Dec. 12, 1939. D. PISAREV 2,182,819

INDUCTION HEATING DEVICE

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Fig. 1.

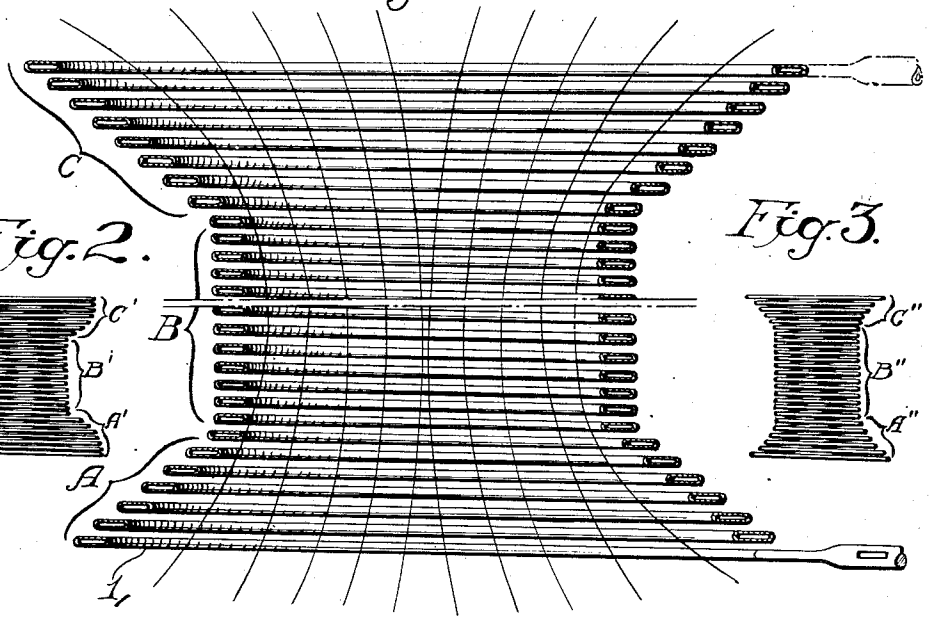
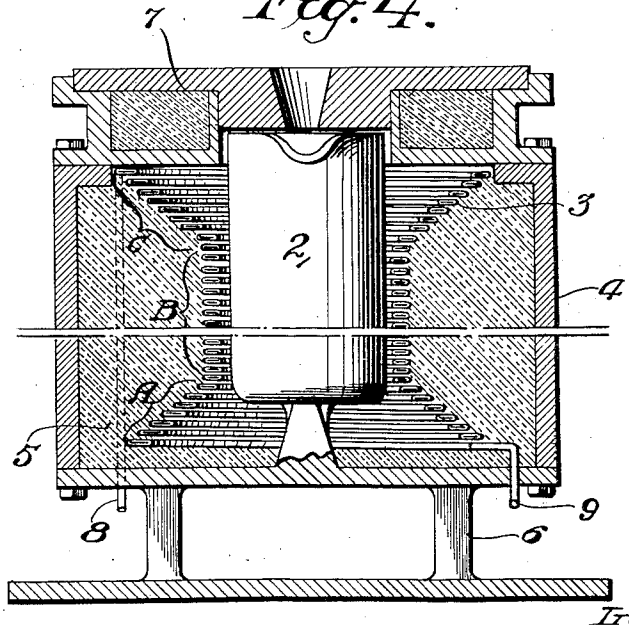


Fig. 2.

Fig. 3.

Fig. 4.



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INDUCTION HEATING DEVICE

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8 Claims. (Cl. 13—27)

This invention relates to new and useful improvements in induction coils, and more particularly to a novel induction coil which is particularly adapted for use in high frequency induction furnaces.

At the present time, the induction coils employed in high frequency furnaces are generally straight-sided and are usually of substantially cylindrical shape. It is desirable to employ a coil of this character in order that the electromagnetic coupling between the coil and article being heated may be uniformly maximum throughout the length of the coil. That is to say, since the electromagnetic coupling between the coil and the article being heated determines the heating action, and since the coupling at any point along the length of the coil depends upon the proximity of the coil at that point to the article, it is desirable to employ a straight-sided or cylindrical coil to obtain uniform maximum coupling and consequent maximum heating throughout the length of the article.

It is characteristic of a high frequency furnace employing such a coil, however, that the article does not heat uniformly throughout its cross section due to the fact that the magnetic field does not penetrate sufficiently into the said article toward the axis of the coil. When electromagnetic energy flows into the interior of a conducting means, its conversion into heat starts at the surface where it enters. The quantity of energy converted diminishes by an equal percentage of its still unconverted value at every point distant below the surface, and at a certain depth below the surface, this absorption or conversion of the total electromagnetic energy supplied is substantially complete. In a solid cylindrical body surrounded by a cylindrical coil, for example, no appreciable electromagnetic energy ever reaches its axis, and, therefore, the axial or inner portions of such cylindrical body must be heated, if at all, by conduction of the heat induced in the peripheral or surface portions thereof. This is evidenced by the visible reddening of the outer cylindrical portion while the inner portion remains black for a considerable period, giving the appearance of a black cylindrical core surrounded by a red cylindrical jacket. The result of this is, of course, that it requires operation of the furnace for a longer period of time than would otherwise be necessary, to compensate for the time required to permit conduction of the induced heat from the peripheral or surface portions to the inner portions of the object and to heat said inner portions to the desired temperature. In any instance, considerable heat is dissipated or lost by radiation and conduction from the object being heated, and this longer period of time required for operation of the furnace consequently results in an increase in such radiation and conduction losses.

By the present invention, this deficiency of the straight-sided or cylindrical coil is materially minimized and, at the same time, the advantages of such a coil are retained. In the present instance that is accomplished by providing at the ends of a straight-sided or cylindrical coil outwardly flared coil extensions which serve to direct the magnetic flux toward the axis of the cylindrical coil, thereby providing a stronger magnetic field along and adjacent the coil axis with the result that the time required to heat an object is materially reduced. These flared end coils operate to direct magnetic flux more toward the axis of the cylindrical coil, thus increasing the extent of penetration or distance below the surface of an object at which absorption of the electromagnetic energy substantially takes place, and reducing the cross sectional area of the inner portions of such object which is heated by conduction only of the induced heat in the peripheral or surface portions thereof.

With the foregoing observations in mind, the principal object of the present invention is to provide an induction coil wherein the flux or magnetic field is directed more toward the axis of such coil and these and other objects of the invention, as well as the features and details of its construction and arrangement, are fully set forth hereinafter and shown in the accompanying drawing, in which

Figure 1 is a view in section vertically through an induction coil made according to this invention;

Figures 2 and 3 are diagrammatic illustrations showing modified arrangements of an induction coil embodying said invention; and

Figure 4 is a view in section vertically through an induction furnace employing an induction coil made in accordance herewith.

As pointed out above, the invention consists essentially in the discovery that by constructing an induction coil to provide at its opposite ends portions arranged in outwardly flared or offset relation, in contrast to the conventional, cylindrical or straight-sided form of coil, the flux or magnetic field set up within the body of the coil is directed more toward the axis of the cylindrical portion of such coil, and referring to

the drawing an induction coil made according to the present invention is composed of a continuous single layer or winding of relatively flat tubular wire 1 wound to form a lower upwardly inclining portion A which terminates at its upper end in a substantially cylindrical portion B which in turn terminates at its upper end in an outwardly flaring portion C of the same general configuration or shape as the first-mentioned portion A. In some instances, it may be desirable to have the portion B slightly tapered, and, therefore, it will be understood that the invention contemplates such modification.

The induction coil is preferably wound upon a suitable mandrel having a surface configuration conforming to the desired shape of the coil, and the number of turns or coils of wire 1 embodied in the cylindrical portion B of the induction coil will, of course, depend upon the axial length of that portion desired in the completed coil. The number of turns or coils of wire provided in the outwardly flaring end portions A or C of the coil may vary as desired to provide any desired ratio between the number of turns or coils of wire in said portions A or C and the cylindrical portion B and, of course, as the length of said cylindrical portion B decreases or is decreased, the more critical or narrow will become the region of concentration of the magnetic field therein.

The induction coil contemplated by this invention is not restricted to the particular configuration or shape illustrated in Figure 1 of the drawing, and similar results are obtained, for example, by constructing an induction coil to provide at the ends of a central cylindrical portion B', portions A' and C' which curve concavely outwardly therefrom as shown in Figure 2, or as shown in Figure 3 wherein outwardly curving convex portions A'' and C'' respectively are provided at opposite ends of a central cylindrical portion B''. Still other forms or shapes may, however, be employed with satisfactory results, and, for example, the convex portions A'' and C'' of Figure 3 may, if desired, extend through an arc of 180° or more.

By directing the flux or magnetic field more toward the axis of the induction coil, a coil constructed in accordance with this invention may be employed to advantage to materially increase the efficiency of a high frequency induction furnace of, for example, the type disclosed in Figure 4 of the drawing, which comprises a crucible 2, an induction coil 3 disposed thereabout and a casing 4 in which said induction coil 3 is suitably mounted and insulated as indicated by reference numeral 5. The casing 4 is supported upon a base structure 6 and is also provided with a suitable closure or cover member 7.

As shown, the induction coil 3 comprises a plurality of turns of wire wound to the general shape or form shown in Figure 1 and consists of a central cylindrical portion B and outwardly flaring opposite end portions A and C, a high frequency current being supplied to said coil 3 through the opposite end portions 8 and 9 thereof which lead respectively to the exterior of the casing 4. For the purpose of cooling the coil, water or other cooling fluid may be passed through the tubular wire forming said coil through the openings afforded at the extremities of the end portions 8 and 9 thereof just mentioned. Use of the coil 3 for heating purposes as described is confined essentially to the central cylindrical portion thereof in order to obtain maximum coupling and consequently maximum heating and also in order that the magnetic field is directed more toward the axis so that the entire length of an object to be heated may receive the full force or action of the flux or magnetic field induced and be heated thereby to a maximum distance below its surface, thus materially reducing the cross sectional area of the inner portions of such object heated only by the conduction of such induced heat. Consequently, the length of time required to heat such object, the amount of power consumed, and equipment necessary are each substantially reduced.

While my description of the invention has been confined to the embodiment or adaptation thereof to high frequency induction furnaces, it will be obvious, of course, that the use of said invention is not limited to a device of that nature, but may be employed to advantage in any instance where it is desired to obtain a maximum magnetic field strength at or adjacent the axis of a coil, and where the length of the center cylindrical portion is decreased, the more critical is the region of concentration of the magnetic field therein.

I claim:

1. An induction furnace or the like comprising an induction coil comprising a substantially cylindrical portion and end portions arranged in outwardly opening relation with respect to said cylindrical portion, a crucible disposed within the cylindrical portion of said coil so as to be in the direct path of its magnetic axis, said outwardly opening end portions of the coil constituting means adapted to direct the magnetic flux more toward the axis of said cylindrical portion and centrally of the crucible.

2. An induction furnace or the like comprising an induction coil including a central substantially cylindrical portion and end portions of substantially frusto-conical configuration diverging outwardly therefrom, a crucible disposed within the cylindrical portion of said coil so as to be in the direct path of its magnetic axis, said outwardly opening end portions of the coil constituting means adapted to direct the magnetic flux more toward the axis of said cylindrical portion and centrally of the crucible.

3. An induction heating device comprising an induction coil consisting of a winding of wire having a central substantially cylindrical portion and end portions arranged in outwardly opening relation with respect to said central cylindrical portion constituting means for directing the magnetic flux more toward the axis of said central cylindrical portion of the coil.

4. An induction heating device comprising an induction coil consisting of a winding of wire having a central substantially cylindrical portion and end portions of substantially frusto-conical configuration diverging outwardly from said central cylindrical portion constituting means for directing the magnetic flux more toward the axis of said central cylindrical portion of the coil.

5. An inductive heating device comprising an induction coil consisting of a winding of wire having a central substantially cylindrical portion and end portions arranged in outwardly curving concave relation with respect to said central cylindrical portion constituting means for directing the magnetic flux more toward the axis of said central cylindrical portion of the coil.

6. An inductive heating device comprising an induction coil consisting of a winding of wire having a central substantially cylindrical portion and

end portions arranged in outwardly curving convex relation with respect to said central cylindrical portion constituting means for directing the magnetic flux more toward the axis of said central cylindrical portion of the coil.

7. An inductive heating device comprising an induction coil having a substantially cylindrical portion to receive a susceptor to be heated and end portions disposed in offset relation with respect to said cylindrical portion to control the distribution of heat in the susceptor along the axial direction thereof.

8. An inductive heating device comprising an induction coil having a substantially straight-sided portion to receive a susceptor to be heated and end portions disposed in offset relation with respect to said straight-sided portion to control the distribution of heat in the susceptor along the axial direction thereof.

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