

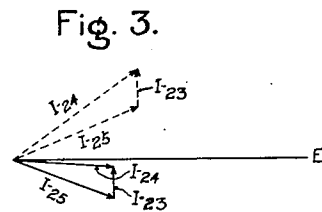
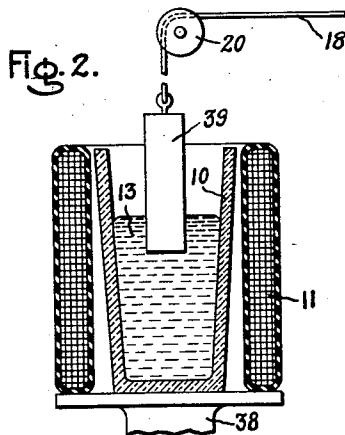
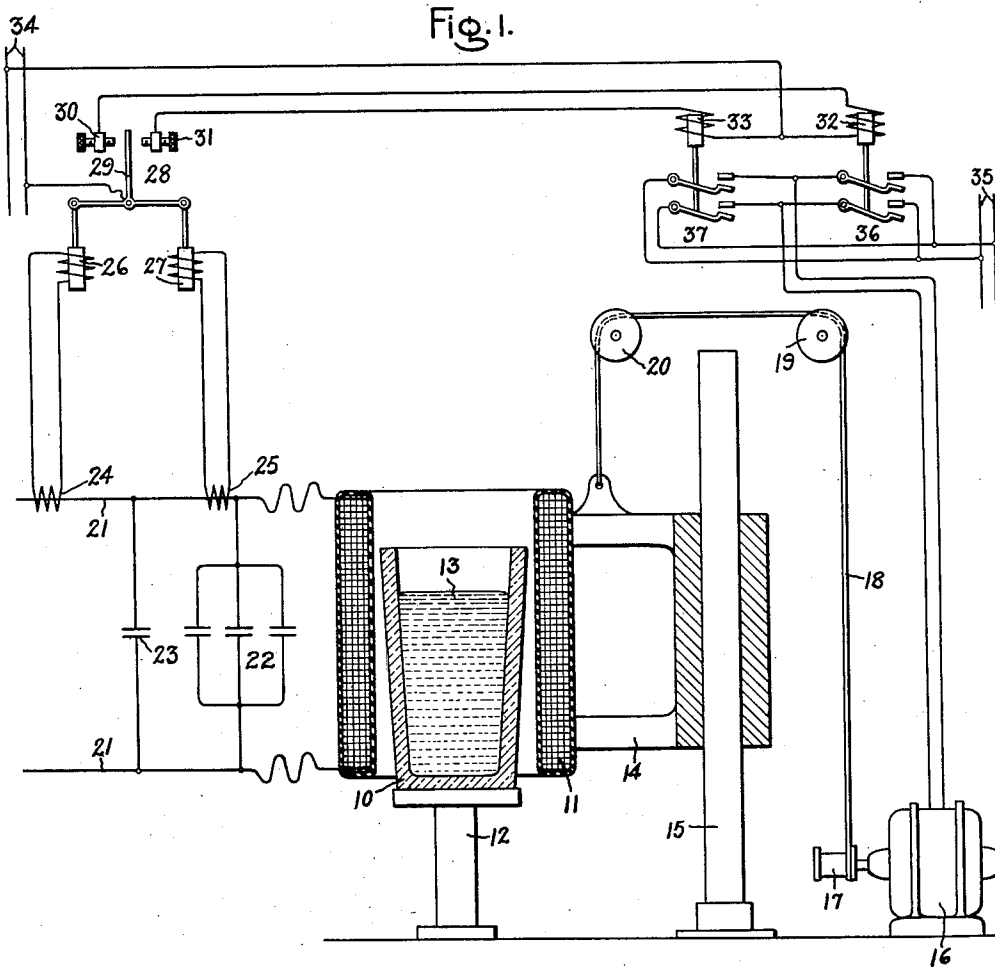
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G. A. CHUTTER

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INDUCTION FURNACE

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Inventor:
George A. Chutter,
by *Charles E. Tuller*
His Attorney.

UNITED STATES PATENT OFFICE

GEORGE A. CHUTTER, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

INDUCTION FURNACE

Application filed April 13, 1928. Serial No. 269,778.

My invention relates to electric induction furnaces, more particularly to high frequency metal melting furnaces, and has for its object the provision of means for maintaining substantially unity power factor while the metal is being melted.

It is well-known that high frequency induction furnaces inherently have low power factors. One method of increasing the power factor is to add capacitor units across the current supply for the primary winding. However, in spite of this addition of capacitor units, as the material in the furnace melts, the power factor becomes lower and lower. This characteristic of the electric furnace makes it necessary to provide generating equipment suitable for operation over a wide range of power factors, which increases the cost of the equipment. Still further disadvantages are encountered inasmuch as instruments, such as an indicating wattmeter, may be calibrated for a circuit operating on unity power factor and may indicate considerably in error on the same circuit if the power factor varies over a wide range. Now the power factor of the furnace circuit to a certain extent depends upon the coupling between the primary coil and the material being melted, which forms a short circuited secondary. By changing the position of the primary coil with respect to the material to be melted the coupling will be changed, and hence in this manner the power factor of the furnace circuit may be varied.

In carrying out my invention I provide means responsive to variations in the power factor of the furnace for causing the coupling between the primary winding and the material to be melted to be increased or decreased as the power factor changes.

For a more complete understanding of my invention, reference may be had to the accompanying drawing in which Fig. 1 is a diagrammatic representation of one embodiment of my invention. Fig. 2 illustrates a modification and Fig. 3 is a vector diagram illustrating the operation.

Referring to Fig. 1 of the drawing, in carrying out my invention in one form, I provide an electric furnace comprising a refrac-

tory crucible 10 for containing the metal to be melted, and a primary winding 11. The crucible 10 is shown as a vertical, elongated container which rests upon a heat and electrically non-conducting base 12. The winding constituting the primary 11 is shown as substantially surrounding the crucible 10 containing the molten metal 13, but it is to be understood that my invention is not limited to this precise arrangement. The winding 11 is supported by a frame 14 which is slidably mounted upon a fixed vertical post 15. The support 14 and post 15 are made of a suitable electrically non-conducting material. A reversible electric motor 16, shown as being of a direct current type, is arranged near the slidable support 14 and the pulley 17 of this motor 16 is connected to the support 14 by means of a flexible rope or chain 18 passing over pulleys 19 and 20. It will be observed that as the motor 16 is operated in one direction the frame 14 and winding 11 will be raised, while when the motor is operated in the opposite direction the support 14 and winding 11 will be lowered. I have disclosed connections for automatically reversing the motor 16 in accordance with changes in the power factor of the furnace circuit from leading to lagging or from lagging to leading. These connections will now be described.

The primary winding 11 is connected to a source 21 of a high frequency alternating current supply. Located in the connections of the source of supply 21 to the winding 11 is a bank of capacitors 22 which serves the purpose of raising the power factor of the circuit. While I have illustrated three capacitors, it is to be understood that any number of units may be used in order to obtain a power factor as near to unity as possible.

Although obviously any suitable power factor responsive means may be used for controlling the coupling between the primary winding 11 and the molten metal charge 13, I preferably use the power factor responsive means described and claimed in my copending application Serial No. 366,055 filed May 25, 1929. This means comprises a capacitor

unit 23 which is connected across the supply lines 21 together with coils 24 and 25 electrically associated with one of the supply lines 21 on opposite sides of the connection leading from that supply line to the capacitor 23. These coils as shown constitute the secondaries of current transformers, the primaries of which are connected in the particular supply line 21 with which they are associated. The coils 24 and 25 are shown as connected directly to operating windings 26 and 27 respectively, and these windings 26 and 27 actuate a contactor 28 which comprises a movable contacting arm 29 and two fixed contacts 30 and 31. For most cases windings 26 and 27 will be connected as shown, to the circuit through current transformers, but in case the voltage and current are low, windings 26 and 27 can be connected directly in the supply line 21. The contacts 30 and 31 are connected to operating windings 32 and 33 respectively, and the windings 32 and 33 and the movable contacting arm 29 are connected to a suitable source of supply 34. The motor 16 is adapted to be connected to a suitable source of supply 35 and in the connections between the motor 16 and the supply source 35 are located reversing switches 36 and 37 operated by the windings 32 and 33 respectively. In the operation of the furnace, if the power factor of the furnace circuit is very far from unity the difference between the currents in the coils 24 and 25 will be sufficient to cause the movable contacting arm 29 to move in one direction or the other. To illustrate this, let us refer to the vector diagram shown in Fig. 3, in which the full line I_{25} represents a lagging current in the circuit which forms the primary of the current transformer 25. Now, if full line I_{23} designates the current in the circuit containing condenser 23, then full line I_{24} will represent the current in that part of the circuit which forms the primary of current transformer 24. Again, assuming that dotted line I_{25} represents a leading current in that part of the circuit which forms the primary of current transformer 25, and dotted line I_{23} the current in condenser 23 then dotted line I_{24} will represent the current in that part of the circuit which forms the primary of current transformer 24. It will be observed that in the case of a lagging current, the current in coil 24 will be less than that in coil 25 as evident from the full lines in the diagram, while in the case of a leading current, the current in coil 24 will be greater than the current in coil 25, as is apparent from the dotted lines in the diagram. Thus, if the power factor of the supply circuit is lagging, the current in coil 25 will be greater than the current in coil 24 and the arm 29 will move to the right, connecting with fixed contact 31 and establishing a circuit from the source 34 through the winding 33, causing the motor 16 to be operated in a direction to lower the sup-

port 14 and winding 11. On the other hand if the power factor is leading, the current in coil 24 will be greater than that in coil 25 and the arm 29 connecting with the contact 30 will establish a circuit from source 34 through winding 32, thus causing the motor 16 to be operated in the opposite direction to raise the support 14 and winding 11. If there is no appreciable difference between the current in coil 24 and the current in coil 25, the contact arm 29 will remain midway between contacts 30 and 31 and the motor 16 will not be actuated.

In Fig. 2 I have illustrated another embodiment of my invention. In some furnace installations, especially in those in which a relatively large furnace is to be used it may be impractical to mount the primary winding so that it may be moved relatively to the crucible, as shown in Fig. 1. In Fig. 2 I have illustrated a furnace in which the crucible 10 and the primary winding 11 are rigidly supported on a suitable electrically non-conducting base 38. In order to secure a variable coupling between the primary winding 11 and the metal 13 I have provided means comprising a block 39 of a refractory material, in or directly suspended over a crucible 10. A flexible member 18 passing over a pulley 20 is secured at one end to the refractory block 39 and at the other end to the pulley of a motor, such as the motor 16 illustrated in Fig. 1.

The operation of this form of my invention is as follows: When the metal 13 in the crucible 10 is cold, the refractory block 39 will be supported upon the top surface of the metal or may be suspended in any position above the crucible 10. When the primary winding 11 is energized and the metal 13 begins to melt, the power factor of the furnace circuit will tend to decrease. On a decrease in the power factor, however, the motor attached to the flexible member 18 will operate to allow the refractory block 39 to be lowered into the metal in the crucible, as is shown in the drawing. As the refractory block 39 lowers into the metal 13, some of the metal will be displaced and will rise in the crucible around the block 39 to a height depending upon the position of the refractory block 39. As the metal 13 rises in the crucible 10 the effective resistance of the metal will be somewhat increased and this will tend to improve the power factor. However, a much greater rise in the power factor will be due to the increased coupling obtained between the winding 11 and the metal which now fills the crucible to a higher level than was obtained before the refractory block 39 was lowered into the metal. The motor which may be attached to the flexible member 18 may be controlled in the same manner and by the same apparatus as was described and illustrated in connection with that form of my invention shown in Fig. 1, the main difference between the two

forms being that in that type shown in Fig. 1 the motor 16 raises or lowers the primary winding 11 in accordance with an increase or decrease in the power factor of the furnace circuit, while in Fig. 2 the motor raises or lowers the refractory block 39 in accordance with an increase or decrease in the power factor of the furnace circuit.

It is to be understood that the illustration of my apparatus is very diagrammatic. The motor 16 may be of any type in which the direction of rotation can be reversed. If necessary, the primary winding may be cooled by any suitable means such as by passing a current of cooling air or water through the winding. Since these details form no part of my invention they have not been illustrated.

While I have described my invention as embodied in concrete form and operating in a specific manner in accordance with the provisions of the patent statutes, it should be understood that I do not limit my invention, thereto, since various modifications thereof will suggest themselves to those skilled in the art without departing from the spirit of my invention, the scope of which is set forth in the annexed claims.

What I claim as new and desire to secure by Letters Patent of the United States is:—

1. An induction heater comprising a primary winding for inducing heating currents in a charge to be heated, a support for said charge, and means responsive to a condition of the circuit of said primary winding for varying the positions of said winding and support with relation to each other.

2. In an induction heater, a support for the material to be heated, a primary winding surrounding said support, and means responsive to variations in power factor for causing relative movement between said support and said winding.

3. In a metal melting furnace, a heat refractory crucible for containing metal to be heated, a primary winding surrounding said crucible, and means responsive to variations in power factor for causing relative movement between said crucible and said winding.

4. In a high frequency induction furnace, a heat refractory crucible for containing metal to be heated, a primary winding adjacent said crucible, a source of alternating current supply for said primary winding, and means responsive to variations in the power factor of the current supplied to said winding for causing a relative movement between said winding and said crucible.

5. In a high frequency induction furnace, a heat refractory crucible for containing metal to be heated, a primary winding surrounding said crucible and mounted for vertical movement, an alternating current supply for said winding, and means responsive to changes in the power factor of said current

for moving said winding relatively to said crucible.

6. In a high frequency induction furnace, a heat refractory crucible for containing metal to be heated, a primary winding surrounding said crucible, a vertical post, a support for said winding slidably mounted on said post, a reversible motor connected to said support so as to raise said support when operated in one direction and to lower said support when operated in the other direction, an alternating current supply for said winding, and means responsive to variations in the power factor of said current for reversing said motor.

7. In a high frequency induction furnace, a heat refractory crucible for containing metal to be heated, a primary winding surrounding said crucible, a vertical post, a support for said winding slidably mounted on said post, a reversible motor connected to said support so as to raise said support when operated in one direction and to lower said support when operated in the other direction, an alternating current supply for said winding, and means responsive to changes in the power factor of said current from lagging to leading or from leading to lagging for reversing the direction of rotation of said motor and consequently the position of said winding, whereby a substantially unity power factor is maintained.

8. In a high frequency induction furnace, a container for metal being heated, a primary winding surrounding said container, a source of alternating current supply for said primary winding, and means responsive to changes in the power factor of the current supplied to said winding for causing relative movement between said winding and said container.

In witness whereof, I have hereunto set my hand this 12th day of April, 1928.

GEORGE A. CHUTTER.