

[54] SLAB HEATING DEVICE

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[56] References Cited

UNITED STATES PATENTS

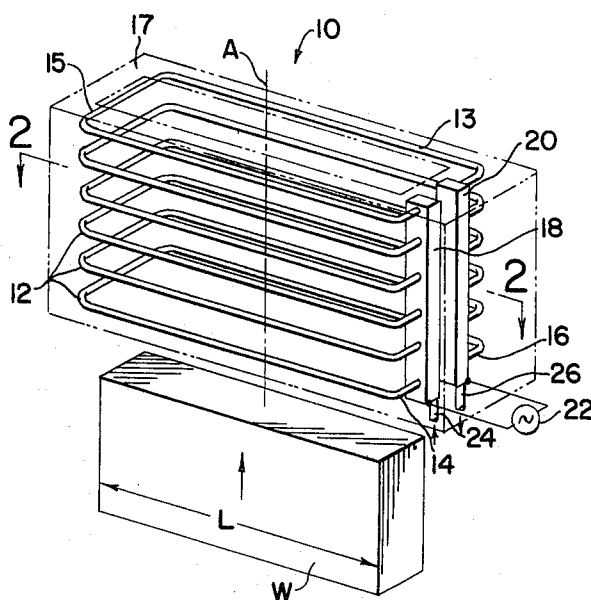
3,522,405	8/1970	Seulen et al.	219/10.79
3,497,658	2/1970	Ross	219/10.79 X
3,505,492	4/1970	Ross	219/10.79 X
3,492,453	1/1970	Hurst	219/10.79 X
3,489,875	1/1970	Ross	219/10.79 X

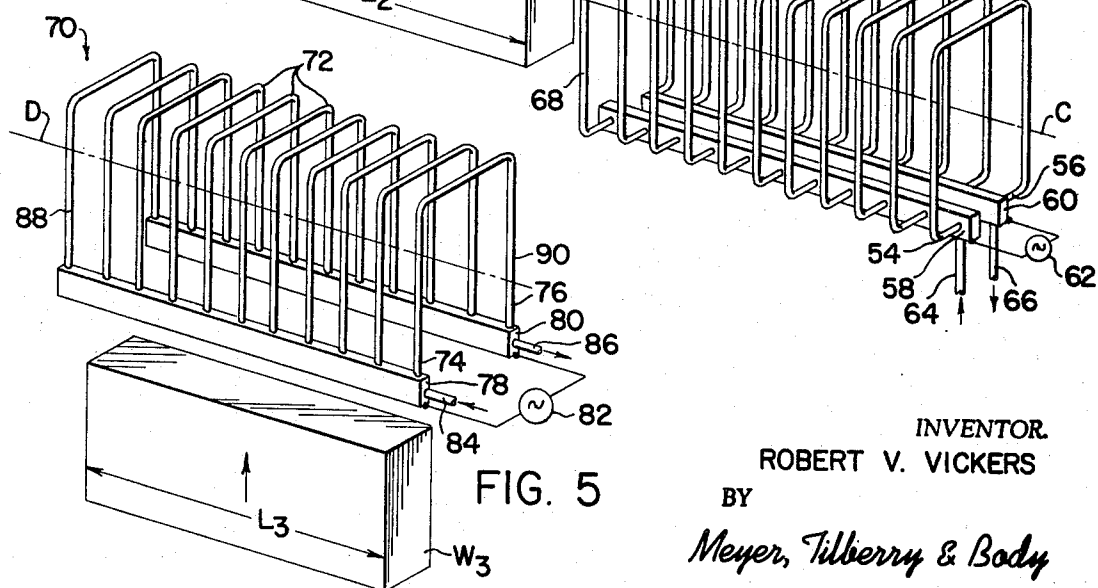
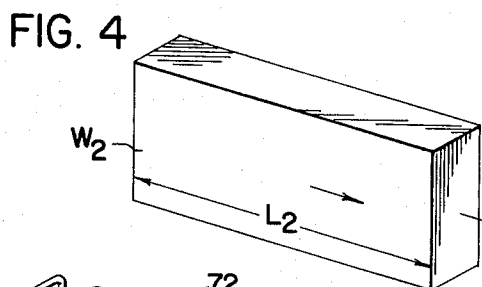
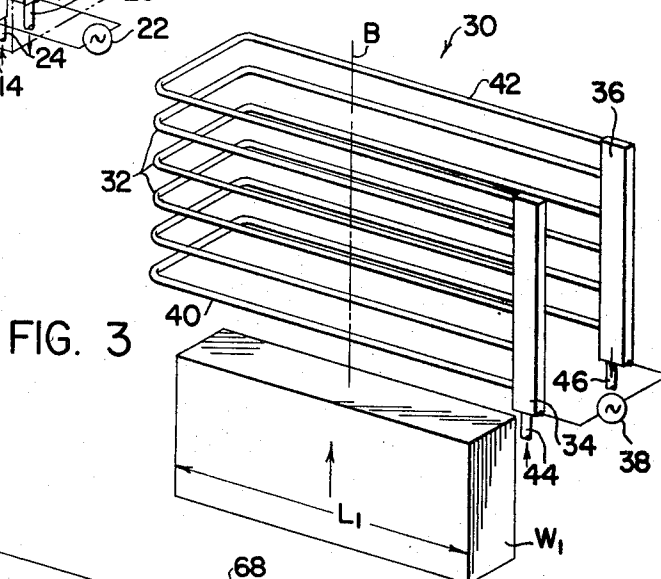
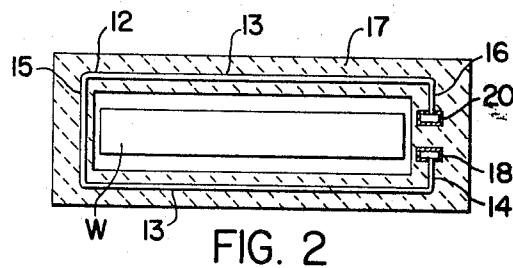
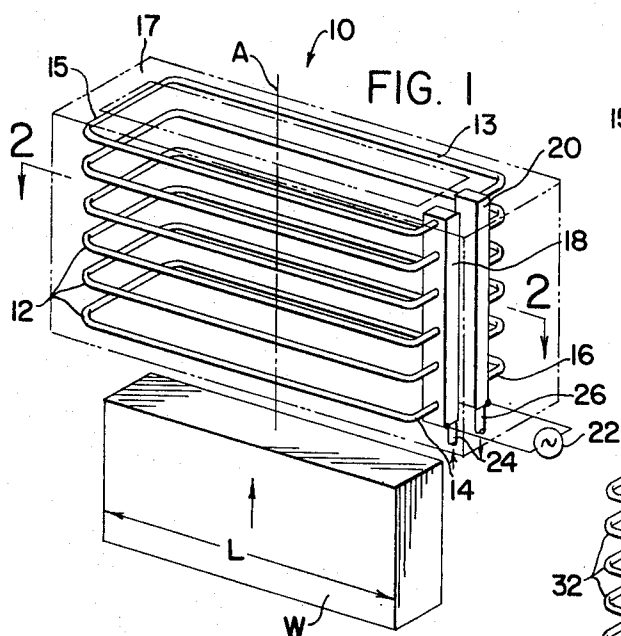
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[57] ABSTRACT

An induction heating unit is provided which is comprised of a plurality of substantially U-shaped or O-shaped tubular conductor sections having opposite ends interconnected one with a first tubular bus bar component and the other with a second tubular bus bar component parallel to the first. The conductor sections are disposed in spaced apart planes which are parallel to one another and perpendicular to the axis of the coil unit. The bus bar components are connected to opposite sides of a source of alternating current, whereby the several conductor sections are connected in electrical parallel. One of the bus bar components serves as an inlet header for coolant fluid for the heating unit and the other of the bus bar components serves as a discharge header for coolant fluid.

6 Claims, 5 Drawing Figures





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SLAB HEATING DEVICE

This invention relates to the art of induction heating and, more particularly, to an induction heating unit structure.

Induction heating coils have been provided heretofore for the purpose of inductively heating metal workpieces including metal ingots. Such heating coils generally are defined by a continuous coil of conductive, non-magnetic material such as copper through which cooling fluid is circulated and the opposite ends of which are connected across a suitable source of alternating current. The conductors of such coil units may have a circular configuration or a rectangular configuration when viewed in the direction of the axis thereof depending on the configuration of the workpiece to be heated. Moreover, such coils may have an inner diameter ranging in size from that capable of inductively heating a 3/16 inch rod to a size large enough to inductively heat a metal ingot such as, for example, a rectangular ingot having a width of 1 foot, a breadth of four feet and a length of 15 feet.

It will be appreciated that the inductive heating of large billets or ingots requires a coil of considerable size. Further, a voltage output to the coil of considerable magnitude is often required to realize a current of sufficient magnitude to achieve desired heating of the billet. One of the most frequently employed power sources is a motor-generator set, which power source has a constant voltage output characteristic. Most often, means must be provided between the power source and induction coil to match the coil and power source. Matching of the coil and power source provides for the induction heating coil to draw the desired amount of power when it is connected to the induction heating machine or power source. The power drawn by an induction heating coil depends, of course, on the voltage and the coil resistance and reactance. For a given coil and workpiece combination, there is only one value of voltage which will result in the desired amount of power. Most often, a coil will be constructed of a size and shape needed for a particular heating operation. Then, by means such as transformers, the coil is matched to the power source which is to be employed to energize the coil. Depending on the voltage which is necessary to provide for the induction coil to draw the desired amount of power, a step-down or step-up transformer is employed. There are instances, of course, wherein matching is not necessary and the induction coil can be connected directly to the motor-generator set. In either instance, however, when the ingot or workpiece to be heated is extremely large or considerable heating power is required to heat the surface of a workpiece rapidly without heating the interior of the workpiece, a motor-generator set of considerable rating and/or a suitable transformer must be employed to provide the necessary voltage. Larger motor-generator sets are, of course, more expensive in initial cost and in operating costs than are smaller sets, and the use of a transformer to match the coil and motor-generator set involves additional costs in the production and operation of a desired induction heating system. Accordingly, it will be appreciated that it would be most desirable to provide a system wherein an induction heating unit could provide a desired high current flow with a lower input voltage than that required with coils heretofore known, whereby smaller motor-generator

sets could be employed to achieve the same heating capacity.

The foregoing desired results are achieved in accordance with the present invention by providing an induction heating unit which is defined by a plurality of conductor sections connected in electrical parallel across a pair of bus bar conductors which are in turn connected across opposite sides of an alternating current power source. By connecting the conductor sections in electrical parallel, a lower voltage source can be employed to achieve a desired current flow through the conductor sections, which current flow is uniform for all of the conductor sections, whereby uniform heating of a workpiece along the length thereof is achieved in a manner similar to that achieved with an induction coil defined by a continuous helical coil. Moreover, by connecting the conductor sections in electrical parallel the heating unit defined thereby is operable even in the event that one of the conductor portions for some reason becomes shorted and fails to function. Such a short in a continuous coil, of course, renders the entire coil useless.

In accordance with a narrower aspect of the present invention, the conductor sections are substantially O-shaped or U-shaped in configuration so that the conductor sections extend substantially completely around a workpiece to be heated. Further, the bus bars and conductors defining the induction heating unit are tubular components which provide for the bus bars to serve as headers for cooling fluid such as water to be flowed through the bus bars and conductor sections to cool the latter.

Accordingly, an outstanding object of the present invention is the provision of an induction heating unit which provides for a desired current flow therethrough to be achieved employing a lower voltage input thereto than heretofore required.

Another object is the provision of an induction heating unit of the above character which is defined by conductor sections connected in electrical parallel across the power source, whereby a desired current flow to the conductor sections can be achieved employing a lower input voltage than heretofore required.

A further object of the present invention is the provision of an induction heating unit of the above character which facilitates the use of smaller power supply equipment to achieve a given current flow therethrough than was heretofore possible, whereby a reduction in the cost and operation of power supply equipment is possible.

The foregoing objects and others will in part be obvious and in part more fully pointed out hereinafter in conjunction with the description of the drawing illustrating preferred embodiments of the present invention and in which:

FIG. 1 is a perspective view of an induction heating unit constructed in accordance with the present invention;

FIG. 2 is a view in section of the unit of FIG. 1, the section being taken along line 2—2 in FIG. 1;

FIG. 3 is a perspective view of a modified form of the heating unit illustrated in FIG. 1;

FIG. 4 is a perspective view of another induction heating unit constructed in accordance with the present invention; and

FIG. 5 is a perspective view of yet another embodiment of an induction heating unit within the present invention.

Referring now to the drawings in greater detail wherein the showings are for the purpose of illustrating preferred embodiments of the present invention only and not for the purpose of limiting the same, induction heating means 10 is illustrated in FIGS. 1 and 2 of the drawing which is comprised of a plurality of conductor sections 12 having opposite ends 14 and 16 conductively connected, respectively, to conductor means 18 and 20.

Conductor means 18 and 20 are connected respectively to opposite sides of a source of alternating current 22 such as a motor generator set. It will be appreciated therefore, that conductor means 18 and 20 define bus bar means for conductor sections 12.

Conductor sections 12 are defined by tubular components of suitable conductive, non-magnetic material such as copper, and bus bar means 18 and 20 preferably are hollow and are constructed of conductive, non-magnetic material such as copper. The conductor sections and bus bar means are disposed in suitable refractory insulating material 17. Further, ends 14 and 16 of the tubular components defining sections 12 open into the interior of tubular bar means 18 and 20 to permit circulation of cooling fluid such as water from one of the bus bar means through sections 12 to the other of the bus bar means. More particularly, one of the bus bar means, for example bar means 18, is provided with inlet conduit means 24 leading from a source of cooling fluid, not illustrated, and the other of the bus bar means, in this instance bar means 20, is provided with outlet conduit means 26 for cooling fluid circulated through the heating unit. Thus, the tubular bar means 18 and 20 also define inlet and outlet header means for cooling fluid.

It will be appreciated that the electrical interconnection of the several conductor sections 12 and bar means 18 and 20 provide for the sections 12 to be connected in electrical parallel, whereby the voltage output from alternating current power source 22 is applied to each of the conductor sections. Accordingly, the current flowing through each conductor is the same and will be of a magnitude which is, of course, dependent on the resistance of the corresponding conductor section. Preferably, the resistance of each conductor section will be the same, whereby current induced into a workpiece to be heated will be uniform along the axial length of the heating unit to provide uniform heating of the workpiece. As mentioned hereinabove, by providing for the conductor sections to be connected in electrical parallel a desired current flow can be provided without necessitating the use of as large a voltage output from source 22 as would be required if the heating unit were defined by a continuous helically coiled conductor. In this respect, less voltage is required to achieve a desired current flow in each of the conductor sections connected in parallel than would be required to achieve the same current flow through a continuous coil having a number of turns corresponding to the number of conductor sections connected in parallel. For example, if a continuous coil having a resistance of 10 ohms and having 10 convolutions or turns is desired and a current flow therethrough of 100 amps is sought,

a power supply of 1,000 volts would be required to achieve the desired current. With the inductive heating arrangement in accordance with the present invention, ten conductor sections connected in parallel each having a resistance of 1 ohm, corresponding to the resistance per coil of the continuous coil, can be energized by a 100 volt power source to achieve a current flow of 100 amps across each conductor section.

The contour or configuration of the individual sections between the bus bar means can be any one of a number of contours. In the embodiment illustrated in FIGS. 1 and 2 for example, each conductor section 12 is of a substantially rectangular O configuration when viewed in the direction of the axis A of the heating unit. This configuration provides for a workpiece W to be introduced axially into the heating unit and for all four sides of the workpiece facing portions of the individual conductor sections to be heated. Further, side leg portions 13 of conductor sections 12 in this embodiment are longer than cross portions 15 and, more particularly, are longer than the axial length of the heating unit, whereby the side portions 13 are adapted to extend along opposite sides of the workpiece in a direction parallel to the longest dimension L of the workpiece when the latter is disposed in inductive heating relationship with the heating unit.

FIG. 3 of the drawing illustrates a further embodiment of heating unit constructed in accordance with the present invention. In this respect, an induction heating unit 30 is illustrated comprised of a plurality of tubular conductor sections 32 having opposite ends interconnected with a corresponding one of a pair of tubular bus bar means 34 and 36. Bus bar means 34 and 36 are connected across a suitable source of alternating current 38, in a manner similar to the heating unit illustrated in FIG. 1 of the drawing. In the present embodiment, tubular conductor sections 32 are substantially U-shaped when viewed in the direction of the axis B of the heating unit. In this respect, side legs 40 and 42 of the conductor sections and the corresponding ends thereof connected to tubular bus bar means 34 and 36 are spaced apart and substantially parallel along the lengths thereof as opposed to having the ends of the sections and the bus bar means turned inwardly toward one another as in the embodiment illustrated in FIGS. 1 and 2. This structure provides an open ended heating unit which permits introduction of a workpiece W₁ axially into the unit to a position between side portions 40 and 42 of sections 32, or permits introduction of the workpiece into the heating unit through the opening defined between bus bar means 34 and 36. In either instance side portions 40 and 42 extend parallel to the longest dimension L₁ of the workpiece. In a manner similar to the embodiment illustrated in FIG. 1, bus bar means 34 and 36 define inlet and outlet header means, respectively, for cooling fluid for the heating unit and, in this respect, are provided with corresponding inlet and outlet conduit means 44 and 46 for cooling fluid.

FIG. 4 of the drawing illustrates yet another embodiment of an induction heating unit of the present invention. In this respect, the heating unit 50 illustrated in FIG. 4 is similar to the unit 10 illustrated in FIG. 1 in that a plurality of conductor sections 52 have opposite ends 54 and 56 thereof connected to tubular bus bar means 58 and 60. Bus bar means 58 and 60 are con-

ected to opposite sides of a suitable source of alternating current 62 and are provided with coolant inlet and outlet means 64 and 66, respectively, to facilitate the circulation of cooling fluid through the unit. In this embodiment, conductor sections 52 are substantially rectangular when viewed in the direction of axis C of the unit, and the opposite side leg portions 68 of the conductor sections are shorter in length transverse to axis C than the axial length of the heating unit. This configuration of the unit provides for a workpiece W_2 to be axially introduced into the unit and to be disposed therein with side leg portions 68 of conductor sections 52 extending perpendicular to the longest dimension L_2 of the workpiece.

FIG. 5 of the drawing illustrates yet another embodiment of an induction heating unit within the present invention. In this embodiment, induction heating unit 70 is similar in structure to embodiments hereinabove described and, in this respect, is comprised of a plurality of conductor sections 72 having opposite ends 74 and 76 interconnected with a corresponding one of a pair of tubular bus bar means 78 and 80. Further, bus bar means 78 and 80 are connected to opposite sides of a suitable source of alternating current 82 and are provided with inlet and outlet conduit means 84 and 86, respectively, to facilitate the flow of cooling fluid through the unit. Moreover, conductor sections 72 are similar to conductor sections 52 of the embodiment illustrated in FIG. 4 in that the side legs 88 and 90 are of a shorter length transverse to axis D than the axial length of the heating unit. In this embodiment, however, ends 74 and 76 of the conductor sections and tubular bus bar means 78 and 80 are spaced apart as in the embodiment of FIG. 3 to define a unit into which a workpiece W_3 can be introduced either axially or in a direction through the open side of the U-shaped unit. In a manner similar to that of the heating unit of FIG. 4, heating unit 70 provides for sides 88 and 90 of the conductor sections to extend in a direction perpendicular to the longest dimension L_3 of the workpiece W_3 when the workpiece is positioned within the unit.

It is to be noted that the conductor sections of the several embodiments herein illustrated are parallel to one another and substantially perpendicular to the axis of the coil unit.

While considerable emphasis has been placed on the fact that the conductor sections of the induction heating units have side and cross portions which are substantially perpendicular to one another, it will be appreciated that the cross portions of the sections can be of an arcuate contour. Further, it will be appreciated that the conductor sections may have any desired contour between the opposite ends thereof. In this respect, the conductor sections could have a circular contour or an elliptical contour. Still further, while it is preferred that the planes in which the conductor sections are disposed extend substantially perpendicular to the axis of the heating unit, it will be appreciated that the planes of the sections of a given unit could be parallel to one another and inclined with respect to the axis of the coil, in which case the conductor sections would extend at

an angle other than 90° from the corresponding tubular bus bar components.

As many possible embodiments of the present invention may be made and as many possible changes may be made in the embodiments herein illustrated and described, it is to be distinctly understood that the foregoing description of the preferred embodiments is to be interpreted merely as illustrative of the present invention and not as a limitation.

I claim:

1. Apparatus for inductively heating a metal workpiece having a longest dimension with respect to said apparatus comprising, a plurality of individual, generally U-shaped conductors of tubular conductor material disposed in parallel spaced-apart planes and having opposite ends connected one to a first bus of tubular conductor material and the other to a second bus of tubular conductor material, means connecting said first and second busses to opposite sides of a source of alternating current, whereby said individual conductors are connected in electrical parallel, said U-shaped conductors having side legs spaced apart to receive a workpiece therebetween, said side legs of said conductors extending in the direction of said longest dimension of a workpiece disposed therebetween, and said planes of said conductors extending generally parallel to the direction of said longest dimension of a workpiece disposed between said side legs.

2. The apparatus of claim 1, wherein said side legs of each said conductor are parallel and spaced apart a first distance in the corresponding plane thereof and are of a length greater than said longest dimension of a workpiece disposed therebetween, and said first and second busses are spaced apart a distance less than said first distance, whereby said conductors substantially surround a workpiece disposed between said side legs.

3. The apparatus of claim 1, wherein said conductors and busses are intercommunicating tubular components, means connecting one of said first and second busses to a source of cooling fluid for said one bus to define inlet header means for coolant for said conductors, and the other of said first and second busses defining header means for discharging cooling fluid from said conductors.

4. The apparatus of claim 3, wherein the side legs of said conductors are of uniform length and are longer than the length of the apparatus as measured perpendicular to said planes of said conductors.

5. The apparatus of claim 1 wherein said conductors and busses are intercommunicating tubular components, means connecting one of said first and second busses to a source of cooling fluid for said one bus to define inlet header means for coolant for said conductors, and the other of said first and second busses defining header means for discharging cooling fluid from said conductors.

6. The apparatus of claim 1 wherein the side legs of said conductors are of uniform length and are longer than the length of the apparatus as measured perpendicular to said planes of said conductors.

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