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(54) INDUCTION HEATING UNITS

(71) We, ILLINOIS TOOL WORKS INC., a corporation organised under the laws of the State of Delaware, United States of America, of 8501 West Higgins Road, Chicago, Illinois 60631, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

Induction heating is a known expedient for heating localized areas of metal objects by the use of RF (radio-frequency) power, which develops a varying electromagnetic field within the metal to be heated. Internal energy losses within the metal cause it to heat up in a relatively short period of time.

One of the primary disadvantages of induction heating units heretofore utilized is that the RF power, which is generated by an oscillator circuit, has needed to be delivered over a transmission line to the heating element. By so transmitting the RF power, much of the energy generated within the system is lost and the general efficiency of the system is greatly reduced. This is not a significant disadvantage when utilizing induction heating units which have large receptacles in which metal objects to be heated are placed, and about which the heating elements are positioned. However, when merely localized areas of large surfaces are to be heated, this problem of transmission line losses becomes significant.

One particular use of the phenomenon of induction heating is in connection with the automotive industry. Heretofore, fastening chrome or stainless steel decorative strips to the side panels or doors of automobiles has involved drilling holes therethrough. However, the drilling of holes can be avoided by fastening the decorative strips to clips which have previously been ad-

hesively secured to the surface of the automobile. By eliminating the holes, the amount of rust and corrosion which would otherwise occur is substantially reduced.

Because of the high rate of mass production of automobiles, such clips must be adhesively secured to the surface of an automobile quickly, i.e. within a matter of seconds. This can be accomplished by coating the clips with thermosetting materials of the kind which become strongly adhesive when heated — either directly or indirectly — to a sufficiently high temperature. However, the temperature at which the materials become adhesive must not be so high that any paint on the automobile surface is damaged or loosened.

It has been found necessary to control the amount of applied heat to within precise limits if satisfactory results are to be obtained. For example, with one particular thermosetting material which becomes adhesive at a temperature of 250°F to 300°F, the time taken to heat a clip (coated with that material) to that temperature must not be in excess of four seconds. Because of the short time duration of the applied heat, it is advantageous to use a heating unit which can be controlled either electrically or electronically to the precise limits necessary. Also, the heating unit must be small and easy to handle, and energy losses over the transmission line between the power supply and the heating element must be minimised so that the system is economically feasible.

According to the present invention, a hand-held induction heating unit comprises an elongate body having a handle at one end thereof and a nosepiece at the other end thereof; a radio-frequency oscillator located within the body and capable of connection to a power source; a first coil which constitutes both an inductance in the

[Price 33p]

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circuit of the oscillator and a primary winding of a voltage transformer; and a second coil which is concentric with and insulated from the first coil, and constitutes a secondary winding of the voltage transformer; the nosepiece being connected electrically to the second coil, and constituting a heater element for inducing currents within a metal article to be heated.

10 The nosepiece is preferably removably attached to the second coil, being formed with a peripheral wall defining a recess which can receive an article to be heated. A base of the recess can be connected to either an air or a vacuum line which is operable, at different times, to both hold an article to be heated within the recess and to eject such an article therefrom.

Preferably, the circuit including the oscillator and the first coil also includes a capacitor, the arrangement being such that said circuit will electrically resonate in use. Preferably, also, the capacitor is partially constituted by the second coil, the capacitor and the second coil comprising three sheets of a metal, each sheet being wrapped around the first coil to form thereby three longitudinally-split and concentrically-arranged cylinders; the interposed cylinder being electrically connected to the first coil, the inner and outer cylinders being electrically connected along first corresponding radially spaced-apart edges and electrically disconnected along second corresponding radially spaced-apart edges, and the nosepiece having one terminal thereof connected electrically to said first corresponding edges, and the other terminal thereof connected electrically only to the radially inner of said second corresponding edges.

Hand-held induction heating units according to the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is a simplified block diagram of an induction heating unit;

Figure 2 shows schematically the electrical circuit of the induction heating unit shown in Figure 1;

Figure 3 is a perspective view showing a second coil connected electrically to a heater element;

Figure 4 is a longitudinal section through an induction heating unit, according to the present invention, which can be hand-held;

Figure 5 is a fragmentary longitudinal section of the nosepiece shown in Figure 4, but taken at 90° therefrom;

Figure 6 is a fragmentary plan of a sheet metal surface, the dotted lines indicating the outline of a peripheral wall of the nosepiece which is to be laid thereagainst;

Figure 7 is a simplified block diagram of

a control circuit for use with the induction heating unit shown in Figure 4;

Figure 8 shows schematically part of an alternative electrical circuit associated with a power amplifier;

Figure 9 is a fragmentary longitudinal section through an alternative form of voltage transformer, for use with the hand-held unit shown in Figure 4, in which the second coil also constitutes part of a capacitor;

Figure 10 is a simplified electrical circuit diagram of the voltage transformer shown in Figure 9;

Figure 11 shows schematically the electrical circuit of control means for turning on and off, and timing the duration of energisation, of RF power applied to the first coil;

Figure 12 is a plan showing an alternative construction of the first and second coils, and heater element, for use with the hand-held induction heating unit shown in Figure 4;

Figure 13 is a perspective view showing a helical coil of a metal, formed on an insulating substrate, which is used in the construction shown in Figure 12;

Figure 14 is a fragmentary section taken along the line 14—14 of Figure 12; and

Figure 15 is a plan showing the electrical circuit arrangement of the voltage transformer shown in Figure 9, also showing the heater element.

Figure 1 shows, in block diagram form, the basic layout of an induction heating unit. A tank circuit and heater coil assembly 1 can be energized by a power supply 2 over a power feed line 3. The assembly 1 may be constructed in such a manner that it can be used as a portable unit.

The electrical circuit of the induction heating unit shown in Figure 1 is shown schematically in Figure 2. The assembly 1 includes a single loop heater element 4 connected to a single turn secondary winding 5a of a voltage transformer 5. The primary winding 5b of the transformer 5 is connected in parallel with a capacitor 6, power being supplied to the parallel circuit over a pair of feed lines 3a and 3b of a cable 3. The power supply 2 includes a radio-frequency oscillator valve 8 of the tuned-plate and tuned-grid type, the arrangement preferably being such that the electrical circuit including the oscillator valve 8, the primary winding 5b (constituting the first coil of the present invention), and the capacitor 6, will electrically resonate in use. The circuit for the plate electrode 7 of the oscillator valve 8 includes the primary winding 5b and the capacitor 6, the oscillator valve 8 also having a circuit 9 connected to the grid elec-

trode thereof. Necessary feedback for oscillation is obtained by means of a capacitance connected between the grid and the plate of the oscillator valve 8.

5 Preferably, the secondary winding 5a (constituting the second coil of the present invention) comprises a single sheet of a conductive material which is wrapped around the primary winding 5b and has the form of a longitudinally-split cylinder. 10 Terminals of the heater element 4 are connected electrically to respective opposed and confronting edges of the sheet (see Figure 3). The single turn secondary winding 5a can be located radially inwardly of the primary winding 5b. Also, the connections of the heater element 4 to the secondary winding 5a can be located at either end, or intermediately, thereof.

20 A hand-held induction heating unit, according to the present invention, is designated by reference numeral 10 in Figure 4. The induction heating unit 10 is carried within an elongate body comprising a cylindrical body 12 having a component-receiving housing 14 secured to one end. A handle 16 is secured to the housing 14, and at the other end of the body 12 is located a nosepiece 18, which constitutes the heater element and is preferably formed with a peripheral wall defining a recess which can receive an article to be heated. For example, the article can be a clip 20 which is to be secured, by thermosetting adhesives, to the surface of a metal sheet 22.

The induction heating unit 10 can apply heat energy to the sheet metal 22 for a short period of time, of the order of two to four seconds, so that the sheet metal 22 itself will then transfer heat to the clip 20. The clip 20 is shown only generally, a main body 24 thereof including resilient clip means for fastening to a decorative strip. The body 24 of the clip 20 has a thermosetting adhesive 26 coated on to one side thereof, which adhesive 26 is thermally activated, by applying a temperature of the order of 200°F to 400°F for about two to three seconds, to set the same. When the unit 10 is removed, the sheet metal 22 rapidly cools, the time taken being of the order of one to three seconds. The unit 10 can hence be used for rapidly applying clips 20, or the like, to the vertical side panels or doors of automobiles without fear that the clips will fall off while the thermosetting adhesive is curing.

Within the body 12 is located a first coil 28 which forms both the primary winding of a voltage transformer and the inductance in a circuit which will resonate electrically in use. The coil 28 is wound helically about a high dielectric support cylinder 30. The first coil 28 is here shown

as being formed of a relatively heavy gauge copper wire or tubing having suitable insulation thereon, such as a polytetrafluoroethylene or a varnish coating, which electrically insulates it from a sheet of metal 34 which itself forms a single turn secondary winding or the second coil of the voltage transformer. The second coil 34 receives RF electrical power from the primary winding 28, the power then flowing through the nosepiece 18 which is secured to the second coil 34 by screws 36. The second coil 34 has the form of a longitudinally-split cylinder, to respective opposed portions of which are connected corresponding spaced-apart electrical terminals of the nosepiece 18. The circulating energizing currents thus flow through a closed loop, as is shown more clearly in Figures 12 and 15.

The helical coil 28 is connected, either in series or parallel, with a capacitor 32. The RF energy supplied to the capacitor 32 and the inductor 28 is preferably in the form of square wave pulses of a frequency corresponding to the resonant frequency of the tuned circuit, this being approximately one megahertz. An RF oscillator and control circuit are mounted on a circuit board 38 which is located in the component housing 14. Therefore, only a single power cable need be connected to the body 12, which cable does not carry RF energy and therefore does not suffer from high energy losses over its length. Since the circuit board 38 and capacitor 32 are connected close together, within the same component housing 14, and since the helical coil 28 is connected to the capacitor and circuit board through a pair of relatively short flexible leads 40 and 42, there are substantially no RF energy losses within the unit and great efficiency is thus achieved.

In the preferred embodiment of this invention the nosepiece 18 is formed with a peripheral wall 18a, having a thin terminating edge 18b so that maximum transfer of RF energy is achieved into the metal sheet 22. The peripheral wall 18a can take any form to snugly fit about the clip 20. The nosepiece 18 is removably attached to the second coil 34 by the screws 36 so that the nosepiece can be quickly interchanged with others for receiving clips of different shapes. The nosepiece 18 has a recess 18c, the base of which is connected by a conduit 44 to a flexible hose 46. Only a fragmentary portion of the flexible hose 46 is shown connected to the conduit 44, most of the hose 46 being eliminated for purposes of clarity. The other end of the flexible hose 46 is connected to an outlet 48 of a valve 50 which is located in the component housing 14.

The valve 50 has a threaded coupling 52

which is connected to either an air or a vacuum line, depending on the construction of the valve 50. If an air line is used, the valve 50 will have a bypass outlet which causes air pressure passing over an orifice within the valve to create a vacuum within the hose 46 to hold a clip 20 in the nosepiece 18 until it is secured to the metal sheet 22. After heating of the thermosetting adhesive 26, the valve 50 will cause a positive pressure to be supplied through the hose 46 to thereby facilitate in ejecting the clip 20 from the nosepiece 18. Alternatively, the valve 50 may be a two-way valve, with both a positive pressure inlet and a negative pressure inlet, so that vacuum and pressure can be utilised, at different times, to hold the clip 20 within the recess 18c, and to eject the clip 20 therefrom immediately after securing it to the sheet metal 22.

The slotted cylinder forming the single loop secondary winding 34 is continuously resiliently biased away from the body 12 so that the nosepiece 18 can be maintained in flat pressure contact with the sheet metal 22 during energisation of the induction heating unit. Upon pressing the nosepiece 18 against the surface of the sheet metal 22, the primary and secondary windings 28 and 34, and all components fixed thereto, move upwardly into the body 12 against the force of a helical compression spring 54 located (as shown in Figure 4) at the lower end of the body 12 exteriorly of the secondary winding 34. An insulating block 56 is secured to the lower end of the secondary winding 34 and provides means for connecting the conduit 44 and the flexible hose 46, while also providing structural support means for the nosepiece 18 and the slotted cylinder 34.

Figure 5 is a section, taken at 90° from that shown in Figure 4, further depicting the rectangular configuration of the peripheral wall 18a of the nosepiece 18 — also showing the thin terminating edge 18b which in use engages the surface of the sheet 22. This is best illustrated in Figure 6, the dotted lines in which indicate the outline of the edge 18b of the peripheral wall 18a. The curved arrowed lines directed inwardly are intended to indicate the direction of heat flow within the sheet metal 22 during the induction heating process.

Referring again to Figure 4, the second coil 34 has a radially outwardly extending flange 34a which normally engages a ring 58 secured within the body 12. The ring 58 provides a stop for that assembly which is being continuously urged downwardly (see Figure 4) by the spring 54. Also located within the body 12 is a switch 60, which has an actuating element 62 depending

therefrom and engageable with the flange 34a. The switch 60 is electrically connected in series with a second switch 64, which is the trigger switch of the unit 10. The switch 60 is closed by pressing the nosepiece 18 against the sheet 22 i.e. by urging the nosepiece 18 against its resilient bias to actuate the element 62. The trigger switch 64 is closed by depressing a trigger 66 manually. The trigger 66 has an extended portion 66a connected to the valve 50 for simultaneous operation thereof.

Figure 7 is a simplified block diagram of a control circuit which can be mounted within the component housing 14 shown in Figure 4. Here a primary winding 70, which corresponds to the winding 28 of Figure 4, is connected in series with a capacitor 71, which corresponds to the capacitor 32 of Figure 4, to form a tuned circuit for receiving square wave pulses from a power amplifier 72. The winding 70 also forms a primary of a voltage transformer, which has a single turn secondary winding 73 positioned in close proximity thereto. The winding 73 corresponds to the slotted cylinder 34 of Figure 4, and is coupled to a looped heating element 74 which applies inductive heating energy to the surface of the metal sheet 22. The circuit shown in Figure 7 includes an IC (integrated circuit) square wave generator 76, which receives operating potential from a terminal 77 and supplies RF signals to a preamplifier 78. The components comprising the IC square wave generator 76, the preamplifier 78, and the power amplifier 72 are of conventional construction. For example, the IC square wave generator 76 can be formed as an integrated circuit supplied by Motorola Corporation under Part No. MC1648.

The preamplifier 78 and the power amplifier 72 may be conventional transistor components. For example, Figure 8 shows a power amplifier transistor 80 having an emitter electrode 81 connected to a positive potential to supply RF pulsating power to an associated tuned circuit. In this instance, the tuned circuit has the inductance 70 and the capacitor 71 reversed. When this is the case the capacitance 71 may be located radially inwardly of the first coil 70, or alternatively be partially constituted by the second coil 73 (as will be described below).

The capacitor 71 can be formed by a number of metal sheets, each being formed as a slotted cylinder similar to the single turn secondary winding 34 shown in Figure 4. This is illustrated in Figure 9, in which an insulating cylinder 82 is shown supporting a helical coil 83. Positioned (radially) outwardly of the helical coil 83 is an insulating sleeve 84, upon which is

positioned a conductive layer or sheet 85 to form a slotted cylinder. A second insulating layer 86 is applied over the sheet 85, and a second conductive layer 87 is applied over the insulating layer 86 to form a second slotted cylinder. A third insulating layer 88, and a third conductive layer 89, are formed as the outermost layers of the cylinder structure. The reader should note that the slots of each of the slotted (or longitudinally-split) cylinders are arranged to be in alignment one over the other as shown in Figure 15.

The interposed cylinder 87 is electrically connected to the bottom portion of the helical coil 83 by means of a conductor 90; the inner and outer cylinders 85 and 89 respectively being electrically connected to one another, and to the top portion of the first coil 83, by a conductor 91. The section shown in Figure 9 is only a fragmentary portion of the entire cylindrical structure, the equivalent electrical circuit of which is illustrated in simplified form in Figure 10. The electrical circuit arrangement is shown more fully in Figure 15, which also indicates the electrical connections of the heater element 18. It can be seen from Figure 15 that the inner and outer cylinders 85 and 89 are electrically connected along first corresponding radially spaced-apart edges and electrically disconnected along second corresponding radially spaced-apart edges, the heater element 18 having one terminal thereof connected electrically to said first corresponding edges, and the other terminal thereof connected electrically only to the radially inner of said second corresponding edges. Alternative arrangements of connections could be used, if desired. The structure shown in Figure 9 can replace the helical coil 28 and the slotted cylinder 34 shown in Figure 4.

Figure 11 shows a control circuit used to control precisely the time interval during which the circuit of Figure 7 is energised. The power supply of Figure 11 may have several different voltage value outputs, or a single voltage value output, and may be connected to one or more of the circuit components of Figure 7. The entire circuit arrangement shown in Figure 7 is illustrated in Figure 11 by a load 92, which has one terminal thereof connected to the output of a bridge rectifier circuit 93 (a DC voltage source), and the other terminal thereof connected to the anode of a silicon-controlled rectifier 94 via a line 96. The line 96 is also connected to a resistor 97, and a timing network 98, which controls the time duration for which the power supply is operative. Silicon-controlled rectifier 94 is maintained in a non-conductive state when the power supply is turned off

or disabled.

The trigger circuit of the silicon-controlled rectifier 94 includes a voltage-developing resistor 99 connected across the gate cathode junction thereof and a resistance/capacitance network 100 to provide a trigger pulse when both of the switches 60 and 64 are closed. Switches 60 and 64 of Figure 11 correspond to switches 60 and 64 of Figure 4, and operate in the manner described above. Whenever both switches are closed, the silicon-controlled rectifier 94 is rendered conductive to connect the line 96 therethrough to the other side of the bridge rectifier 93, thereby completing a circuit through the load 92.

At the time that the rectifier 94 is rendered conductive, a charge path is provided from the output of the bridge rectifier 93, through the timing circuit 98 which includes a timing capacitor 101 connected in series with a variable resistor 102, and finally through the rectifier 94. The timing circuit is voltage regulated by a zener diode 103. Upon reaching a predetermined charge value the capacitor 101 renders unijunction transistor 104 conductive to deliver a pulse of current through the primary winding of a pulse transformer 106. The pulse transformer 106 will then render a second silicon-controlled rectifier 107 conductive which, in turn, causes a commutating capacitor 108 to apply a negative voltage to the anode of the silicon-controlled rectifier 94. The rectifier 94 is thus turned off to de-energise the circuit shown in Figure 7. A resistor 109 is connected in series with the silicon-controlled rectifier 107 to limit the current.

Closure of the switches 60 and 64 thus initiates a supply of direct current to the load 92, which supply is turned off by means of the output pulse from the trigger transformer 106 and the silicon-controlled rectifier 107. The variable resistor 102 allows adjustment of the time interval, during which power is applied to the load 92, from between a fractional part of a second to five or more seconds.

A safety switch 110 is shown in Figure 11 connected in parallel with the variable resistor 102, and is open whenever both of the switches 60 and 64 are closed. Should the heater element 18 then be removed prematurely from the surface of the metal sheet 22, the switch 110 will close to quickly charge the capacitor 101, to render unijunction transistor 104 conductive and provide a gate pulse on silicon-controlled rectifier 107. This will immediately commutate the silicon-controlled rectifier 94 off, and de-energise the load 92.

Referring now to Figures 12, 13 and 14, a further alternative construction of first and second coils, and heater element, is

illustrated. Here an induction heating coil arrangement 120 is shown, which is designed for use within the body 12 shown in Figure 4. The arrangement 120 comprises a number of layers of conductive sheet material either formed on insulating cylinders or deposited thereon; the first coil being formed by depositing a helical coil of a metal conductor, of one-half inch width and between 0.010 and 0.030 inches thickness, on to an insulating substrate. The entire structure is integral, and provides both the inductance and capacitance necessary for the tuned circuit whilst also forming the voltage transformer primary and secondary windings.

The arrangement 120 includes a cylindrical insulating support cylinder 121 upon which is placed a conductive layer 122. A first insulating layer 123 is formed over the conductive layer 122, and provides the dielectric component for a capacitor formed between the plate 122 and a second conductive layer 124. A second layer of insulating material 126 is formed over the conductive layer 124 and provides a support surface upon which is deposited a helical coil 128. This is best seen in Figure 13, which shows the helical coil 128 as being formed of a rectangular conductive element helically being formed about the insulating layer 126. As mentioned above, the width of the conductive elements forming the coil 128 may be of the order of about one-half inch wide and between .010 and .030 inches thick. The flat ribbon-like helical coil 128 forms the primary winding of the voltage transformer and the inductance element of the tuned circuit, the capacitance element thus being formed by the plates 122 and 124. A final insulating layer 130 is formed over the ribbon-like helical coil 128, a single turn longitudinally-split secondary winding 132 being located over the entire assembly. In Figure 12 the slotted cylinder 132 shows confronting edges 132a and 132b, in close proximity to one another, which provide terminating ends to which are connected the open end portions of the nosepiece (heater element) 18. The nosepiece 18 is located as shown in Figure 12 to save space and provide a more compact induction heating unit.

WHAT WE CLAIM IS:—

1. A hand-held induction heating unit comprising an elongate body having a handle at one end thereof and a nosepiece at the other end thereof; a radio-frequency oscillator located within the body and capable of connection to a power source; a first coil which constitutes both an inductance in the circuit of the oscillator and a primary winding of a voltage transformer; and a second coil which is con-

centric with and insulated from the first coil, and constitutes a secondary winding of the voltage transformer; the nosepiece being connected electrically to the second coil, and constituting a heater element for inducing currents within a metal article to be heated.

2. A heating unit according to claim 1, in which the first coil is located within the body and extends helically along the length thereof, the second coil comprising a single sheet of a metal which is wrapped around the first coil and has the form of a longitudinally-split cylinder, with terminals of the nosepiece being connected electrically to respective opposed portions of said longitudinally-split cylinder.

3. A heating unit according to claim 2, in which not all of the second coil is located within the body.

4. A heating unit according to any preceding claim, in which the first coil is formed by depositing a helical coil of a metal on to an insulating substrate.

5. A heating unit according to any preceding claim, in which the circuit including the oscillator and the first coil also includes a capacitor, the arrangement being such that said circuit will electrically resonate in use.

6. A heating unit according to claim 5, in which the capacitor is formed concentrically with the first coil.

7. A heating unit according to claim 6, in which the first coil, the second coil and the capacitor are formed as an integral unit.

8. A heating unit according to claim 6 or claim 7, in which the capacitor is partially constituted by the second coil.

9. A heating unit according to claim 8, in which the capacitor and the second coil comprise three sheets of a metal each sheet being wrapped around the first coil to form thereby three longitudinally-split and concentrically-arranged cylinders; the interposed cylinder being electrically connected to the first coil, the inner and outer cylinders being electrically connected along first corresponding radially spaced-apart edges and electrically disconnected along second corresponding radially spaced-apart edges, and the nosepiece having one terminal thereof connected electrically to said first corresponding edges, and the other terminal thereof connected electrically only to the radially inner of said second corresponding edges.

10. A heating unit according to claim 6 or claim 7, in which the capacitor is located radially inwardly of the first coil, whereas the second coil is located radially outwardly of the first coil.

11. A heating unit according to any preceding claim, in which a power ampli-

illustrated. Here an induction heating coil arrangement 120 is shown, which is designed for use within the body 12 shown in Figure 4. The arrangement 120 comprises a number of layers of conductive sheet material either formed on insulating cylinders or deposited thereon; the first coil being formed by depositing a helical coil of a metal conductor, of one-half inch width and between 0.010 and 0.030 inches thickness, on to an insulating substrate. The entire structure is integral, and provides both the inductance and capacitance necessary for the tuned circuit whilst also forming the voltage transformer primary and secondary windings.

The arrangement 120 includes a cylindrical insulating support cylinder 121 upon which is placed a conductive layer 122. A first insulating layer 123 is formed over the conductive layer 122, and provides the dielectric component for a capacitor formed between the plate 122 and a second conductive layer 124. A second layer of insulating material 126 is formed over the conductive layer 124 and provides a support surface upon which is deposited a helical coil 128. This is best seen in Figure 13, which shows the helical coil 128 as being formed of a rectangular conductive element helically being formed about the insulating layer 126. As mentioned above, the width of the conductive elements forming the coil 128 may be of the order of about one-half inch wide and between .010 and .030 inches thick. The flat ribbon-like helical coil 128 forms the primary winding of the voltage transformer and the inductance element of the tuned circuit, the capacitance element thus being formed by the plates 122 and 124. A final insulating layer 130 is formed over the ribbon-like helical coil 128, a single turn longitudinally-split secondary winding 132 being located over the entire assembly. In Figure 12 the slotted cylinder 132 shows confronting edges 132a and 132b, in close proximity to one another, which provide terminating ends to which are connected the open end portions of the nosepiece (heater element) 18. The nosepiece 18 is located as shown in Figure 12 to save space and provide a more compact induction heating unit.

WHAT WE CLAIM IS:—

1. A hand-held induction heating unit comprising an elongate body having a handle at one end thereof and a nosepiece at the other end thereof; a radio-frequency oscillator located within the body and capable of connection to a power source; a first coil which constitutes both an inductance in the circuit of the oscillator and a primary winding of a voltage transformer; and a second coil which is con-

centric with and insulated from the first coil, and constitutes a secondary winding of the voltage transformer; the nosepiece being connected electrically to the second coil, and constituting a heater element for inducing currents within a metal article to be heated.

2. A heating unit according to claim 1, in which the first coil is located within the body and extends helically along the length thereof, the second coil comprising a single sheet of a metal which is wrapped around the first coil and has the form of a longitudinally-split cylinder, with terminals of the nosepiece being connected electrically to respective opposed portions of said longitudinally-split cylinder.

3. A heating unit according to claim 2, in which not all of the second coil is located within the body.

4. A heating unit according to any preceding claim, in which the first coil is formed by depositing a helical coil of a metal on to an insulating substrate.

5. A heating unit according to any preceding claim, in which the circuit including the oscillator and the first coil also includes a capacitor, the arrangement being such that said circuit will electrically resonate in use.

6. A heating unit according to claim 5, in which the capacitor is formed concentrically with the first coil.

7. A heating unit according to claim 6, in which the first coil, the second coil and the capacitor are formed as an integral unit.

8. A heating unit according to claim 6 or claim 7, in which the capacitor is partially constituted by the second coil.

9. A heating unit according to claim 8, in which the capacitor and the second coil comprise three sheets of a metal each sheet being wrapped around the first coil to form thereby three longitudinally-split and concentrically-arranged cylinders; the interposed cylinder being electrically connected to the first coil, the inner and outer cylinders being electrically connected along first corresponding radially spaced-apart edges and electrically disconnected along second corresponding radially spaced-apart edges, and the nosepiece having one terminal thereof connected electrically to said first corresponding edges, and the other terminal thereof connected electrically only to the radially inner of said second corresponding edges.

10. A heating unit according to claim 6 or claim 7, in which the capacitor is located radially inwardly of the first coil, whereas the second coil is located radially outwardly of the first coil.

11. A heating unit according to any preceding claim, in which a power ampli-



fier is located between the output of the oscillator and the input to the first coil.

12. A heating unit according to any preceding claim, and including control means for turning on and off the radio-frequency power applied to the first coil, and for timing the duration of energisation of that radio-frequency power.

13. A heating unit according to claim 12, in which the control means includes a DC voltage source, a first silicon-controlled rectifier having the cathode and anode thereof connected to the DC voltage source through the oscillator in such a manner that the oscillator is rendered operative upon conduction of the first rectifier, switching means connected to the gate of the first rectifier to render it conductive, a second silicon-controlled rectifier which is also connected to the DC voltage source, a commutating capacitor connected between the first and second silicon-controlled rectifiers, and a timing circuit which is connected to the first rectifier and is energized upon conduction thereof, the timing circuit including means connected to the gate electrode of the second rectifier to render it conductive, which action commutates the first rectifier to a non-conductive state, thereby terminating the DC voltage applied to the oscillator

14. A heating unit according to any preceding claim, in which the nosepiece is removably attached to the second coil.

15. A heating unit according to any preceding claim, in which the nosepiece is

formed with a peripheral wall defining a recess which can receive an article to be heated.

16. A heating unit according to claim 15, in which a base of the recess is connected to either an air or a vacuum line which is operable, at different times, to both hold an article to be heated within the recess and to eject such an article therefrom.

17. A heating unit according to any preceding claim, in which the nosepiece is continuously resiliently biased away from the body by a helical compression spring acting therebetween.

18. A heating unit according to claim 13 and claim 17, including a first switch which is closed by depressing a trigger, and a second switch which is closed by urging the nosepiece against its resilient bias, the arrangement being such that radio-frequency electrical power is not applied to the first coil until both the first and the second switches, constituting said switching means, are closed.

19. A hand-held induction heating unit according to claim 1 and substantially as described hereinbefore with reference to Figures 1 to 3, Figures 4 to 7, Figure 8, Figures 9 to 11 and 15, or Figures 12 to 14 of the accompanying drawings.

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