit $16^2$ is also oppositely wound with respect to the lower section 19 of the upper unit 16′. Thus the inductor coil sections are alternately wound counterclockwise and clockwise from top to bottom.

The inductances $29^2$, $30^2$, $29^3$ and $30^3$, and the switching means 32′, 33′, $32^2$ and $33^2$, for the respective units, are connected as indicated in Figure 2. One side of the line from the power source is connected through the lead 21 to points 17 on each unit intermediate between the extremities of the respective unit. It will be understood of course that power taps and the choke coil could be inserted at this point according to the principles shown in Figure 4.

Between the leads 56 and 57 from each inductor coil unit and the lead 22 are placed inductances 58 and 59 joined together at a point 60, and switches 61 and 62 for shunting the inductances.

It will be understood that more than two units could be placed in parallel in the manner shown in Figure 11, or that any number of sets of units connected in parallel as there shown could again be connected in parallel with a similar unit or set of units, forming circuits of increasing complication indefinitely.

It will be evident that with the connections of Figure 11 the adjacent turns 63 and 64 of the inductor coil units will have a similar polarity at any given instant, so that there will not be a tendency to break down the insulation between them as would be the case if they were of opposite polarity. This I consider a distinct advantageous feature of the structure of Figure 11.

In the operation of the furnace of Figure 11 it will be seen that I can selectively decrease the ratio of the current carried by the upper unit 16′ to that carried by the lower unit $16^2$ by opening the switch 61 while the switch 62 is closed, thus reducing the stirring in the furnace. On the other hand, if the switch 61 be closed and the switch 62 be open, the inductance 59 in the oscillation circuit of the lower unit $16^2$ of the coil will reduce the ratio of the current carried by the lower unit to that carried by the upper unit, causing an upward movement of the point of maximum flux density at the axis and concurrent vigorous stirring in the furnace.

For either of these switch positions, further variations in the stirring effect may be obtained by opening either one of the pairs of switches 32′ and 33′ or $32^2$ and $33^2$. Thus, for example, if the switch 61 be closed and the switch 62 be open, I can still further increase the violent stirring in the furnace by opening the switches $32^2$ and $33^2$. Similarly I can decrease the violence of this stirring by opening the switch 32′, leaving the switch 33′ closed.

In the same way if the switch 61 be open and 62 be closed, the consequent low stirring may be decreased by opening the switches 32′ and 33′. Numerous other variations and combinations may be obtained by opening or closing the respective switches 61, 62, 32′, 33′, $32^2$ and $33^2$.

It will be understood that where I refer herein to the extremity or extremities of the inductor coil or of any other coil I mean a point near the physical end or ends of the winding, and not the electrical points of negative or positive polarity necessarily.

It will of course be recognized that inductance might be put in or taken out of the circuit in parallel instead of as shown in the figures to accomplish the results shown, or that resistance in series or in parallel could be used somewhat less efficiently instead of inductance, and I intend the use of the word "inductance" in my claims to cover such equivalent uses.

In the descriptive matter where parts of an inductor coil are referred to it is my intention to include separate portions of a continuous inductor coil, or separated inductor coil parts, since the mere physical separation of the parts of the coil into two distinct coils would make no difference.

Various gradations and variations in stirring effects may be produced according to my invention by making slight alterations in the connections used, or a part of the advantage from my invention may be secured by applying my method to only a part of the inductor coil or through the use of only certain portions of my circuit, but I intend to claim any such as may involve my broad invention or may apply the features which I have taught to variant construction.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. The method of controlling the stirring in an induction furnace which consists in passing current from top and bottom respectively toward the middle in opposite directions about adjacent parts of the furnace charge while retaining an instantaneous uni-directional flux in the charge and varying the ratio of currents passed about the parts.

2. The method of controlling the stirring in an electric induction furnace which consists in passing an electric current about the charge from top and bottom respectively toward the middle in opposite directions respectively above and below an intermediate point in the charge while retaining an instantaneous unidirectional flux in the charge and varying the ratio of one opposite current to the other.

3. The method of controlling the stirring in an electric induction furnace which consists in distributing power to the furnace inductor coil between its extremities and points intermediate between the extremities and inductively changing the ratio between the currents carried by the respective portions of the coil between each extremity and its point of power application by outside inductances.

4. The method of operating an electric induction furnace which consists in applying power to the furnace coil in two separated sections of the coil and varying the extent of said sections to vary the power, supplying current to the remainder of the coil by autotransformer action, interposing outside inductance to reduce the current through a part of the coil as distinguished from the current through the entire coil.

5. The method of controlling the stirring in an electric induction furnace which consists in passing an electric current about the charge from top and bottom respectively toward the middle in opposite directions respectively above and below an intermediate point in the charge while retaining an instantaneous unidirectional flux in the charge, concentrating the ampere turns of the current passed in each direction at points in the charge remote from the center of gravity of the charge, and varying the ratio of one opposite current to the other.

6. The method of controlling the stirring in an electric induction furnace which consists in passing an electric current about the charge from top and bottom respectively toward the middle in opposite directions respectively above and below an intermediate point in the charge, while retaining an instantaneous uni-directional flux in the charge progressively increasing the ampere turns of the opposite currents about the charge from a minimum near the center of gravity of the charge to a maximum at points remote therefrom, and varying the ratio of one opposite current to the other.

7. The method of controlling the stirring in an electric induction furnace which consists in passing about the charge a plurality of electric currents from the top and bottom progressively toward the middle oppositely directed with respect to adjacent currents but maintaining the same instantaneous flux directions in the charge, and inductively varying the ratio of any of the individual oppositely directed currents to the total current by variation of inductance.

8. The method of varying the stirring effect in an induction furnace, which consists in passing an alternating current about the upper part and the lower part of the charge respectively in such a direction as to produce instantaneous unidirectional magnetic flux in the charge, in selectively forming oscillation circuits for the upper and lower currents and in separately varying the inductance of the oscillation circuits to comparatively change the currents about the upper and lower portions of the charge.

9. The method of varying the stirring of a molten pool of metal, which consists in separately passing electric current about two different parts of the pool and in varying the current about one part of the pool as compared with that about the other part of the pool by varying the inductance within the circuit about the one while maintaining the inductance within the circuit of the other.

10. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another from a point intermediate between the extremities and switching means and inductive means outside of the coil for applying current from the source differently to the portions of the inductor coil at the will of the operator, whereby the stirring at various heights in a molten charge in the furnace may be controlled.

11. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another from a point intermediate between the extremities, a connection from one side of the source to the intermediate point, inductance for each portion of the inductor coil, connections from the extremities of the inductor coil through the respective inductance to the opposite side of the source and switching means for shunting each inductance.

12. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another from a point intermediate between the extremities, a connection from one side of the source to the intermediate point, oscillation circuits for each inductor coil portion, cored inductance in each oscillation circuit, and connections from the extremities of the inductor coil to the other side of the power source.

13. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another, an inductance which is highly inductive to current tending to pass between its extremities and having little inductance to current tending to pass from a point intermediate between its extremities to either extremity, connection from one side of the source to an intermediate point on said inductance, connections from the extremities of said inductance to points on the inductor coil intermediate between its extremities and connections from the extremities of the inductor coil to the other side of the current source.

14. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another, an inductance which is highly inductive to current tending to flow between its extremities and having little inductance to current tending to flow from an intermediate point of said inductance to the power source, connections from the extremities of the inductance to spaced points of the inductor coil intermediate between its extremities, means for varying the points along the inductor coil with which the extremities of the inductance are connected, and connections from the extremities of the inductor coil to the other side of the power source.

15. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another, a cored inductance wound continuously and having a second winding in the same direction in series with the first and connections for carrying the current through the second winding in the same direction as in the first, so that the inductance will be highly inductive to current tending to pass from one extremity of one winding to the opposite extremity of the other, but having little inductance to current tending to pass from an intermediate point to either extremity, connections from such an intermediate point to one side of the current source, connections from opposite extremities of the different windings to spaced points on the inductor coil intermediate between its extremities, and connections from the extremities of the inductor coil to the other side of the power source.

16. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another, connections from one side of the power source to the inductor coil at spaced points intermediate between its extremities, inductances for the portions of the inductor coil, connections from the extremities of the inductor coil through the respective inductances to the other side of the power source and means for altering the respective inductances, whereby the stirring at various heights in a molten charge in the furnace may be controlled.

17. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another, an inductance which is highly inductive to current tending to pass between its extremities and having little inductance to current flowing from an intermediate point to either extremity, connection from one side of the power source to such an intermediate point, connections from the extremitites of the said inductance to spaced points on the inductor coil intermediate between its extremities, other inductances for the portions of the inductor coil, connections through the respective other inductances from each extremity of the inductor coil to the other side of the power source and means for altering the respective other inductances.

18. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another, connections from one side of the power source to the inductor coil at spaced points intermediate between its extremities, connections from the extremities of the inductor coil to the opposite side of the power source, oscillation circuits for the respective inductor coil portions, and inductance in the oscillation circuit of the lower portion, whereby vigorous stirring is produced in the upper portion of the furnace charge.

19. In an electric furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another, connections from one side of the power source to the inductor coil at spaced points intermediate between its extremities, connections from the extremities of the inductor coil to the opposite side of the power source, oscillation circuits for the respective inductor coil portions, and inductance in the oscillation circuit of the upper portions, whereby submerged stirring is produced in the lower portion of the furnace charge.

20. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with repect to one another from a point intermediate between the extremities, and having its number of turns per unit axial dimension increased near the extremities, connections from one side of the source to the

inductor coil between its extremities and connections from the other side of the source to the extremities of the inductor coil.

21. In an electric induction furnace, an inductor coil having portions oppositely wound with respect to one another and having the number of ampere turns per unit axial dimension increased at the extremities.

22. In an electric induction furnace, an inductor coil having portions oppositely wound with respect to one another and having the number of ampere turns per unit axial dimension progressively increased from a minimum at a point intermediate between the extremities to a maximum at the extremities.

23. In an electric induction furnace, a source of current supply, an inductor coil having portions oppositely wound with respect to one another from a point intermediate between the extremities and having the number of turns per unit length increased toward the extremities, connections from one side of the source to the intermediate point, oscillation circuits complete for each inductor coil portion, inductance in each oscillations circuit, means for varying the inductance and connections from each extremity of the inductor coil to the other side of the power source.

24. In an electric induction furnace, a source of current supply, an inductor coil having the number of turns per unit length increased toward its extremities and having portions oppositely wound with respect to one another from a point intermediate between the extremities, connection from one side of the source to the intermediate point, inductance for each portion of the inductor coil, connections from the extremities of the inductor coil through the respective inductance to the opposite side of the source and switching means for shunting each inductance.

25. In an electric induction furnace, a source of current supply, an inductor coil having the number of turns per unit length increased toward its extremities and having portions oppositely wound with respect to one another from a point intermediate between the extremities, connection from one side of the source to the intermediate point, oscillation circuits for each inductor coil portion, adjustable cored inductance in each oscillation circuit, and connections from the extremities of the inductor coil to the other side of the power source.

26. In an electric induction furnace, a source of current supply, an inductor coil consisting of a plurality of electrically separate units, each unit having portions oppositely wound with respect to one another from a point intermediate between its extremities, connections from one side of the power source to the intermediate point on each unit, oscillation circuits complete for each inductor coil unit portion, inductance for each oscillation circuit, means for shunting each inductance, and connections from the other side of the power source to the extremities of each inductor coil unit.

27. In an electric induction furnace, a source of current supply, an inductor coil consisting of electrically separate units each having portions oppositely wound with respect to one another, connections from the current source to each portion, oscillation circuits for each portion, and means for varying the inductance in the respective oscillation circuits.

28. An inductor furnace having its inductor made up of two parts, separate means for supplying current to the two parts, separate oscillation circuits including respectively the two parts and means for varying the induction of said oscillation circuits to vary the ratio of currents through the two parts of the coil and secure selective stirring by this variation.

29. A furnace inductor coil having its upper and lower turns closer together than the intermediate turns, connections at an intermediate point and at its extremities whereby current is passed through the coil in two circuits in parallel to cause instantaneous unidirectional magnetic flux, inductances in the circuits through the parts of the coil to form oscillation circuits therewith and means for independently varying the inductances to reduce the current through either of the coil parts with respect to the other.

30. An inductor coil having two parts, the upper having the turns closer together at the top than at any place below the top and the lower having the turns closer together at the bottom than at any place above the bottom and induction means outside of the coil parts for varying the current through one part of the coil with respect to another part thereof.

31. An inductor coil having two parts, the upper having the turns closer together at the top than at any place below the top and the lower having the turns closer together at the bottom than at any place above the bottom, induction means outside of the coil parts for varying the current through one part of the coil with respect to another part thereof and supply means therefor connecting at an intermediate portion of the coil parts and the extremities thereof respectively.

32. In an inductor furnace, an inductor coil of uniform cross section oppositely wound above and below a point intermediate between its extremities and having the number of turns per unit length increased toward the extremities.

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