

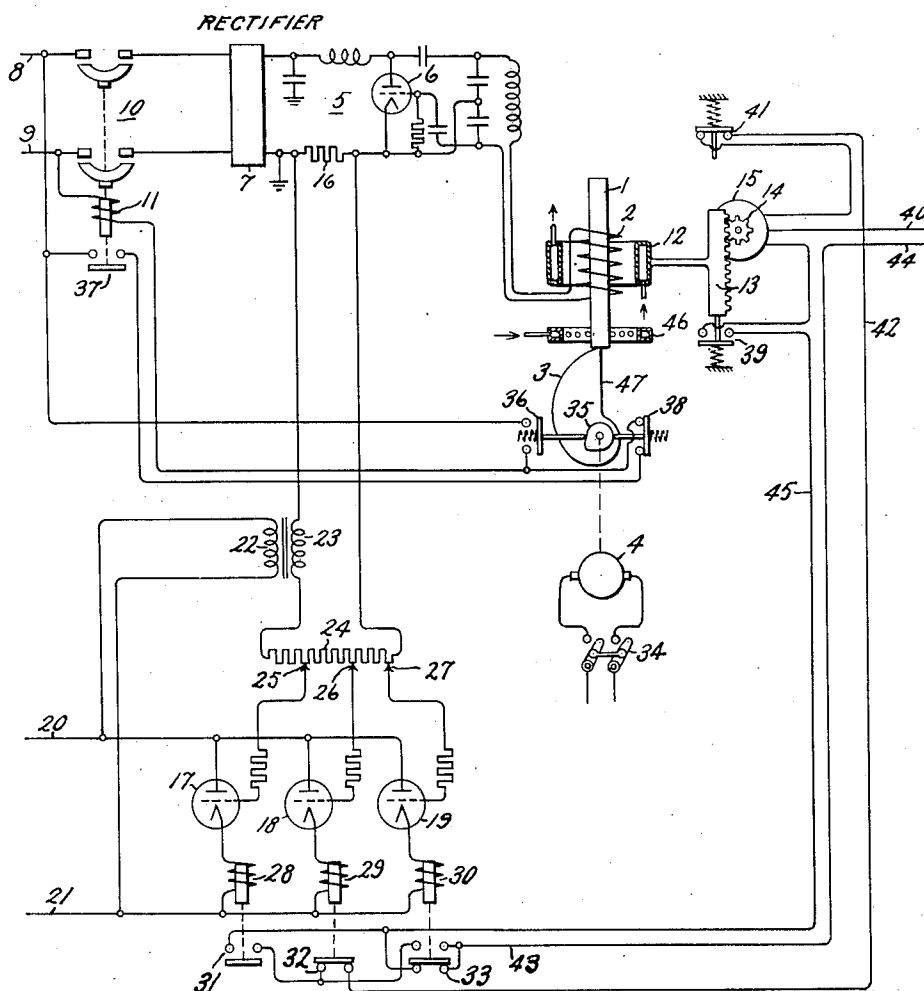
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J. P. JORDAN

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HIGH-FREQUENCY HEATING REGULATOR

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Inventor:
John Paul Jordan,
by *Cande A. Matt*
His Attorney.

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HIGH-FREQUENCY HEATING REGULATOR

John Paul Jordan, Scotia, N. Y., assignor to General Electric Company, a corporation of New York

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My invention relates to high frequency heating regulators, more particularly to regulators for high frequency apparatus for heating magnetic materials, and has for its object simple, reliable and efficient means for maintaining substantially a uniform power input and rate of heating throughout the entire heating operation to temperatures above the decalescent temperature.

In the heating of magnetic materials by high frequency induction heating, the power input and hence rate of heating decreases sharply when the temperature reaches the decalescent point and the material becomes nonmagnetic. Further increases in temperature are, as a result, delayed, with consequent decreased output of the heating apparatus. A manual adjustment of the power supply apparatus to increase the power input to its initial value is of course possible, but not desirable or practicable with automatic or semi-automatic heaters for heating large numbers of parts separately.

In accordance with my invention I regulate the power input by means of a shading ring or conductor around the heating coil or conductor, the ring being made of a highly conductive material, preferably copper. At the start of the heating operation the heating apparatus is adjusted to give full capacity power input with the shading ring at least partly surrounding the coil. The position of the shading ring is thereafter adjusted axially with respect to the coil by means responsive to the power input so as to maintain a predetermined power input, the ring being progressively removed from the coil to increase the power input.

For a more complete understanding of my invention reference should be had to the accompanying drawing, the single figure of which is a diagrammatic representation of high frequency heating apparatus embodying my invention.

Referring to the drawing, I have shown my invention in one form as applied to the heating of a predetermined portion of a bar or rod 1 made of magnetic material, such as steel, for the purpose of surface hardening that portion of the bar. The bar is heated by a stationary induction heating coil 2, having a plurality of axially spaced turns and supported with its axis vertical, into which the bar is inserted endwise in a downward direction with its lower end resting on a feeding cam 3 turned at a predetermined constant speed in a clockwise direction by an electric motor 4. In the starting position shown the cam 3 is holding the bar in a maximum raised position.

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High frequency current is supplied to the coil or conductor 2 by means of a suitable electronic oscillation generator 5, shown diagrammatically as a Colpitts type oscillation generator, at a suitable frequency such as 530,000 cycles a second. This generator comprises a three element electric discharge device 6 to which direct current is supplied from a suitable rectifier 7, the discharge device 6 as shown being provided with a plate, a cathode, and a control grid. Alternating current at a suitable voltage is supplied from the supply mains 8 and 9 through a biased open contactor or switch 10 which is closed by a coil 11.

In accordance with my invention I regulate the power input to the coil 2 by means of a single turn shading ring or conductor 12, preferably made of copper, which is hollow for the flow of cooling water therethrough as indicated by the arrows. This shading ring fits closely around the coil 2 in inductive relation therewith, but because of its high conductivity very little power loss occurs in the ring. The ring functions as a short circuited single turn secondary conductor or coil with respect to its primary coil 2 with high currents generated in it which produce a counter magnetic flux bucking the magnetic flux of the coil 2 and reducing the flux linkage with the bar 1. As a result the power input and heating rate are decreased and by adjusting the position of the ring axially with respect to the coil the power input can be regulated.

When the ring 12 is in a position of complete encirclement of the heating coil, as shown in the drawing, i. e., the entire axial length of the ring surrounding and coextensive with the heating coil so that each portion of the ring surrounds the heating coil, the ring gives the maximum flux bucking or shielding action and consequently the maximum reduction in the power input to the heating coil. As the ring is moved upward from the position shown in the drawing, its upper end portions move successively above the upper end of the heating coil to nonencirclement positions with decreasing shielding action. When the entire ring is above the heating coil so that no portion of the ring encircles the heating coil the ring provides substantially no flux bucking or shielding action.

As shown the ring is mounted in concentric relation with the coil and for adjustment axially in a vertical direction parallel with the axis of the coil on a vertical rack 13 with which cooperates a pinion 14 driven by an electric motor 15. The motor 15 is controlled automatically in response to the power input to the coil by means

responsive to the voltage across a resistance 16 connected in circuit with the oscillation generator 5. Preferably as shown the resistance 16 is connected in the direct current plate-cathode power circuit of the discharge device 6 so that the current in the resistance is responsive to the high frequency power supplied to the coil 2. The control means for the motor 15 comprising the three element electric discharge devices 17, 18 and 19 is responsive to a change in the voltage drop across the resistance 16, and hence the current in the resistance, to cause the motor to adjust the ring 12 so as to restore substantially the current in the resistance 16 thereby to maintain substantially a predetermined power input to the coil 2. As shown, each of the discharge devices 17, 18, and 19 is provided with a plate, a cathode, and a control grid.

Power is supplied to the plate-cathode input circuits of the discharge devices 17, 18 and 19 from alternating current supply mains 20 and 21. The grids of these discharge devices are normally biased to render them non-conductive by means of a transformer having a primary coil 22 connected across the mains 20 and 21 and its secondary coil 23 connected in series circuit relation with the resistance 16 and a resistance 24 having a resistance many times greater than the resistance 16. Taps 25, 26 and 27 lead from selected points of the resistance 24 respectively to the grids of the devices 17, 18 and 19. With normal full load current in the resistance 16 the voltage supplied to the grid of the device 17 is sufficiently high with respect to the plate-cathode voltage to render the grid of the device 17 negative when its plate is positive but the grids of the devices 18 and 19 are then positive with respect to their plate-cathode voltages, thus causing them to be conductive and thereby maintain the motor 15 in operation. In the plate-cathode circuits of the discharge devices are operating coils 28, 29 and 30 for three switches 31, 32 and 33 in the circuit of the motor 15.

The heater coil 2 is constructed for maximum heating with a selected number of turns to present full power input to the generator 5 when a cold bar 1 is in the coil and with the shading ring 12 in a position of substantial shading. The heating operation is started by starting the motor 4 by closing a supply switch 34 for the motor which turns the cam 3 at a predetermined low speed thereby to lower slowly the bar 1. When the portion of the bar to be heated reaches the coil the cam 35, secured to the cam 3, closes a biased open switch 36 which closes a circuit for the coil 11 across the mains 8 and 9. The coil 11 thereupon closes the switch 10 and also an interlock switch 37 which closes a holding circuit for the coil 11 through a biased closed switch 38 arranged to be opened by the cam 35 to terminate the heating operation. At this time ring 12 is in its lowermost position, as shown, surrounding the coil 2 substantially midway of the length of the coil in a maximum shielding position of complete encirclement, the motor 15 having been stopped by the opening of the biased closed limit switch 39 in its circuit by the lower end of the rack 13. Upon the closing of the switch 10 the generator 5 supplies power to the coil 2, and a direct current voltage is impressed on the resistors 16 and 24 which is proportional to the plate-cathode current of the generator and therefore proportional to the power load or input to the coil 2.

Preferably the power supplied to the coil at

the start will be somewhat lower than full load but the direct current voltage across the resistances 16 and 24 is sufficient to increase the grid voltage of the discharge device 19 to render the discharge device conducting and energize the coil 30 which closes its upper biased open switch 33 thereby energizing the motor 15 in a direction to raise the ring 12. The motor circuit may be traced from a direct current supply main 40 through one field winding and armature of the motor, a biased closed limit switch 41, conductor 42, biased closed switch 32, the upper pair of contacts of switch 33 and the conductor 43 to the opposite supply main 44. The motor 15 now moves the ring upward, thereby increasing the load on the generator with increased voltage across the resistance 24. When this voltage has increased to a predetermined value caused by the predetermined full load current supplied to the heating coil the discharge device 13 becomes conductive and the coil 29 opens the switch 32 to stop the motor 15. In a possible maximum raised nonencirclement position of the ring the rack 13 opens the limit switch 41 to stop the motor.

As the heating proceeds, if the load current increases above the full load value, the discharge device 17 becomes conductive whereby the coil 28 closes the switch 31 for reverse operation of the motor to lower the ring and reduce the power input until the discharge device 17 again becomes non-conducting and the switch 31 opens. This reverse circuit for the motor leads from the main 40 through the reverse field coil and armature of the motor, limit switch 39 which is now closed, conductor 45, switch 31, the upper contacts of switch 33 and conductor 43 to the main 44.

The ring 12 is thus adjusted to maintain a predetermined maximum power input to the coil 2. Over the heating operation the ring will probably be lowered somewhat from its initial adjusted position as the power input increases up to the decalescent temperature at which time the sharp drop in power input will cause the ring to be raised to a still higher position to reestablish the power input.

A hollow quench ring 46 is provided for quenching the bar 1 as its heated portion leaves the coil 2. A quenching fluid such as water is supplied to the ring and sprayed through inner apertures on to the bar.

Upon the heating and quenching of a predetermined length of the bar, the cam 35 opens the switch 38 which deenergizes the coil 11 whereupon the switch 10 moves to its biased open position to terminate the heating operation. This renders the discharge devices 17, 18 and 19 non-conducting and the switch 33 which was held by its coil in its upper position returns to its lower biased position shown in the drawing. The switch 33 closes a circuit for the motor 15 through its lower pair of contacts in a lowering direction whereby the ring 12 is lowered to the position shown when the motor is stopped by the opening of the limit switch 39.

For the heat treating of a plurality of bars 1 the motor 4 may operate continuously, the heat treated bar being discharged by engagement with the radial face 47 of the cam 3 as the cam completes a revolution and another bar 1 being dropped into the coil when the cam 3 reaches the position shown in the drawing. The heating operation just described is then repeated.

While I have shown a particular embodiment of my invention, it will be understood, of course, that I do not wish to be limited thereto since many

modifications may be made and I therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. High frequency heating apparatus comprising a high frequency induction heating coil provided with a plurality of axially spaced turns, a short circuited coil surrounding said heating coil having an axial length substantially the same as the axial length of said heating coil, and means for moving relatively said heating coil and said short circuited coil axially between positions of substantial nonencirclement of said heating coil by said short circuited coil and positions of substantially complete encirclement of said heating coil by said short circuited coil thereby to vary substantially the power input to said heating coil.

2. High frequency heating apparatus comprising a high frequency induction heating coil provided with a plurality of axially spaced turns, a short circuited coil surrounding said heating coil having an axial length substantially the same as the axial length of said heating coil, and means for moving said short circuited coil axially to vary the encirclement of said heating coil by said short circuited coil thereby to vary substantially the power input to said heating coil.

3. High frequency heating apparatus comprising a high frequency induction heating coil, a short circuited coil surrounding said heating coil having an axial length substantially the same as the axial length of said heating coil, and means for moving said short circuited coil axially between a position of substantial nonencirclement of said heating coil and a position of substantially complete encirclement of said heating coil thereby to vary substantially the power input to said heating coil.

4. High frequency heating apparatus comprising a high frequency induction heating conductor provided with a plurality of turns, connections for supplying high frequency current to said heating conductor, a short circuited conductor surrounding said heating conductor having an axial length substantially the same as the axial length of said heating conductor, operating means for moving one of said conductors axially with respect to the other thereby to vary the degree of encirclement of said heating conductor by said short circuited conductor and the power input to said heating conductor from said current supply connections, and means responsive to the power supplied to said heating conductor for con-

trolling said operating means thereby to maintain a predetermined power input to said heating conductor.

5. High frequency heating apparatus comprising an induction heating coil provided with a plurality of turns, a high frequency oscillation generator connected to supply current to said coil, a resistance connected in a power circuit of said generator, a ring made of a material having a high electrical conductivity surrounding said coil and having an axial length substantially the same as the axial length of said coil, means mounting said ring for movement axially relative to said coil, a driving motor mechanically connected to said mounting means to move said ring axially, and means responsive to the current in said resistance for controlling said motor to adjust the position of said ring axially so as to maintain substantially a predetermined current in said coil.

6. High frequency heating apparatus comprising a vertically arranged induction heating coil, a high frequency oscillation generator connected to supply current to said coil, a resistance connected in a power circuit of said generator, a ring made of a material having a high electrical conductivity surrounding said coil and having an axial length substantially the same as said coil, means mounting said ring for vertical movement axially relative to said coil, a driving motor mechanically connected to said mounting means to move said ring vertically, means responsive to the current in said resistance for controlling said motor to adjust the position of said ring vertically so as to maintain substantially a predetermined current in said coil, a first cam means at the lower end of said coil for feeding an article to be heated downward through said coil, means for driving said first cam means at a predetermined speed, a second cam means driven by said driving means, and switching means operated by said second cam means for controlling said generator thereby to start and stop the supply of current to said coil.

JOHN PAUL JORDAN.

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