

[54] HIGH FREQUENCY INDUCTION HEATING APPARATUS

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[58] Field of Search..... 219/10.79, 10.75, 219/10.49

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[57]

ABSTRACT

An apparatus for high frequency induction heating of elongated workpieces wherein the induction heating inductor is mounted as an integral part of the transformer secondary portion. The transformer secondary is comprised of one or more spaced apart disc members having the inductor, which defines a desired workpiece heating pass, disposed therein and extending therebetween. The transformer secondary portion is releasably retained between a pair of spaced apart transformer primary pancake coils with one of the coils positioned in a magnetic coupling relationship with each of the disc members. The transformer secondary portion is easily removable from its magnetic coupling relationship with the transformer primary so as to permit selective use of other secondary portions which include inductors defining different sized workpiece passes.

2 Claims, 4 Drawing Figures

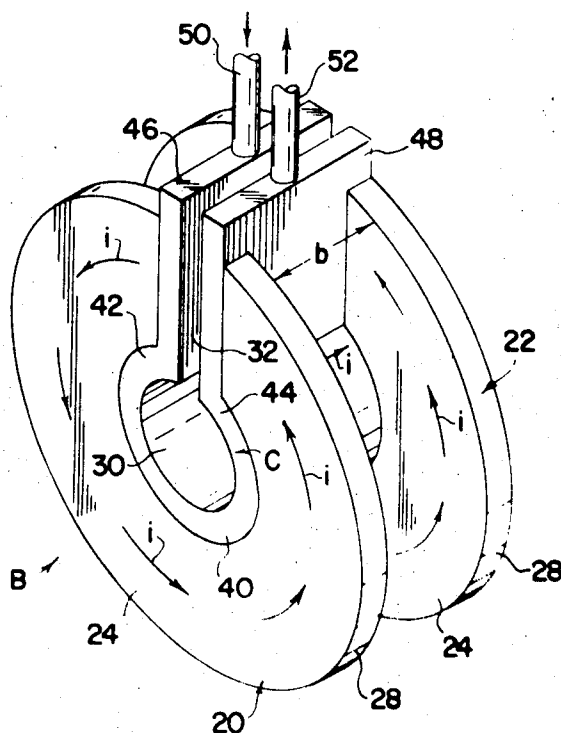


FIG. 1

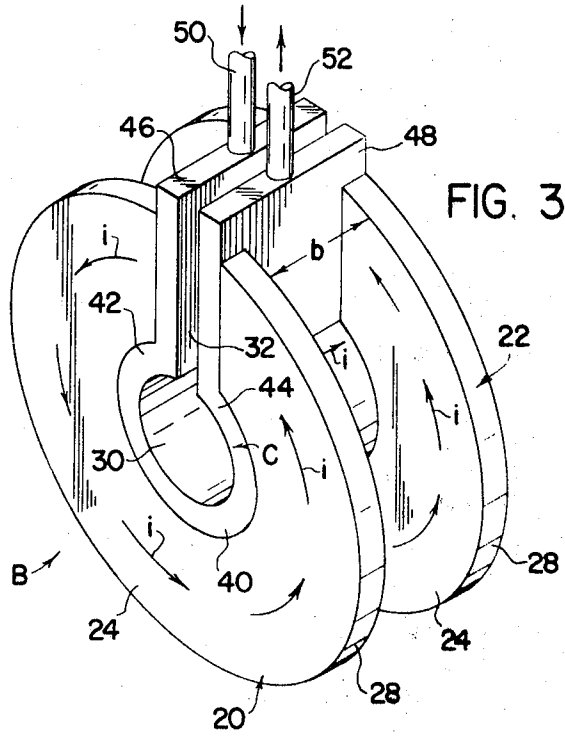
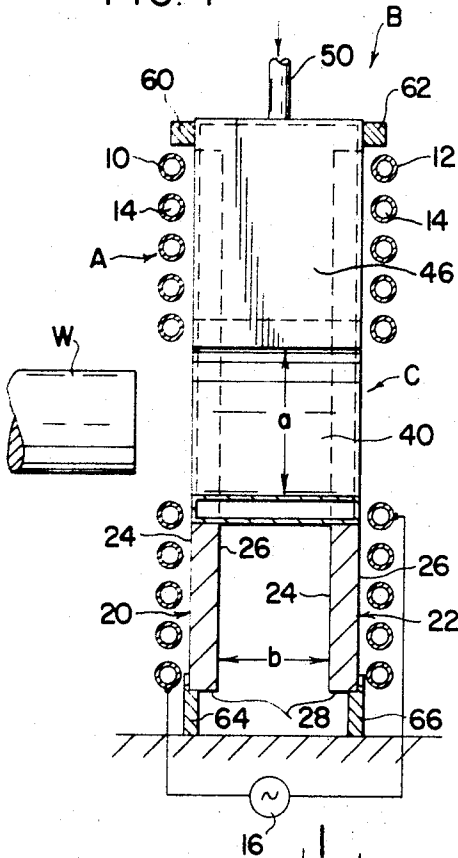


FIG. 2

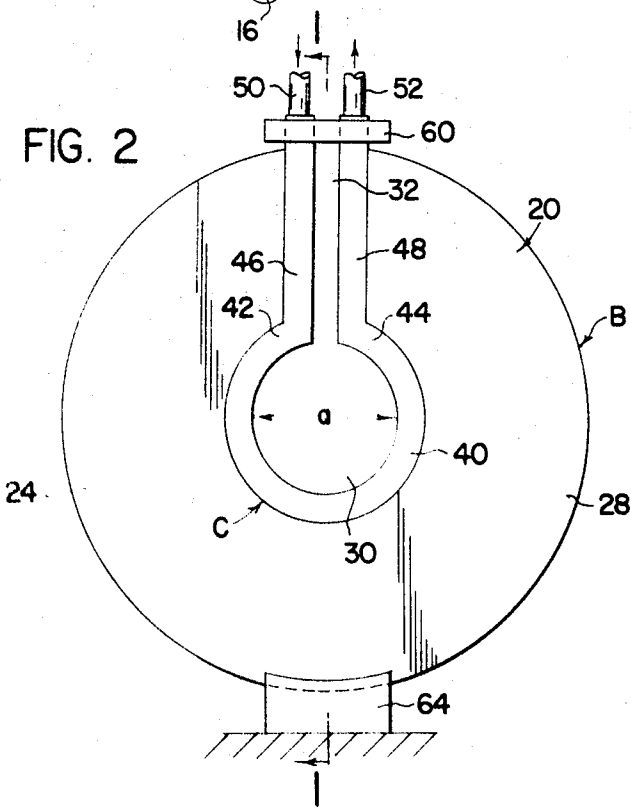
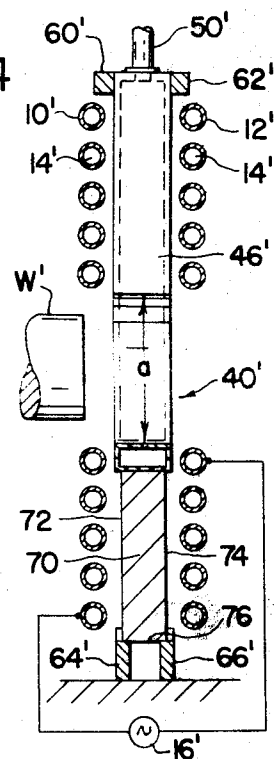


FIG. 4



HIGH FREQUENCY INDUCTION HEATING APPARATUS

This application pertains to the art of induction heating and more particularly to induction heating apparatus.

The invention is particularly applicable to a high frequency induction heating apparatus for heating elongated steel shafts and will be described with particular reference thereto; however, it will be appreciated by those skilled in the art that the invention has broader applications and may be used for inductively heating other types and configurations of workpieces.

Heretofore, when employing high frequency electrical energy, that is, radio frequencies in the range of from about 15 kc to approximately 490,000 c, it has been known to provide at least one thin disc shaped transformer secondary winding disposed in a magnetic coupling relationship with a spiral or pancake type transformer primary winding. This type of arrangement has proved to be advantageous from the standpoint that there is increased coupling between the primary and secondary transformer windings. However, the difficulty encountered with the previous arrangements has been the need for lead lines extending between the secondary winding and the load. A current flow through these lines necessarily involved line losses which reduced the heating efficiency of operation of the inductor since the longer the line length, the greater the line losses.

The present invention contemplates a new and improved apparatus which overcomes all of the above referred problems and provides a new high frequency induction heating apparatus which is simple to construct, economical to use, and provides means whereby the transformer is quickly and readily adapted to use for inductively heating a plurality of different sized or shaped workpieces.

In accordance with the present invention, there is provided a high frequency induction heating apparatus. The apparatus includes a transformer primary winding comprising at least one, generally flat, spiral pancake coil adapted to be electrically connected to a high frequency electrical generator. A transformer secondary winding which comprises at least one electrically conductive disc having spaced apart face areas, a peripheral edge surface and a generally centrally located inductor receiving area extending therethrough is disposed in a magnetic coupling relationship with the primary winding. An inductor is closely received in and substantially surrounds the receiving area so as to define a workpiece heating pass having a cross sectional dimension adapted to permit a workpiece to be passed therethrough in an inductive coupling relationship therewith.

In accordance with another aspect of the present invention, there is provided means for releasably locating the secondary winding relative to the primary winding with one of the face areas in a magnetic coupling relationship with the primary.

In accordance with a limited aspect of the present invention, the secondary winding is comprised of a pair of discs disposed in an electrically conductive relationship to each other and in an electrically conductive relationship with the inductor. The transformer primary winding comprises a pair of pancake coils spaced apart from each other with one of the coils being disposed in a magnetic coupling relationship with the outwardly

facing face area of each of the pair of discs when the secondary winding is received in the locating means.

The principal object of the present invention is the provision of a high frequency induction heating apparatus wherein the induction heating inductor is integral with the transformer secondary portion.

Another object of the present invention is the provision of a high frequency induction heating apparatus which is simple in construction.

Another object of the present invention is the provision of a high frequency induction heating apparatus which is economical to manufacture.

Still another object of the present invention is the provision of a high frequency induction heating apparatus wherein the transformer secondary and inductor are interchangeable relative to the transformer primary in order to permit selective use of the apparatus with a plurality of different sized and shaped workpieces.

The invention may take physical form in certain parts and arrangements of parts, a preferred embodiment of which will be described in detail in this specification and illustrated in the accompanying drawings which form a part hereof and wherein:

FIG. 1 shows a cross sectional view of the apparatus comprising the subject invention;

FIG. 2 is a front view showing the secondary portion and the induction heating inductor of the apparatus;

FIG. 3 is a perspective view of the secondary portion and the induction heating inductor of the apparatus; and,

FIG. 4 is a cross sectional view of an alternative apparatus employing the concepts of the subject invention.

Referring now to the drawings wherein the showings are for the purposes of illustrating the preferred embodiment of the invention only and not for purposes of limiting same, the FIGURES show the subject apparatus comprising a transformer primary winding or portion A, a transformer secondary winding or portion B and an induction heating inductor portion C.

More specifically, primary portion A is comprised of a pair of parallel spaced apart pancake-type coils generally designated 10,12. These coils may be constructed as is conventional and in a flat spiral shape so as to define generally flat planes. These pancake coils may, for example, be manufactured from copper tubing to include a passageway 14 therethrough in order that a cooling fluid, such as for example water, may be continuously passed therethrough as is also conventional in the art. Coils 10,12 are conveniently interconnected to a high frequency electrical generator generally designated 16, also conventional in the induction heating art, to provide a source of high frequency electrical energy. It should be here noted that generator 16 is schematically shown as being connected to the inside loop of coil 10 and the outside loop of coil 12 for reasons which will hereinafter become apparent.

Secondary portion B is comprised of a pair of thin, generally circular discs 20,22 each having spaced apart face areas 24,26 and a peripheral edge surface 28 extending between areas 24,26. These thin discs may be manufactured from any material conventionally used for transformer secondary construction such as, for example, copper. Disposed in each of discs 20,22 and generally centrally located therein is a circular heating conductor receiving recess 30 and cooling leg conductor receiving slot 32 extending radially outward from recess 30 to peripheral edge surfaces 28. It should be

noted that recess 30 and slot 32 extend completely through each of discs 20,22 so that the discs per se are generally U-shaped. The particular cross sectional dimensions of recess 30 and slot 32 are primarily dependent upon the specific configuration of inductor portion C and the dimensions of the workpiece to be heated. These considerations will hereinafter become more fully apparent.

Inductor portion C includes a generally circular heating conductor 40 having adjacent spaced apart end portions 42,44. Extending generally radially outward from end portions 42,44 is a pair of cooling leg conductors 46,48. Inductor portion C may be constructed from any material suitable for use as an inductor and, in the preferred embodiment, rectangular copper tubing is employed. Conductors 40,46 and 48 are hollow, as is conventional, in order to permit a continuous cooling fluid passage therethrough. Adjacent the end of conductor 46 is a cooling fluid inlet 50 and adjacent the end of conductor 48 is a cooling fluid outlet 52. In the preferred embodiment of the invention, inlet 50 is connected to a water supply and outlet 52 is connected to a drain although other arrangements could also be advantageously employed.

As can best be seen in FIGS. 1 and 3, at least conductor 40 of inductor portion C is slightly elongated so that the total width thereof is slightly greater than the combined thickness of discs 20,22. Although, in the preferred embodiment, heating conductor 40 is shown as being generally circular, it will be appreciated that other configurations could be used where the type of workpiece and desired heating so dictated. In any event, recess 30 and slot 32 are dimensioned to closely receive inductor portion C, i.e., conductors 40,46 and 48, therein with diameter a of generally circular conductor 40 defining the width of an induction heating pass and with conductors 46,48 spaced apart from each other so that they will not cause an electrical short circuit during apparatus operation. It will be appreciated that an insulating material could be placed between conductors 46,48 to further eliminate any possibility of short circuiting. Disc 20 is received at least over conductor 40 adjacent one end thereof and disc 22 is received at least over conductor 40 adjacent the other end thereof so that there is defined between face area 26 of disc 20 and face area 24 of disc 22 a clearance gap b in order to prevent shorting between discs 20,22 during apparatus operation. Again, an insulating material could also be placed in gap b . Discs 20,22 may be held in position on conductor 40 relative to inductor portion C by any convenient means such as, for example, brazing. It should be here noted that discs 20,22 are each also in a closely spaced electrically conductive relationship with conductors 46,48. Disposed adjacent the outermost peripheral edge of pancake coils 10,12 are upper retaining blocks 60,62 and lower retaining blocks 64,66. These blocks are so dimensioned that the transformer secondary and inductor portions, as shown in FIGS. 1 and 3, may be received in a desired magnetic coupling relationship between coils 10,12. It is desirable that retaining blocks 60,62,64 and 66 permit secure retention but easy release of the transformer secondary and inductor portions in order that they may be easily interchangeable with other, similar transformer secondary and inductor portions for reasons which will hereinafter become more fully apparent.

With secondary portion B and inductor portion C in position as shown in FIG. 1, and with high frequency electrical generator 16 energized, a current is induced to flow through discs 20,22 and conductor 40. In FIG. 3, as shown by arrows i , a current flow path is established which extends generally circularly around discs 20,22. In the preferred embodiment of the invention and with generator 16 hooked up as schematically shown in FIG. 1, the alternating directional current flow paths in the discs are always in the same direction relative to each other. Thus, a workpiece W passed longitudinally through the workpiece heating pass defined by heating conductor 40 and in an inductive coupling relationship with the conductor will be inductively heated as is conventional. The amount of heating to workpiece W is dependent upon the conventional variables associated with induction heating. Continuous coolant flow through coils 10,12 and inductor portion C retains those components at a temperature below their melting points during apparatus operation.

Should it be desired to provide different workpiece heating pass dimensions a or different heating pass configurations in order to achieve an efficient inductive coupling relationship with the inductor, it is merely only necessary to provide a plurality of other transformer secondary and inductor portion combinations into which the various pass dimensions a or configurations are incorporated. When a particular pass size is then required for heating, the transformer secondary and inductor portion in association with the transformer primary portion is removed from its releasably clamped position relative thereto and the transformer secondary and inductor portion having the desired pass is inserted therefor. Only the cooling fluid inlet and outlet must be connected in order to make the apparatus operative.

It should also be noted, and with reference to FIG. 4, that the concepts of the subject invention may be employed when only one disc 70 is used. In FIG. 4 and for ease of illustration, identical components have identical primed numerals and new components have new numerals. Disc 70 is similar to discs 20,22 and includes face areas 72,74 and a peripheral edge surface 76. Disposed in a generally centrally located recess 78 is a circular heating conductor 40' having cooling leg conductors 46',48'. In this arrangement, the current flow is in the same direction on both face areas similar to the current flow in discs 20,22 in the embodiment shown in FIGS. 1-3. Operation or heating of workpiece W' is also the same as hereinabove described with reference to FIGS. 1-3 and workpiece W as will be appreciated.

If desired, and with reference to both embodiments as shown in FIGS. 1-3 and FIG. 4, at least the transformer secondary portions, i.e., discs 20,22 and disc 70 and the associated inductor portions C, may be advantageously rotated in order to secure more even heating of workpieces W , W' .

The invention has been described with reference to the preferred embodiment. Obviously, modifications and alterations will occur to others upon the reading and understanding of the specification. It is my intention to include all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

Having thus described my invention, I now claim:

1. A high frequency induction heating apparatus comprising: an induction heating inductor having a

workpiece encircling portion with a central workpiece receiving passage moving along a given path, and a slot intersecting said passage and generally radially extending from said path and defining opposite ends of said inductor; a transformer secondary plate secured to said inductor in a plane generally perpendicular to said path and coextensive with said inductor between said ends, said plate having at least one generally flat surface in a plane generally perpendicular to said path, an inner peripheral surface engaging said inductor, an outer peripheral surface and a slot aligned with said inductor slot and extending between said peripheral surface; a generally flat spiral pancake-type primary coil having a central opening surrounding said path, positioned

parallel to said flat surface and magnetically coupled thereto; and, means for connecting said primary coil to a source of high frequency current.

2. A high frequency induction heating device as defined in claim 1 wherein said secondary plate includes two generally parallel discs with one of said discs having a surface forming a generally flat surface and the other of said disc having a generally flat surface generally perpendicular to said path and a second generally flat spiral pancake-type primary coil positioned parallel to said flat surface of said other disc and magnetically coupled therewith, said means for connecting said second primary coil to said high frequency power source.

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