# United States Patent

**Kasper**

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[54] **PIVOTALLY MOVABLE SLAB HEATING UNIT**


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[52] **U.S. Cl.**.....**219/10.57**, 219/10.79

[51] **Int. Cl.**.....**H05b 5/00**, H05b 9/06

[58] **Field of Search**..219/10.57, 10.59, 10.67, 10.69, 219/10.71, 10.73, 10.79



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[57] **ABSTRACT**

Apparatus is disclosed for inductively heating a large metal ingot having a length dimension which is greater than the greatest cross-sectional dimension thereof. The apparatus includes support means for an ingot to be heated, and induction heating coil means which surrounds an ingot on the support means. The coil means is pivotally supported relative to the support means for movement between first and second positions relative to the support means. In one of the coil positions the support means is exposed for the removal or placement of an ingot thereon, and in the other of the coil positions the support means and ingot are surrounded by the coil means. Wall means may be provided at opposite ends of the coil means to define therewith and with the support means an enclosure for heating an ingot.


**14 Claims, 11 Drawing Figures**

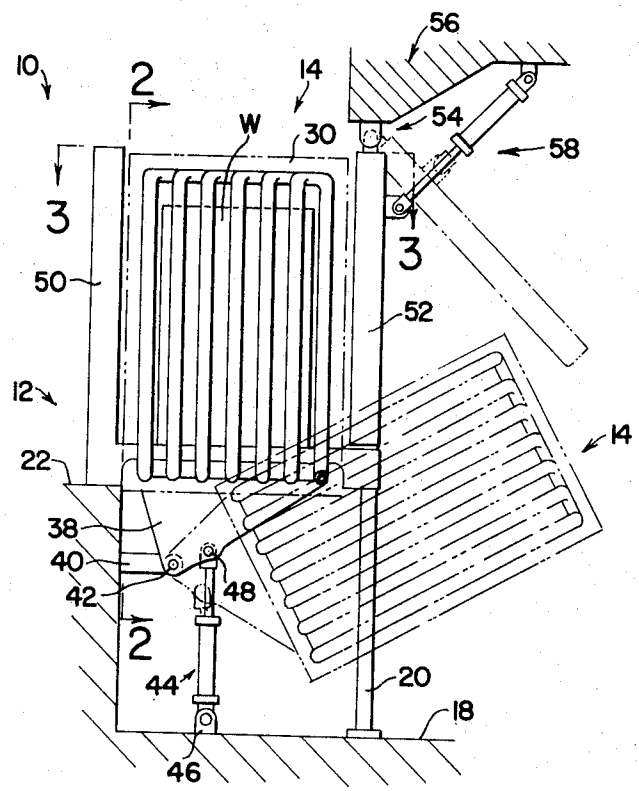


FIG. 1

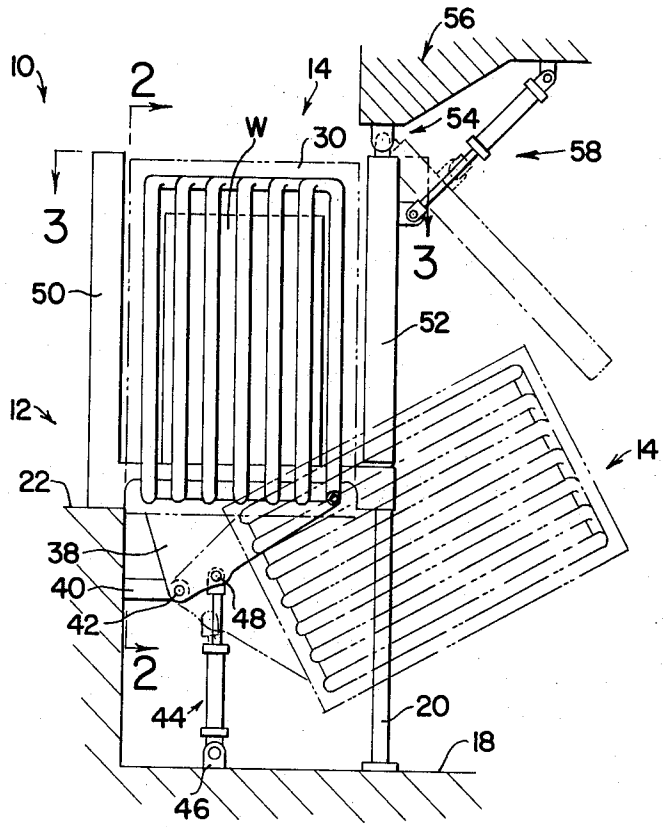
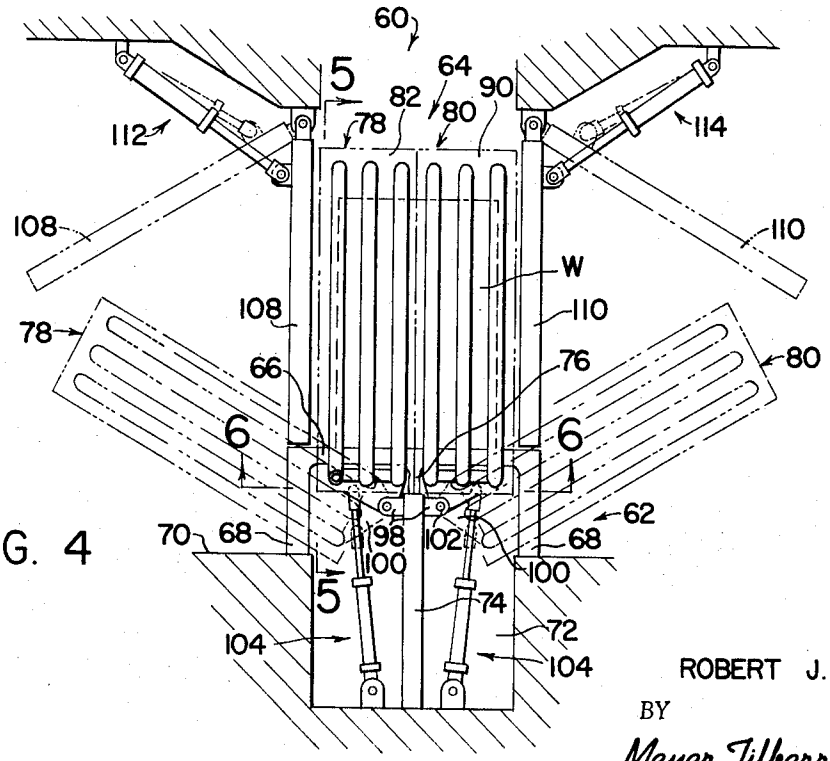



FIG. 4




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FIG. 2

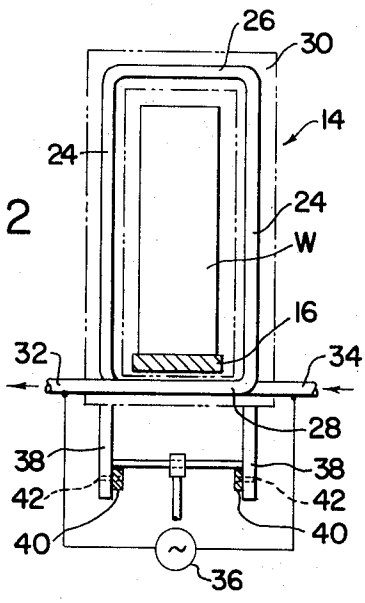



FIG. 3

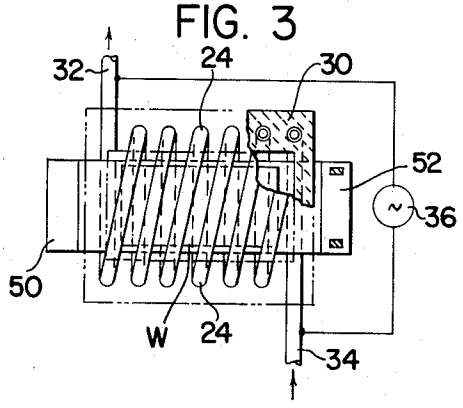
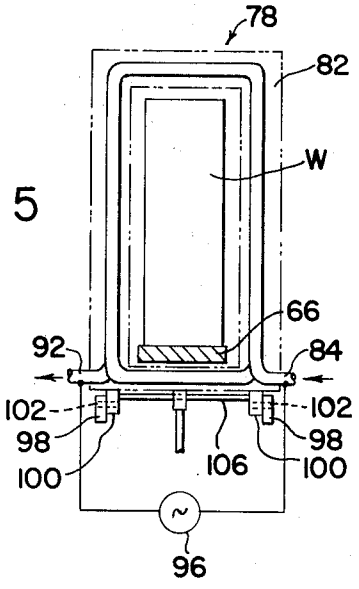



FIG. 5



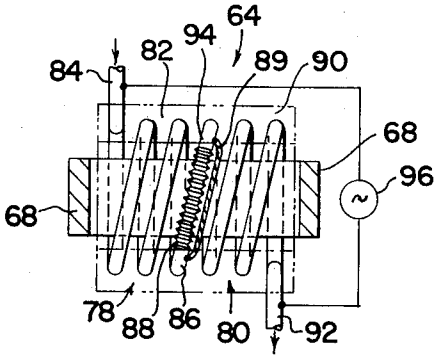




FIG. 6

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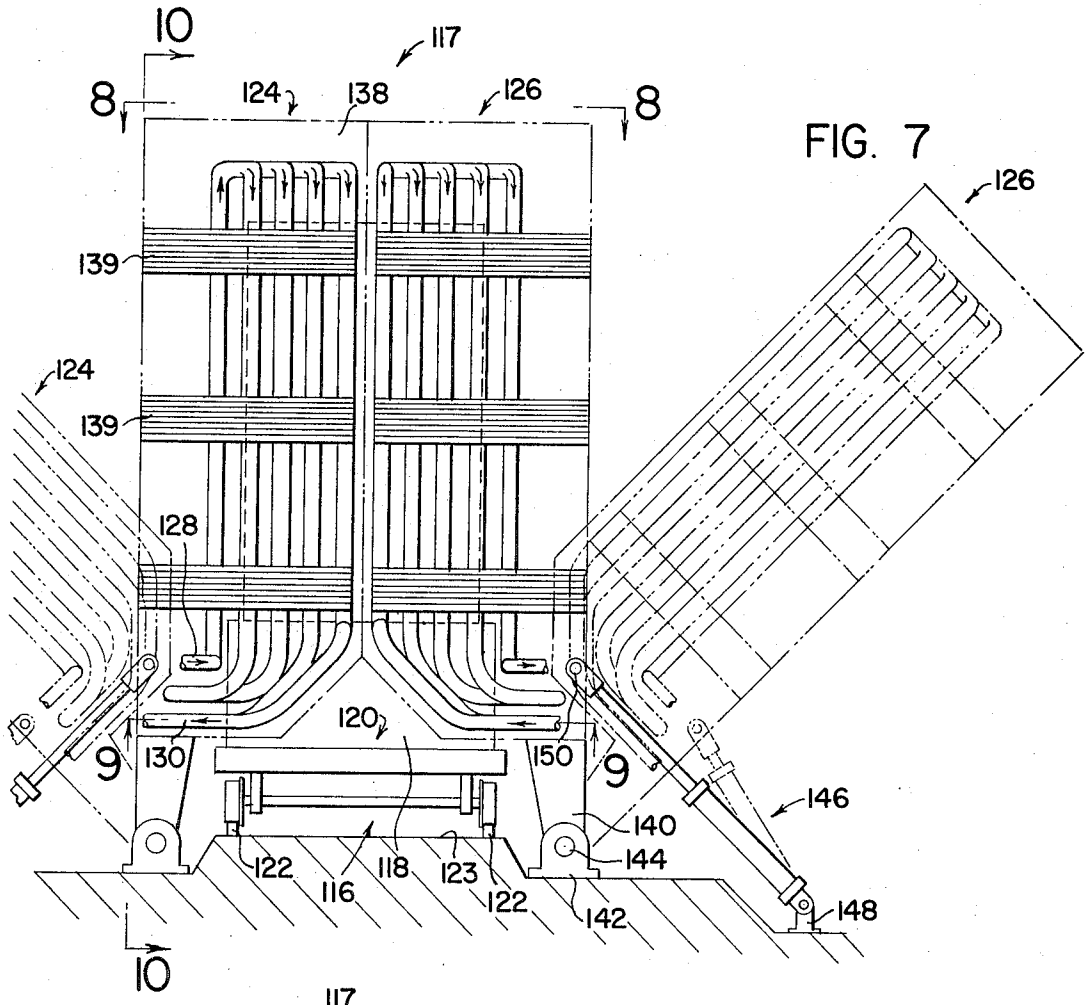



FIG. 7

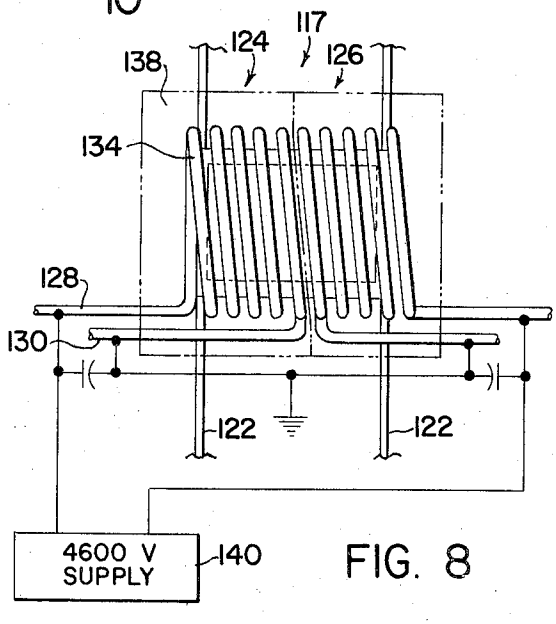



FIG. 8

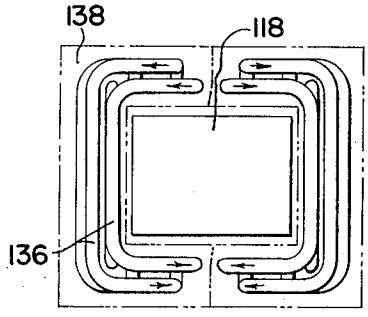



FIG. 9

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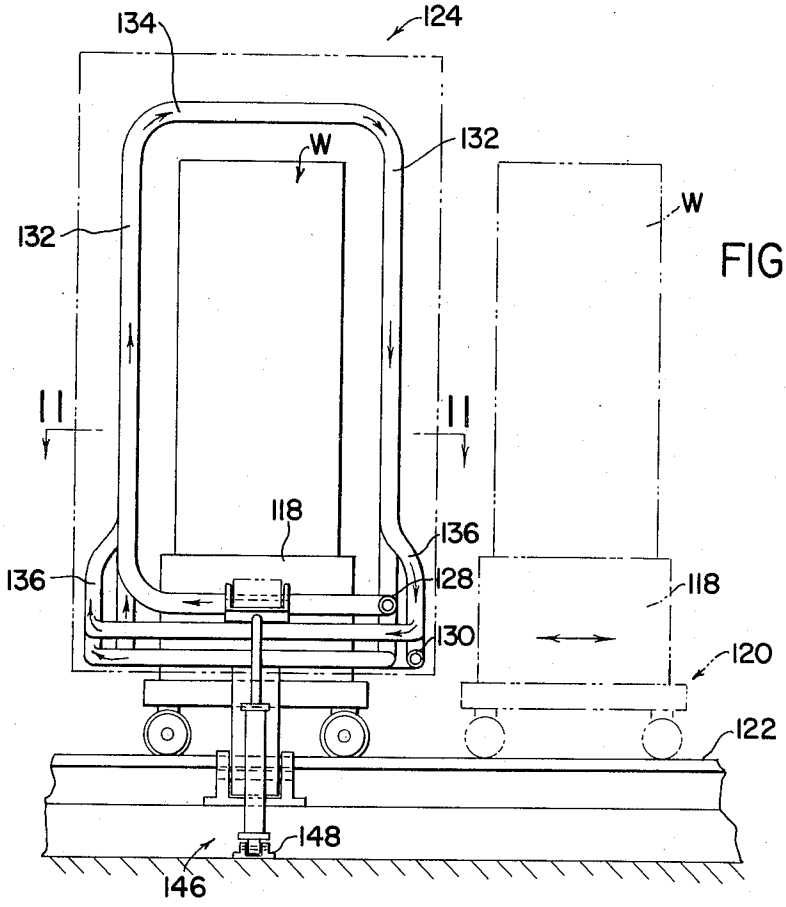



FIG. 10

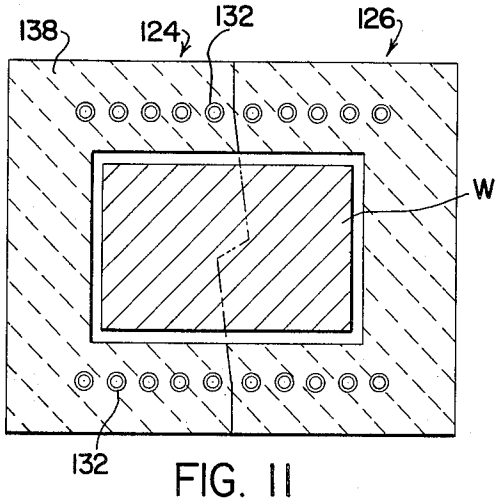



FIG. 11

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# PIVOTALLY MOVABLE SLAB HEATING UNIT

This invention relates to induction heating apparatus and, more particularly, to an induction heating coil arrangement.

Heretofore, the general approach to induction heating of large metal ingots has been to surround the ingot with a vertically disposed induction heating coil. Such a system requires either that the heating coil be raised, or that the ingot be lowered in order to facilitate movement of the ingot into the coil and movement of the ingot from the coil to a subsequent next work station. Where the ingot has a length dimension which is greater than its greatest cross-sectional dimension, it becomes advantageous to dispose the ingot with its length dimension vertical. It will be appreciated that with an ingot having a length dimension of several feet, vertical placement or removal of the ingot from a vertically oriented coil is most difficult. Still, the vertical disposition is desirable from a space standpoint. With regard to heating an ingot of such length, the most efficient heating is achieved when the ingot is vertically positioned and the induction heating coil encircles the ingot in a configuration in which the coil axis is horizontal. Further, it is preferred that the narrowest dimension of the ingot extends transverse to the coil axis. Such a coil disposition, however, makes it extremely difficult to provide for relative movement between the coil and ingot which is necessary to introduce and remove the ingot from within the confines of the coil. Usually, complicated and expensive mechanisms are required to facilitate insertion and removal of the ingot longitudinally of the coil, which mechanisms are expensive, space consuming and otherwise undesirable.

In accordance with the present invention, the foregoing advantages of coil and ingot disposition are provided for, while the disadvantages relating to the introduction and removal of an ingot from the coil are desirably and advantageously avoided. In this respect, induction heating coil means is pivotally mounted relative to support means for an ingot so that the coil means can be pivoted away from the support means to expose the latter for introduction or removal of an ingot therefrom. When the ingot is properly positioned, the coil is pivoted to a second position in which it is disposed so as to inductively heat the ingot. It will be appreciated, therefore, that the induction heating apparatus in accordance with the present invention facilitates the positioning of an ingot relative to coil means for heating, and the removal of the ingot from the coil means after heating in a manner whereby the horizontal coil axis configuration is retained and space requirements for the apparatus are maintained at a minimum.

In accordance with a narrower aspect of the present invention, a pair of coil sections are disposed in axial alignment and are mounted for pivotal movement away from one another to expose ingot support means therebetween and are pivotal toward one another to enclose an ingot disposed on the support means. This arrangement provides for heavier ingots to be supported during heating thereof, while maintaining the aforementioned advantages of horizontal coil axis disposition and ingot disposition.

Further, in accordance with the present invention, the pivotal coil structure can be employed in conjunction with movable ingot support means. Thus, the coil means can be supported relative to track means or the like along which ingots to be heated and ingots which have been heated can be moved to facilitate ingot handling before and after heating. Moreover, the pivotal coil structure provides for the desired coil and ingot disposition to be maintained.



An outstanding object of the present invention is the provision of induction heating apparatus including induction coil means movably supported relative to ingot support means to facilitate ingot handling in conjunction with an induction heating process.

Another object is the provision of induction heating apparatus of the character mentioned above having movable coil means which facilitates positioning and removal of an ingot relative to the coil means.

Yet another object of the present invention is the provision of induction heating apparatus including induction heating coil means pivotally mounted as a unit relative to ingot support means and movable between a position in which the support means is exposed to facilitate positioning or removal of an ingot relative to the coil means and a second position in which the coil is disposed in induction heating relationship with an ingot.

Still another object of the present invention is the provision of induction heating apparatus including a pair of coil sections mounted for pivotal movement relative to one another and relative to support means for an ingot to be heated, and wherein the coil sections are movable between a first position in which the support means is exposed for introduction or removal of an ingot relative to the coil sections and second positions in which the coils are disposed to inductively heat an ingot on the support means.

A further object of the present invention is the provision of induction heating apparatus including induction heating coil sections associated with support means including a movable ingot support and wherein the coil sections are mounted for pivotal movement relative to the support means and between a first position which permits positioning of an ingot relative to the coil sections and a second position in which the coil sections are disposed to inductively heat the ingot.

These objects will in part be obvious and in part more fully pointed out hereinafter in conjunction with the description of the drawing in which:

FIG. 1 is a side elevation view of induction heating apparatus of the present invention;

FIG. 2 is a sectional elevation of the apparatus taken along line 2—2 of FIG. 1;

FIG. 3 is a sectional view of the apparatus taken along line 3—3 of FIG. 1;

FIG. 4 is an end elevation of another embodiment of induction heating apparatus within the present invention;

FIG. 5 is a sectional elevation of the apparatus taken along line 5—5 of FIG. 4;

FIG. 6 is a sectional view of the apparatus taken along line 6—6 of FIG. 4;

FIG. 7 is an end elevation of yet another embodiment of induction heating apparatus within the present invention;

FIG. 8 is a sectional view of the apparatus taken along line 8—8 of FIG. 7;

FIG. 9 is a sectional view of the apparatus taken along line 9—9 of FIG. 7;

FIG. 10 is a sectional elevation taken alone line 10—10 of FIG. 7; and

FIG. 11 is a sectional view taken along line 11—11 of FIG. 10.

Referring now to the drawing in greater detail wherein the showings are for the purpose of illustrating the preferred embodiments of the invention only and not for the purpose of limiting the same, FIGS. 1–3 illustrate induction heating apparatus designated generally 10, which apparatus is comprised of ingot support means 12 and induction heating coil means 14. Support means 12 includes a bottom wall component 16 of non-magnetic material which is suitably supported above a floor or the like 18 by means of a post 20 at one end thereof and wall means 22 at the opposite end thereof.

Coil means 14 is defined by tubing of copper or the like bent to form a plurality of convolutions which are rectangular in configuration and which extend axially a distance sufficient for the coil to be disposed beyond the opposite ends of a work piece or ingot W disposed on bottom wall 16. More particularly, the convolutions of tubing define a coil having side portions 24, a top portion 26 and a bottom portion 28. The coil is embedded in suitable thermal and electrical insulating refractory material 30 and the opposite ends 32 and 34 of the tubing define inlet and outlet means for cooling water for the coil. Further, ends 32 and 34 are connected to a suitable source of high or low frequency current 36. The space between the side, top, and bottom portions of the coil defines a chamber adapted to receive ingot W, and it will be noted that bottom portion 28 of the coil extends transversely beneath bottom wall 16 of the support means.

Coil means 14 is supported for pivotal movement relative to support means 12 between the positions thereof illustrated by solid and broken lines in FIG. 1. More particularly, coil means 14 is provided with a pair of bracket components 38 connected to corresponding brackets 40 by pin means 42. Brackets 40 are suitably attached to wall means 22. The pivotal connection thus defined permits pivotal movement of coil means 14 about an axis transverse to the coil axis, and such pivotal movement is achieved by suitable means such as hydraulic piston and cylinder means 44 having one end thereof pivotally connected to bracket means 46 on floor 18 and the other end thereof pivotally connected to brackets 38 by means of a rod 48 extending between the brackets. Hydraulic piston and cylinder means 44 is connected to a suitable source of hydraulic fluid under pressure, not shown, and any suitable controls for flow to and from the piston and cylinder means may be employed. When the coil is in the position indicated by broken lines in FIG. 1, bottom wall 16 of the support means is exposed to facilitate overhead introduction or removal of a workpiece or ingot therefrom. When the coil is in the position indicated by solid lines in FIG. 1, the coil is disposed in inductive heating relationship with an ingot disposed on bottom wall 16.

Preferably, wall means 50 and 52 of non-magnetic material are disposed at opposite ends of coil means 14 when the latter is positioned to inductively heat ingot W. In the embodiment illustrated, wall means 50 is integral with bottom wall 16 of the support means, and wall means 52 is supported for pivotal movement relative to coil means 14 between the positions thereof illustrated by solid lines and broken lines in FIG. 1. More particularly, wall means 52 is mounted for pivotal movement relative to bottom wall 16 by suitable hinge means 54 interconnecting wall means 52 with support means 56 provided therefor. Hydraulic piston and cylinder means 58, or other suitable drive means, is provided for moving wall means 52 between the two positions thereof. Wall means 50 and 52 cooperate with coil means 14 to define a chamber in which an ingot to be heated is disposed when supported on bottom wall 16. Wall means 52 is adapted to be pivoted away from coil means 14 to facilitate pivotal movement of the coil means to the dotted line position thereof indicated in FIG. 1. It will be appreciated, however, that wall means 52 could be attached or otherwise associated with coil means 14 for movement therewith.

In operation of the embodiment illustrated in FIGS. 1–3, wall means 52 is pivoted away from coil means 14 by hydraulic piston and cylinder means 58, and hydraulic piston and cylinder means 44 is actuated to pivot coil means 14 clockwise about the axes of pins 42 to the position thereof illustrated by broken lines in FIG. 1. Bottom wall 16 of the support means is thus exposed to facilitate introduction of an ingot W thereonto. Thereafter, hydraulic piston and cylinder means 44 is actuated to pivot coil means 14 counterclockwise to the position thereof illustrated by solid lines in FIG. 1, and hydraulic piston and cylinder means 58 is actuated to pivot wall means 52 to its position adjacent the corresponding end of the coil means. Coil means 14 is then energized to facilitate the induction heating of ingot W.

FIGS. 4–6 illustrate another embodiment of the present invention. In this respect, induction heating apparatus indicated generally by the numeral 60 is illustrated which includes support means 62 and coil means 64. Support means 62 includes bottom wall means 66 of non-magnetic material having depending leg portions 68 which rest upon a floor or the like 70. Further, floor 70 is provided with a recess 72, and a support component 74 extends upwardly from the bottom recess 72 to engage a central rib 76 provided on the underside of bottom wall 66 of the support means.

Coil means 64 is defined by a pair of coil sections 78 and 80 each of which is comprised of a plurality of convolutions of copper tubing or the like bent to have a rectangular configuration similar to that of coil means 14 described hereinabove. The tubing of coil 78 is embedded in suitable thermal and electrical insulating refractory material 82, and one end 84 of the tubing defines inlet means for cooling water to be circulated through coil means 64. Similarly, the copper tubing of coil section 80 is embedded in suitable thermal and electrical insulating refractory material 90, and one end 92 of the tubing defines outlet means for cooling fluid for coil means 64. Further, ends 84 and 92 are connected to a suitable source of high or low frequency current 96.

Coil sections 78 and 80 together define a continuous coil and in this respect, the inner ends 86 and 94 of the tubing thereof are conductively interconnected and interconnected for fluid flow be any suitable flexible

coupling means such as is defined, for example, by flexible, nonsconductive tube means **88** and flexible stranded conductor means **89**. The flexible coupling means permits relative pivotal displacement of the coil sections and is preferably provided at the bottom of the coil sections to provide for pivotal movement of the coil sections with a minimum of coupling flexure.

In this embodiment, the bottom portions of the coils **78** and **80** extend under bottom wall **66** of the support means in a manner similar to coil means **14** hereinabove described. Further, coil sections **78** and **80** are each supported for pivotal movement between the positions thereof illustrated by solid lines and broken lines in FIG. **4**. More particularly, support component **74** is provided with bracket means **98** pivotally interconnected with bracket means **100** of the corresponding coil by means of pins **102**. Further, each of the coil sections **78** and **80** is provided with hydraulic piston and cylinder means **104** having one end thereof suitably secured to the bottom wall of recess **72** and the other end thereof pivotally interconnected with the corresponding coil bracket **100** by rod means **106**. Hydraulic piston and cylinder means **104** are suitably connected to a source of hydraulic fluid and may be operated independently or together to impart independent or simultaneous pivotal movement to the corresponding coil section in a manner similar to that described hereinabove with regard to coil means **14** of the embodiment illustrated in FIGS. **1–3**.

The heating apparatus in this embodiment further includes wall means **108** associated with coil section **78** and wall means **110** associated with coil section **80**. Wall means **108** and **110** are non-magnetic material and are each mounted for pivotal movement relative to bottom wall **66** of the support means in a manner similar to wall means **52** described in conjunction with the embodiment of FIG. **1**. In this respect, wall means **108** and **110** are provided with hydraulic piston and cylinder means **112** and **114**, respectively, for imparting pivotal movement thereto, which piston and cylinder means operate in a manner similar to piston and cylinder means **58** described hereinbefore. When coil sections **78** and **80** and wall means **108** and **110** are in the positions thereof illustrated by solid lines in FIG. **4**, the coil sections and wall means define a chamber in which an ingot W is adapted to be inductively heated. It will be appreciated, that wall means **108** and **110** may be suitably attached to the corresponding coil sections **78** and **80** for pivotal movement therewith as opposed to being mounted for pivotal movement relative thereto.

In operation of the embodiment illustrated in FIGS. **4–6**, hydraulic piston and cylinder means **112** and **114** are actuated to pivot the corresponding wall means **108** and **110** to the positions thereof illustrated by broken lines in FIG. **4**. Thereafter, hydraulic piston and cylinder means **104** are energized to pivot coil sections **78** and **80** to the corresponding positions thereof illustrated by broken lines in FIG. **4**. With the wall means and coil sections in the latter positions, bottom wall means **66** of the support means is exposed to facilitate introduction of an ingot W thereonto. Thereafter, hydraulic piston and cylinder means **104** are actuated to pivot coil sections **78** and **80** back to the positions thereof illustrated by solid lines in FIG. **4**, and hydraulic piston and cylinder means **112** and **114** are actuated to pivot wall means **108** and **110**, respectively, back to the positions thereof illustrated by solid lines in FIG. **4**. Coil sections **78** and **80** are thus disposed in inductive heating relationship with ingot W and may be energized to achieve inductive heating of the ingot.

The split coil configuration of the embodiment illustrated in FIGS. **4–6** provides for heavier ingots to be inductively heated in that the bottom wall means **66** of the support means can be provided with a central support therebeneath such as is provided by support component **74**.

FIGS. **7–11** illustrate yet another embodiment of induction heating apparatus within the present invention. In this respect, induction heating apparatus is illustrated which includes ingot support means **116** and induction heating coil means **117**. Support means **116** in this instance is defined by a base element **118** mounted on a wheeled carrier **120** adapted for rolling movement along track means **122**. Base **118** is adapted to support a workpiece or ingot W to be heated and is defined by any suitable non-magnetic material. Any suitable means, not shown, may be provided for moving wheeled carrier **120** along track means **122**.

Coil means **117** is defined by a pair of coil units **124** and **126** mounted on either side of track means **122** for pivotal movement laterally of the path of movement of wheeled carrier **120** along the track means. Coil units **124** and **126** are identical and, accordingly, only one of the coil units, namely coil unit **124**, will be described in detail. Coil unit **124** is defined by copper tubing having opposite ends **128** and **130** defining, respectively, inlet and outlet means for cooling fluid to be circulated through the coil. The tubing is bent to define side portions **132**, top portion **134** and bottom portions **136**. The tubing defining top portion **134** extends across the coil axis, and the tubing defining side portions **132** extend downwardly relative to the coil axis. The bottom portions **136**, as best illustrated in FIG. **9**, extend outwardly toward the outer most end of the coil, thence across the coil axis and forwardly toward the inner most end of the coil. This configuration provides for the coil units to together define a chamber in which workpiece or ingot W is disposed when the support means is positioned between the coil units and the coil units are disposed in the solid line positions thereof illustrated in FIG. **7**. The tubing of each of the coil units is embedded in suitable thermal and electrical insulating refractory material **138** and each coil section may include laminations **139**. Wall means are defined at the outermost ends of the coil sections by providing for the refractory insulating material to extend across the ends of each section.

Coil sections **124** and **126** are energized from a suitable source of high or low frequency current. In this particular embodiment, the power source is illustrated as a single supply high voltage source **140** which is connected to tubing ends **128** and **130** of coil section **124** and to the corresponding tubing ends of coil section **126** in a manner whereby one half of the supply voltage to ground is connected across each coil section to energize the corresponding coil section. Moreover, it will be appreciated that, the coil sections are energized in a manner whereby current flow therethrough is in the same direction. It will be appreciated, of course, that

separate supply systems, in phase, could be employed for each coil section. Still further, it will be appreciated that the power supply system illustrated in FIG. **8** could be employed in conjunction with the coil arrangement of the embodiment illustrated in FIGS. **4–6**.

Each of the coil sections **124** and **126** is supported for pivotal movement relative to support means **116** and, more particularly, laterally of track means **122** between the positions of the coil sections illustrated in solid lines and broken lines in FIG. **7**. The pivotal support means for the coils is similar and with reference to coil section **126**, for example, the coil section is provided with a pair of brackets **140** pivotally interconnected with corresponding bracket components **142** by pin means **144**. Pivotal movement is imparted to the coil sections by corresponding motor means such as hydraulic piston and cylinder means **146** illustrated in conjunction with coil section **126**. Hydraulic piston and cylinder means **146** has one end thereof pivotally attached to bracket means **148** on support surface means **123**, and the other end thereof is pivotally interconnected with the coil section by pin means **150**. It will be appreciated that the hydraulic piston and cylinder means for the two coil sections will be supplied with operating fluid from a suitable source, not shown, and that the hydraulic motor means may be suitably controlled for individual operation or operation in unison.

In operation of the embodiment illustrated in FIGS. **7–11** the hydraulic piston and cylinder means of the coil sections are actuated to pivotally displace the corresponding coil section to the position thereof illustrated by broken lines in FIG. **7**. Wheeled carrier **120** with ingot or workpiece W thereon is then moved along track means **122** to a position in which the wheeled carrier and ingot are positioned between the coil units. The hydraulic piston and cylinder means of the units are then actuated to displace the corresponding coil unit to the position thereof illustrated by solid lines in FIG. **7**. The coil units are then energized whereby the ingot or workpiece is inductively heated. Following the induction heating process, the coil units are displaced laterally outwardly relative to track means **122** and wheeled carrier **120** is moved from between the coil units and along track means **122** to a succeeding work station or the like. The coil units are then positioned for another wheeled carrier having an ingot thereon to be positioned therebetween.

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

I claim:

**1**. Apparatus for the induction heating of a metal ingot comprising, support means for an ingot to be heated, a heating coil having an axis and including continuous conductor means extending about said axis, means supporting said heating coil for pivotal movement between first and second positions relative to said support means and about an axis transverse to said coil axis, said coil when in one of said positions exposing said support means and when in the other of said positions being disposed to inductively heat an ingot on said support means, and means to supply said coil with alternating current.

**2**. Apparatus according to claim **1**, and means to pivot said coil between said first and second positions.

**3**. Apparatus according to claim **1**, and wall means at opposite ends of said coil, said wall means, ingot support means and coil defining an enclosure, and at least one of said wall means being movable relative to said support means to permit pivotal movement of said coil.

**4**. Apparatus in accordance with claim **3**, wherein said one wall is a door pivotally supported for movement relative to said support means and independent of said coil means, and means to move said door.

**5**. Apparatus according to claim **1**, wherein said coil is comprised of two coil sections each supported for pivotal movement between first and second positions relative to said support means.

**6**. Apparatus according to claim **5**, and means to move each of said coil sections between said first and second positions thereof.

**7**. Apparatus according to claim **5**, and wall means at opposite ends of said coil sections, both of said wall means being movable relative to said support means to permit pivotal movement of said coil sections.

**8**. Apparatus according to claim **7**, wherein said wall means are doors disposed transversely of the axis of said coil adjacent the outer most ends of said coil sections, each of said doors being pivotally supported for movement relative to said support means and independent of the corresponding one of said coil sections, and means to move said doors.

**9**. Apparatus according to claim **5**, wherein said support means includes means movable relative to said coil sections and transverse to said coil axis.

**10**. Apparatus according to claim **9**, wherein said support means includes track means, and said movable means includes wheeled carrier means on said track means.

**11**. Apparatus according to claim **9**, and wall means at opposite ends of said coil sections.

**12**. Apparatus according to claim **1**, and a second coil having an axis and including continuous conductor means extending about the axis thereof, means supporting said second coil for pivotal movement between first and second positions relative to said support means and about an axis transverse to the axis of said second coil, and means to separately supply alternating current to said second coil.

**13**. The apparatus according to claim **12**, wherein said support means includes means movable relative to said coil and second coil and transverse to the axes thereof.

**14**. Apparatus according to claim **13**, wherein said support means includes track means, and said movable means includes wheeled carrier means on said track means.

* * * * *