

July 24, 1956

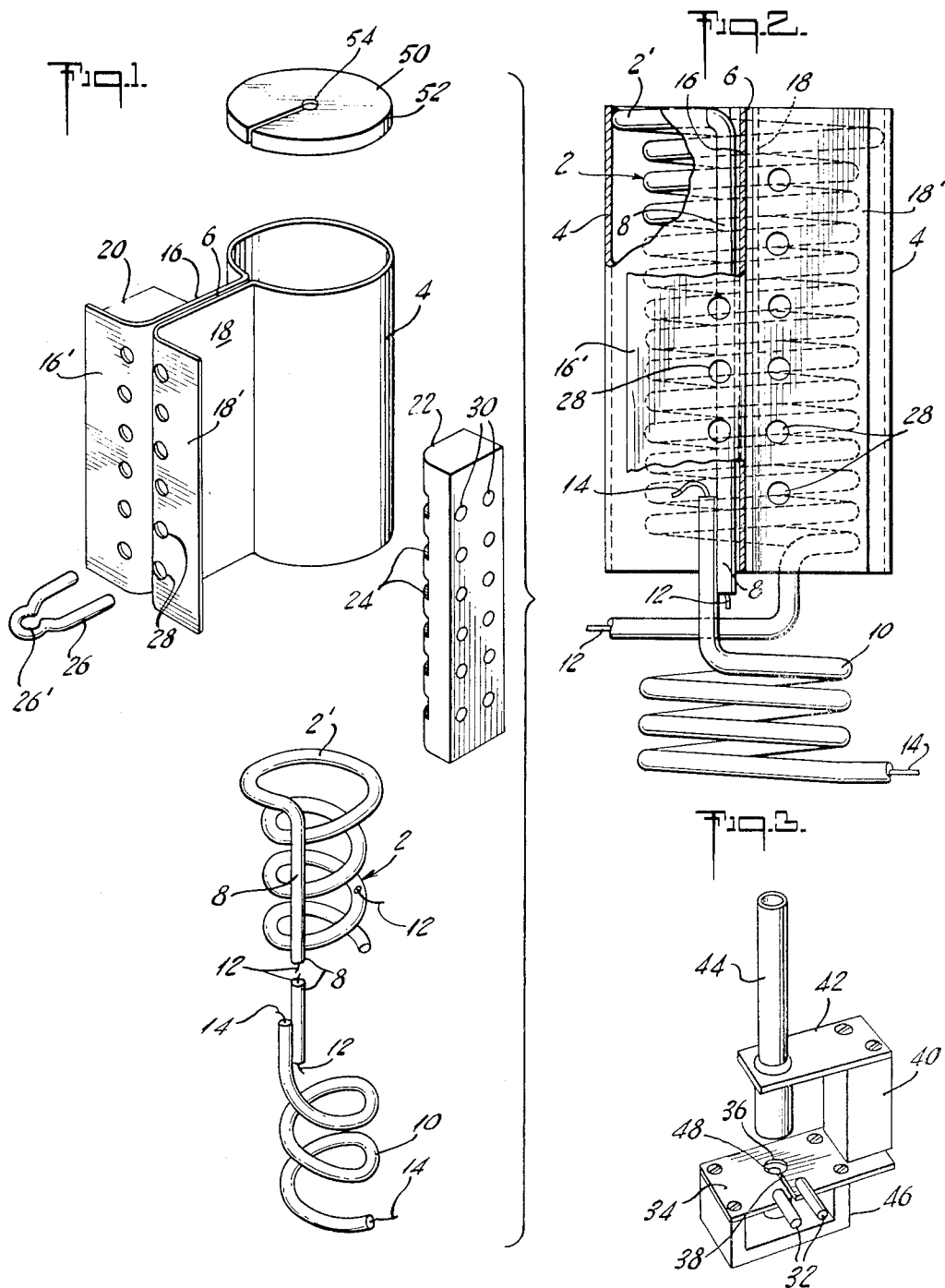
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2,756,313

HIGH FREQUENCY INDUCTION HEATER

Filed July 8, 1953

3 Sheets-Sheet 1



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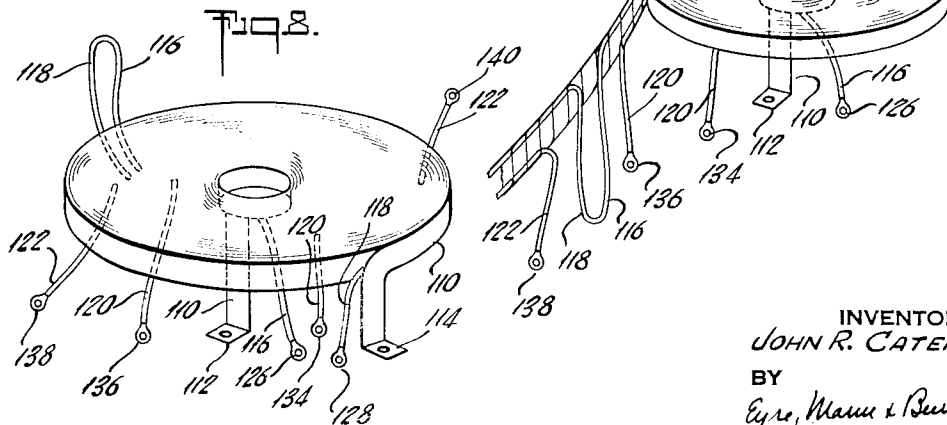
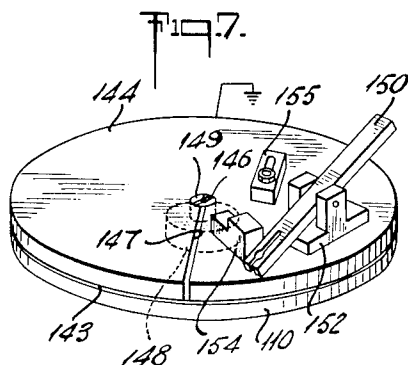
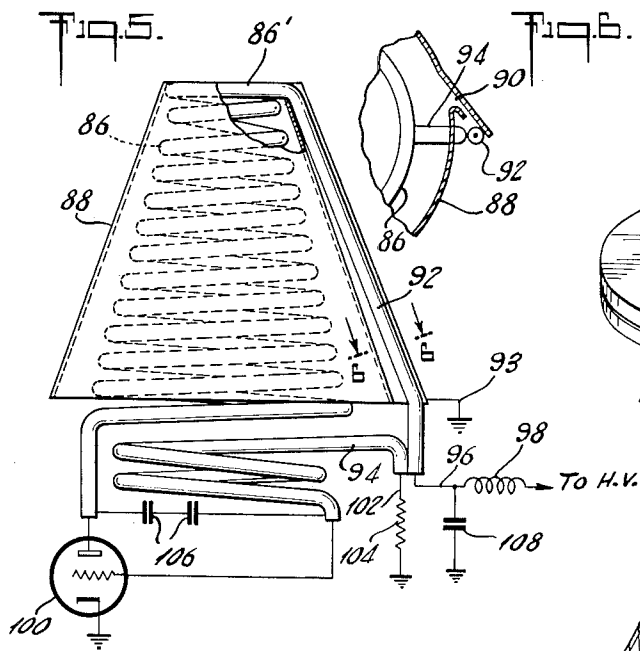
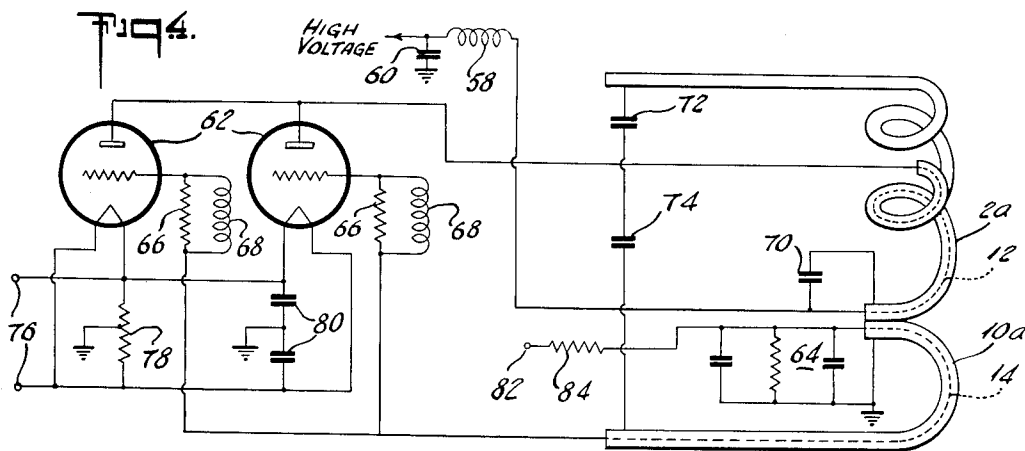
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HIGH FREQUENCY INDUCTION HEATER

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Fig. 10.

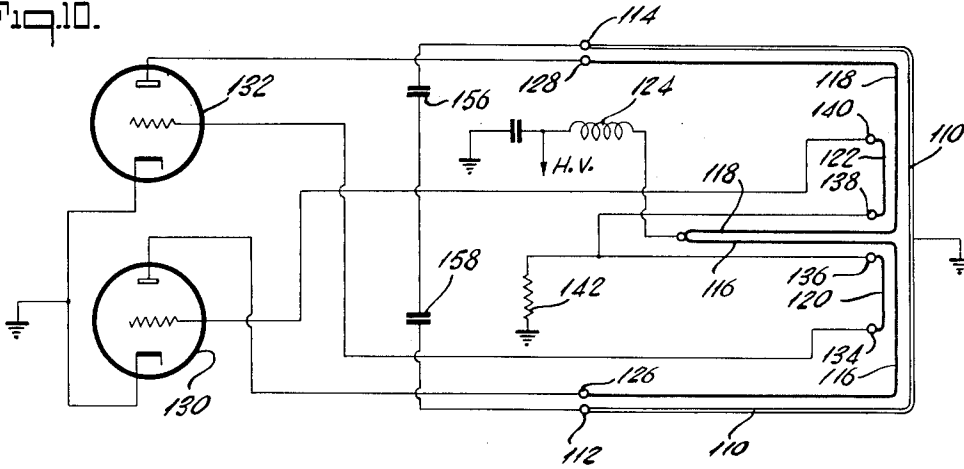


Fig. 11.

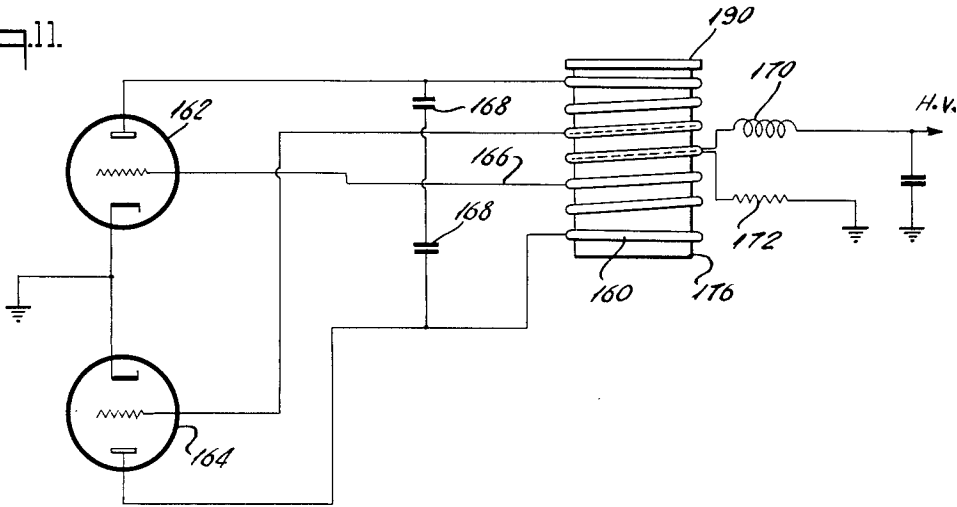
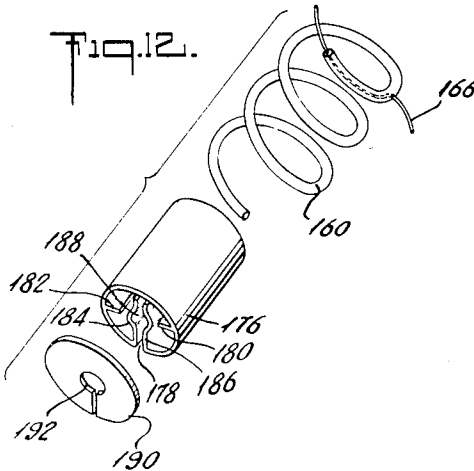


Fig. 12.



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HIGH FREQUENCY INDUCTION HEATER

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3 Claims. (Cl. 219—10.75)

The present invention relates to high frequency heating and, more particularly, to high frequency induction heating and comprises an efficient induction heater particularly designed for use where it is desired to concentrate intense heat over a small area. The new heating device may be constructed of relatively few parts, can be readily made portable and is safe to operate.

In many applications it is important to be able to concentrate heat at a definite small location as, for example, when a crystal is to be mounted on the end of a metal pin as in the manufacture of transistors or crystal diodes, or when the getter in a subminiature tube is to be vaporized. The new induction heater includes low resistance windings forming part of an oscillatory circuit and so constructed and coupled as to concentrate the high frequency field at the desired work region. In each embodiment of the invention the carrier of the high frequency induced currents in the neighborhood of the work region is at D. C. ground potential thus minimizing danger to the operator. In certain of the embodiments of the invention one carrier of the high frequency currents is a longitudinally split cylindrical or conical sheet member which is inductively coupled to a primary winding comprising a plurality of turns of copper tubing and serves as a single turn secondary therefor. Associated with this secondary is a field localizer which may be a work loop providing a low impedance path for the high frequency current, in parallel with the paths provided by one surface of the secondary sheet member and in series with the path provided by the opposite surface of the secondary sheet member. The work loop concentrates the high frequency field for application of heat at the desired location. Alternatively the field localizer may be a current concentrator in the form of a radially split and centrally apertured cap or cover for the cylindrical or conical sheet member. In the preferred embodiment of the invention, the single turn sheet member is conductively, as well as inductively, coupled to the primary winding thus forming therewith an auto-transformer and the field localizer is a work loop bridging the longitudinal slot of the sheet member and preferably constructed as an integral part of a jig for holding the work to be heated. In still another embodiment of the invention the high frequency current carrier is a flat spirally wound metallic ribbon forming the inductance element of a tank circuit of an oscillator. This is inductively coupled to a flat, slotted, centrally apertured disc providing a central highly concentrated high frequency field.

For a better understanding of the invention and of various embodiments thereof, reference may be had to the accompanying drawings, of which:

Fig. 1 is an exploded view of an auto-transformer type of induction heater embodying the invention and representing the presently preferred form thereof;

Fig. 2 is a side view, partly broken away, of the assembled auto-transformer of the heater of Fig. 1;

Fig. 3 is an isometric view of a combined work loop

2

and jig which may be used with the auto-transformer of Figs. 1 and 2 as an alternative to the simple form of work loop shown in Fig. 1;

Fig. 4 is a schematic diagram of a circuit incorporating the auto-transformer of Figs. 1 and 2, the single turn secondary not being shown in the figure;

Fig. 5 is a side view of a conical induction heater of auto-transformer type embodying the invention, the associated circuit being indicated diagrammatically;

Fig. 6 is an enlarged sectional detail view taken on the line 6—6 of Fig. 5;

Fig. 7 is an isometric view of an induction heater representing another embodiment of the invention;

Fig. 8 is an isometric view of the spirally wound coil of the heater of Fig. 7;

Fig. 9 is a view similar to Fig. 8 but showing the coils partly unwound to illustrate the construction thereof;

Fig. 10 is a schematic diagram of a circuit incorporating the heater of Fig. 7;

Fig. 11 is a schematic diagram of an induction heater and oscillatory circuit therefor representing still another embodiment of the invention; and

Fig. 12 is an exploded view of the transformer and current concentrator of the embodiment of the invention illustrated in Fig. 11.

The invention will first be described with reference to the auto-transformer type of induction heater illustrated in Figs. 1 through 4. In this embodiment of the invention a helical coil 2 of copper tubing has an upper turn 2' which has been spread to give it a larger radius of curvature than the remaining turns. A copper sheet 4 is disposed about coil 2 in the form of a cylinder but with its meeting edges turned radially outward to provide a longitudinal slot 6. The upper edge of the sheet 4, through an arc of 300° or more, is soldered to the top turn 2' of coil 2, the sheet thus serving as a single turn secondary conductively and inductively coupled to the primary winding 2. Beyond turn 2' the tubing is brought down to the base of the coil 2 internally of the sheet 4 and adjacent the slot 6 as indicated at 8. Soldered to the lower end of the tubing part 8 is a coil 10 comprising a few turns of copper tubing and threaded through most of the turns of coil 2 and through coil 10 are wires 12 and 14, respectively, which are sheathed in a suitable insulating material, as for example the tetrafluoroethylene polymer manufactured by E. I. du Pont de Nemours & Co. under the trademark Teflon. The sides 16 and 18 of the sheet 4 defining the slot 6 extend radially outward from the axis of the coil 2 for a distance sufficient to accommodate steel blocks 20 and 22, each of which is provided with a series of horizontal slots 24 which, together with the adjoining wall 16 or 18, define passages for reception of the prongs of a work loop 26. The walls 16 and 18 beyond the blocks 20 and 22 are curved smoothly to provide wing sections 16' and 18' in each of which is formed a plurality of holes 28 which align with the passages provided by the slots 24. The blocks 20 and 22 are soldered to the walls 16 and 18 and to the wing sections 16' and 18' and each is smoothly curved at one corner to conform with the curvature of the junction between wall 16 and wing 16' or wall 18 and wing 18'. The prongs of work loop 26 are held in any selected pair of slots 24 by means of set screws (not shown) which are inserted into threaded openings 30 in the outer walls of the steel blocks and which intersect the slots 24. The walls 16 and 18 and flanges 16' and 18' increase the length of the conductive path on the outer surface of the secondary, in parallel with the work loop 26. These walls and flanges also serve to shield the steel blocks 20 and 22 from the radio frequency field and hence permit the use of

such wear resistance material for attachment of the work loop.

The work loop 26, when the prongs thereof are plugged into one or another pair of the openings 28 and aligned slots 24, provides a conductive path between the wings 16' and 18' for the high frequency currents induced in the single turn secondary comprising the sheet 4, the wall sections 16 and 18 and the wing sections 16' and 18'. The current path through the work loop 26 is thus one of low impedance as compared to the path in parallel therewith, namely, the outer surfaces of the sheet 4 and walls adjoining the slot 6. A high frequency field is thus concentrated in the neck 26' of the work loop 26 and any small conductive object to be heated, held within this region, will be subjected to intense heat. The sheet 4 is electrically grounded and therefore the work loop 26, when coupled to the sheet 4, is at D. C. ground potential. Accordingly, the work loop may be incorporated in a jig for holding the work and such a jig is illustrated in Fig. 3.

The jig of Fig. 3 includes a pair of prongs 32 which, like the prongs of the work loop 26, are adapted to be inserted into any pair of holes 28 in the walls 16' and 18'. The inner ends of the prongs are soldered to a copper plate 34 having a central small aperture 36 and a slot 38 connecting the aperture 36 with one side of the plate 34 intermediate the locations at which the prongs 32 are soldered. The plate 34 supports a block 40 upon the upper end of which is mounted a plate 42 carrying an arbor 44 for holding a work element, the arbor being preferably movable toward and away from the aperture 36 in the plate 34. Plate 34 is supported on a U-shaped bracket 46, in the base of which, beneath the opening 36, is mounted a work element support 48, also preferably adjustable toward and away from the opening 36.

Instead of providing a work loop coupled to the wings 16' and 18', a work loop or current concentrator may be coupled to the upper end of the cylindrical portion of the sheet 4. For this purpose, a disc 50, having an annular flange 52, a central aperture 54 and a radial slot 56 extending from the aperture 54 through the flange 52, may be provided. The disc 50, when positioned on the upper end of the sheet 4 with the slot 56 bridging the walls 16 and 18, provides a low impedance path for the high frequency currents in parallel with the path including the outer surfaces of the sheet 4, of walls 16 and 18 and of wings 16' and 18'. Thus, the high frequency field is concentrated within the aperture 54 providing an area at which intense heat may be developed in a work element. As the disc 50, when the sheet 4 is grounded, will also be at D. C. ground potential, no danger to the operator from arcing will result when a work element is held in the aperture 54.

The circuit of the above described heater will be clear from Fig. 4 to which reference may now be had. In Fig. 4 the turns 2a represent the coiled tube 2, and the half-turn 10a represents the coil 10, certain of the turns 2a and the turn 10a being threaded by the insulated leads 12 and 14, respectively. One end of lead 12 is connected through a high frequency choke 58 to a source of high voltage as, for example, 1½ kilovolts, a condenser 60 being connected between the high voltage side of the choke and ground. The other end of the wire 12 is connected to the anodes of a pair of triodes 62. One end of the wire 14 is connected through an RC network 64 to ground and the other end is connected to the grids of the tubes 62 through a pair of circuits each comprising a resistor 66 and an inductor 68 in parallel therewith. The junction of turns 2a and 10a is grounded and an R. F. bypass condenser 70 is connected between the high voltage end of the conductor 12 and the grounded junction of the turns 2a and 10a. A pair of condensers 72 and 74 are connected in series between the high end of plate coil 2a and the ungrounded end of the grid coil 10a. The cathodes of the triodes 62 are connected in parallel across a suitable source of potential connected to terminals 76.

Across the terminals 76 is connected a resistor 78 and a circuit comprising series connected condensers 80. The junction of the condensers 80 is grounded as is the center of resistor 78. For test purposes, a terminal 82 connected through a resistor 84 to the high potential end of the RC network 64 may be provided.

The operation of the above described oscillatory circuit will be readily apparent. The inductive element of the tank circuit comprises the coil 2a in the plate circuit of the triodes and the coil 10a in the grid circuit of the triodes. Condensers 72 and 74 comprise the capacitive element of the tank circuit. When a high voltage is impressed upon the anodes of the triodes 62, the circuit will oscillate due to the inductive coupling between the coils 2a and 10a in the plate and grid circuits, respectively, and high frequency currents will flow in the single turn 4 and work loop connected thereto.

In Fig. 5, a high frequency induction heater of the general type of Figs. 1 and 2, but of a slightly different geometric form is disclosed. In this embodiment of the invention, a copper tube is wound into a conically shaped coil 86 and to the upper turn 86' thereof is soldered a conical sheath 88 which corresponds to the one turn secondary 4 of Fig. 2. The sheath 88 is continuous about the coil 86 except through a small angle where the side edges of the sheath are turned outwardly to provide an opening 90 corresponding to the slot 6 of the embodiment of the invention illustrated in Fig. 1. A length 92 of the tubing beyond the turn 86' is brought down along one side of the opening 90 and is soldered to the sheath 88. Preferably a layer of mica, or the like, is provided within the opening 90 to insure that the gap will not be electrically bridged. The length 92 and sheath 88 are grounded as indicated at 93. To the lower end of the length 92 is soldered one end of a copper coil 94 corresponding to the grid coil 10a of Fig. 4. An insulated wire 96, one end of which is connected through a high frequency choke 98 to a source of high voltage, and the other end of which is connected to the anode of a triode 100, is threaded through the length 92 of copper tubing and through the turns 86 thereof. A second insulated wire 102, one end of which is connected to ground through a resistor 104 and the other end of which is connected to the grid of the tube 100, is threaded through tubing 94. Tank condensers 106 are connected in series across the lower ends of the coils 86 and 94. A bypass condenser 108 for the high frequency currents is connected between ground and the junction of wire 96 with the choke 98. With this embodiment of the invention, because of the conical shape of the coil 86 and sheath 88, the high frequency field is more or less directional and concentrated substantially in a region below the apex of the cone defined by the heater. Consequently, this form of device is of particular value when the work element cannot be brought into close juxtaposition with the heater, as for example, when the element to be heated is within an enclosure such as a vacuum tube. As the sheath is grounded both for direct current and for high frequency current, it may be held in the hands of an operator and directed at the work element for concentration of the heat at the desired locality. Obviously an additional triode in parallel with triode 100 could be provided as in the circuit of Fig. 4. If the sheath 86 is brought substantially over the upper end of the winding 86 to concentrate the induced currents in that region, or if a current concentrator of the type indicated at 50 in Fig. 1 is added, the heating region can be squeezed into a very small area and the apparatus used for heating objects located substantially at the upper end of the coil.

The embodiment of the invention illustrated in Figs. 7 through 10 differs from those heretofore described primarily in that the low resistance carrier of the high frequency currents is in the form of a flat ribbon rather than in the form of a tubular element. The physical construction of this embodiment of the invention will

be understood from Figs. 7, 8 and 9 and the circuit will be understood by reference to Fig. 10. A flat copper ribbon 110, the end terminals of which are indicated at 112 and 114, is wound in a continuous spiral and lashed to the edges of the ribbon for certain of the turns thereof are insulated wires 116, 118, 120 and 122. One end of the insulated wire 116 is brought out substantially mid-way of the spiral for connection through a choke 124 to a source of high potential, and one end of the insulated wire 118 is brought out at substantially the same point for connection to wire 116 and to the choke 124. Wires 116 and 118 which are lashed along the same edge of the ribbon extend in opposite directions and are brought out adjacent the ends of the copper ribbon 110 to terminals 126 and 128, respectively. Terminal 126 of wire 116 is connected to the anode of a triode 130 and terminal 128 of wire 118 is connected to the anode of a triode 132. The insulated wires 120 and 122 are lashed to the ribbon 110 along the edge of the ribbon opposite to that to which the anode wires 116 and 118 are lashed and through a lesser number of turns of the spiral. The terminals of wire 120 are indicated at 134 and 136 and the terminals of wire 122 are indicated at 138 and 140. Terminal 134 is connected to the grid of triode 132 and terminal 140 is connected to the grid of triode 130. Terminals 136 and 138 are connected together and to ground through a resistor 142. The copper ribbon 110 adjacent its mid-section is grounded as indicated in Fig. 10, the ground lead not being visible in the view of Fig. 8. The heater is completed by a high conductivity metal disc 144 which is closely spaced to the spiral coil by means of an effective insulating sheet 145 such as mica and may conveniently carry a jig for holding a work element. The disc 144 has a central aperture 146 and a radial slit 147 extending therefrom to the periphery of the disc. The disc is grounded at a point on its periphery diametrically opposite to the end of the slit. In the particular embodiment of the invention illustrated in Fig. 7, a hub 148 of dielectric material is centrally mounted on the underside of the disc to fit within the space defined by the inner turn of the coil and disposed in the aperture 146 of the disc 144 and supported in the hub 148 is a cylindrical insert 149, also of dielectric material but of smaller diameter than the hub 146. The disc 144 serves to concentrate the high frequency field at the center of the disc so that a conductive element placed upon the insert 149 will be subjected to intense heat.

In the particular embodiment of the invention illustrated in Fig. 7, an arm 150, having a slotted opening at one end for holding a work element is pivotally mounted between furcations of a bifurcated bracket 152 rotatably mounted on the disc 144. Adjacent the inset 149 on the disc 144 is mounted a brace or step 154 upon which the work-holding end of the lever 150 may be braced during the heating operation and also mounted on the disc 144 is an adjustable stop 155 for the lever to assure exact positioning of the work element. Obviously any other suitable means for positioning an element to be heated over the inset 149 and for supporting the insert 149 could be provided. The oscillatory circuit of the pancake type of induction heater above described is of the push-pull type as is obvious from Fig. 10. The tank circuit comprises the coil of ribbon 110 and condensers 156 and 158 connected in series across the end of the ribbon. The anode circuits of the tubes 130 and 132 are inductively coupled to the winding 110 through different sections thereof and the grid circuits are inductively coupled with the anode circuits of the opposite tubes.

Still another embodiment of the invention, similar in some respects to that of Figs. 1 and 2, is illustrated in Figs. 11 and 12. The induction heater of Figs. 11 and 12 is of the transformer type, but not an auto-transformer as in the case of Figs. 1, 2 and 5. A copper coil 160 is connected at one end to the anode of a triode 162 and at its other end to the anode of a triode 164. An insulated

wire 166 is threaded through the tubing 160 for a few turns adjacent its midsection and cross-connected at its ends to the grids of triodes 164 and 162. A pair of condensers 168 are connected in series across the ends of the coil 160. The midpoint of the copper coil 162 is connected through a choke 170 to a source of high voltage and the midpoint of the wire 166 is connected through a resistor 172 to ground. A bypass condenser 174 is connected between the high frequency source and ground. Positioned within the copper coil 160 is a generally cylindrical element 176 which has the outer configuration of a longitudinally slotted cylinder, the slot being indicated at 178 in Fig. 12.

The internal structure of the member 176 comprises longitudinal ribs or baffles 180 and 182 which extend radially inward from the inner wall and terminate short of the axis and short of inwardly extending wall portions 184 and 186 defining the slot 178. The wall portions 184 and 186, which extend nearly to the opposite side of the member are curved outwardly and then inwardly around the axis as is indicated at 188. The above described internal structure insures a relatively long internal path for the induced high frequency currents. A current concentrator 190 generally similar to concentrator 50 of Fig. 1 and comprising a centrally apertured and radially slotted cap completes the assembly and provides a low impedance current path in parallel with the longer paths provided by the member 176. The central aperture 192 is the work region at which an element to be heated is placed during the heating operation. The structure of Figs. 11 and 12 and associated push-pull circuit may be conveniently mounted in a portable unit with the member 176 grounded for minimizing electrical shock to the operator.

The invention has now been described with reference to various embodiments, each of which has been found in use to be efficient and effective for localized heating of small parts.

The following is claimed:

1. A high frequency induction heater comprising a helically wound tube of high conductivity, a cylindrical longitudinally split sheet member encompassing said tube and conductively connected to an end turn thereof to serve as a secondary winding inductively and conductively coupled thereto, a looped conductor of low resistance connected to said sheet member at opposite sides of the slot therein to provide a current path of low impedance in parallel with the path comprising the outer surfaces of said sheet member and to define a work area, an oscillatory circuit including said helically wound tube as one element thereof, the edges of said sheet adjacent the longitudinal slit extending radially outwards and then diverging smoothly to provide wing portions and means associated with said wing portions for detachably connecting said looped conductor thereacross.

2. The induction heater according to claim 1 wherein said last mentioned means include steel members welded to said outwardly extending edges of said sheet member and to said wing portions and protected thereby from radio frequency fields.

3. A high frequency induction heater comprising a helically wound tube of high conductivity, a cylindrical longitudinally split sheet member encompassing said tube and conductively connected to an end turn thereof to serve as a secondary winding inductively and conductively coupled thereto, a looped conductor of low resistance connected to said sheet member at opposite sides of the slot therein to provide a current path of low impedance in parallel with the path comprising the outer surfaces of said sheet member and to define a work area, an oscillatory circuit including said helically wound tube as one element thereof, said oscillatory circuit including at least one electronic tube having an anode, a grid and a grounded cathode, an insulated wire threaded through turns of said helically wound tube and con-

nected at one end to said anode and at its other end through a high frequency choke to a source of high potential, a second helically wound tube connected at one end to the same end of said first helically wound tube as that to which said sheet member is connected and capacitatively coupled at its other end to the other end of said first helically wound tube and an insulated wire threaded through said second helically wound tube and connected at one end to said grid and at its other end through an impedance to ground.

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