Nov. 16, 1948. L. S. LAPPIN ET AL 2,453,994

HIGH-FREQUENCY POWER OUTPUT CONTROL

Filed May 22, 1945

2 Sheets-Sheet 1

Fig. 1.

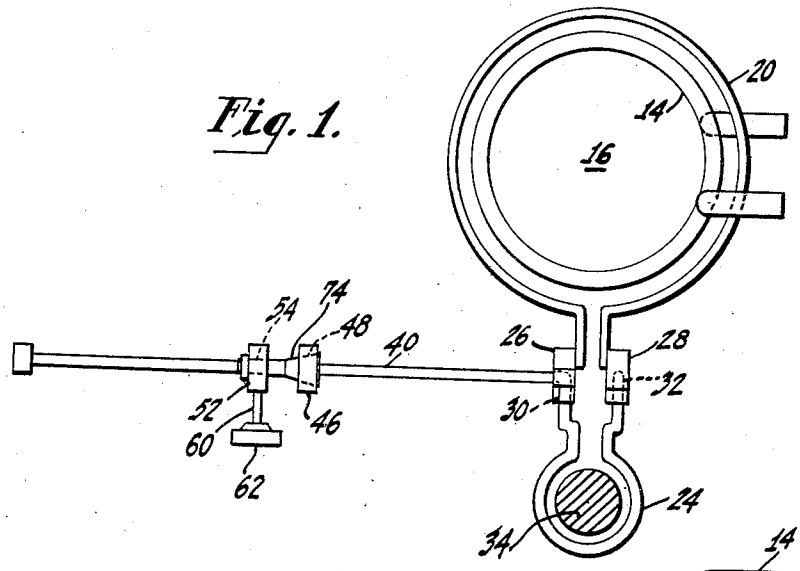


Fig. 2.

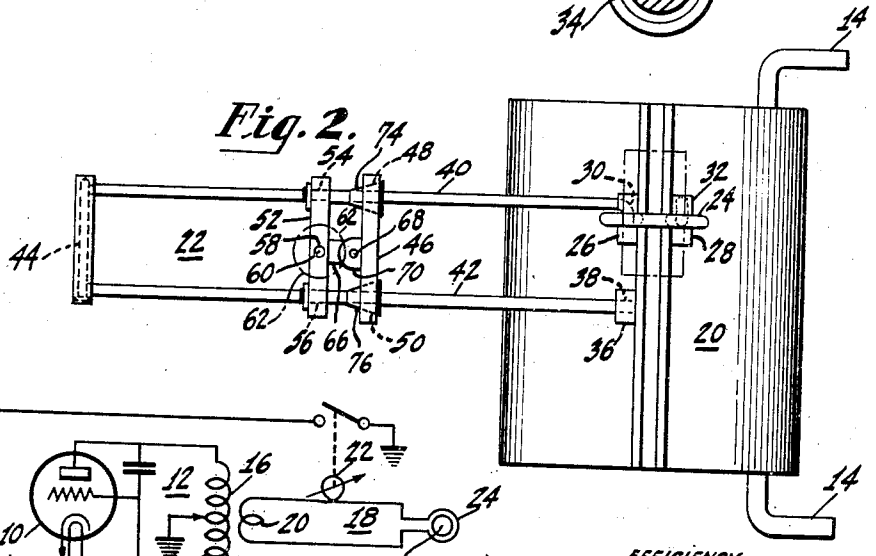


Fig. 6.

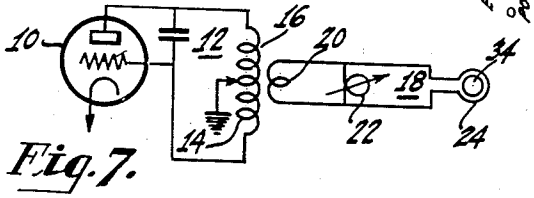


Fig. 7.

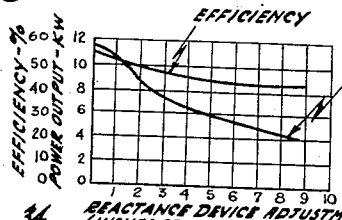


Fig. 8.

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2 Sheets-Sheet 2

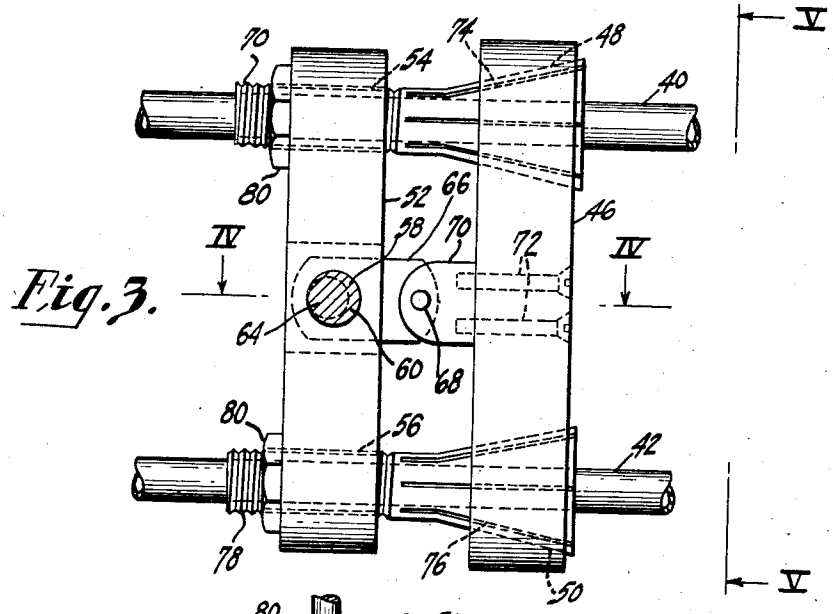


Fig. 3.

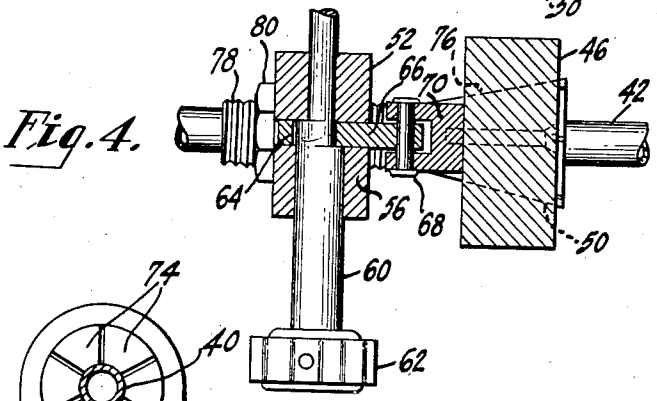


Fig. 4.

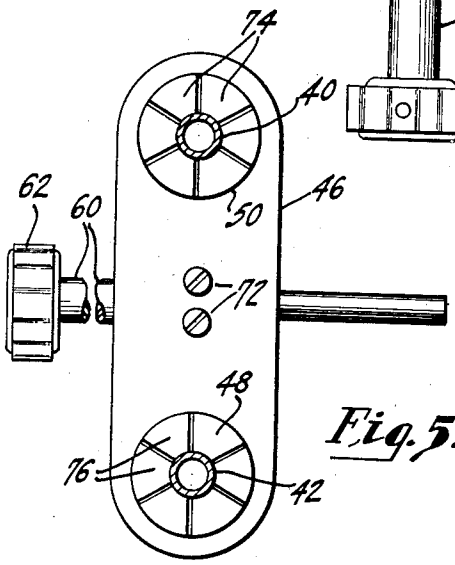


Fig. 5.

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HIGH-FREQUENCY POWER OUTPUT CONTROL

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2 Claims. (Cl. 178—44)

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This invention relates to high or radio frequency devices, and more particularly to a variable reactor for controlling the power output of high frequency generators or for tuning such devices.

In many applications in which high frequency induction heaters are employed, for example in the case hardening of metals and in brazing, soldering and the like, it is frequently necessary or desirable to vary the power output of the heater over a considerable range. Thus, where a comparatively small metal object is to be treated it may be desirable to reduce the power output considerably to prevent excessive heating or even melting of the object under treatment.

When the heater includes one or more electron tubes, variable grid leak resistors have been used to vary the grid voltage of at least one of the tubes and thus to control the high frequency power produced. The range of control which may be obtained by this means is however far too limited for many applications. It has also been proposed to use transformers with a multiplicity of taps to vary the anode voltage of one or more of the tubes forming part of the heater. The objection in this case is that the transformer with its auxiliary apparatus is both bulky and expensive. Gas tubes have also been used for power control purposes but are open to the same objections as the other expedients mentioned, the circuits required for their operation are complicated, and the tubes sometimes cause interference with adjacent telephone and radio equipment.

It is therefore an object of the invention to provide a simple, compact and inexpensive means for controlling the power output of a high frequency induction heater over a wide range. A further object is the provision of means of the character described which shall be capable of carrying and controlling heavy currents, for example, of the order of 700 to 1000 amperes.

According to the invention, these objects are achieved by the inclusion in the output circuit of the heater of a variable reactor for varying the current flowing in that circuit and hence the power transferred therefrom to the load. In one embodiment according to the invention, the reactor comprises a pair of parallel tubular conductors so arranged in combination with a shorting bar as to effect a tight electrical connection between the two conductors at any desired point along their length. The conductors are also arranged in combination with a conduit providing a continuous passage for cooling fluid through

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the reactor, and are thus enabled to carry heavy currents of the order indicated.

The invention may be better understood from the following description of two embodiments thereof when read in conjunction with the accompanying drawing in which:

Figure 1 is a plan view of the output circuit of a high frequency induction heater including the reactor of the invention,

Figure 2 is a view in elevation of the circuit of Fig. 1,

Figure 3 is a view in elevation of the control assembly of the reactor of Fig. 1,

Figure 4 is a sectional view of the assembly of Fig. 3 taken along the lines IV—IV of that figure,

Figure 5 is an end view of the assembly of Fig. 3 looking in the direction of the arrow V—V of that figure,

Figure 6 is a simplified circuit diagram of an induction heater including the output circuit of Fig. 1,

Figure 7 is a diagram similar to Fig. 6 but showing an alternative connection of the reactor of the invention, and

Figure 8 is a graph showing the range of control which was obtained with one embodiment of the reactor of Figs. 1 to 6.

In Fig. 6 there is shown an induction heater comprising an oscillator 10 provided with a tank circuit 12 which includes a primary winding 14 of a current transformer 16. An output circuit 18 of the heater includes a secondary member 20 of the transformer 16, a control reactor 22 according to the invention, and a work coil 24, all connected in series.

The secondary member 20 may consist of a cylindrical sheet of copper or other highly conductive material (Figs. 1 and 2) provided with terminals 36 and 28 constituted by copper blocks which include apertures 38, 32 respectively.

A further copper block or terminal 26 is affixed to but insulated from the secondary member 20 and similarly including an aperture 30.

The work coil 24 which may consist of a single turn of copper tubing fits into the apertures 30, 32.

In Fig. 1 the work coil is shown in inductive relation with a metal rod or other load 34. The term "work coil" as used in this specification and in the accompanying claims is intended to mean any form of inductor capable of being placed in inductive relation with work to transfer high frequency energy thereto.

A pair of tubular conductors 40, 42 of copper or similar low-loss material, in spaced parallel

relation with each other, fit tightly into the apertures 30 and 38 of the terminals 26 and 36. A conduit 44 connects the opposite ends of the conductors 40, 42 so that cooling fluid may pass continuously through the work coil, the reactor constituted by the two conductors mentioned, and the secondary member 20.

Referring to Figs. 3, 4 and 5, a copper shorting bar 46 provided with apertures 48, 50 is mounted on the tubular conductors which are thus effectively connected in series between the work coil and the secondary member.

In addition to the shorting bar 46 the conductors 40, 42 also bear a control bar 52 which need not be of copper but may be of brass or other similar sturdy material. The control bar is provided with a pair of apertures 54, 56 in which the conductors 40, 42 are contained. The control bar and shorting bar are thus slidably mounted upon the tubular conductors.

The control bar is provided with a transverse aperture 58 which forms a bearing for a shaft 60 to one end of which a control knob 62 is secured. The shaft 60 has an eccentric portion 64, constituting a cam, on which a link 66 is mounted. A pivot 68 connects the link 66 to a further link 70 to which the shorting bar 46 is secured by screws 72 or other appropriate means. By the mechanical coupling just described, rotation of the control knob 62 causes movement of the shorting bar 46 with respect to the control bar 52.

A collet or chuck 74 of highly conductive material holds the conductor 40 within the aperture 48 of the shorting bar 46 and a similar collet 76 holds the conductor 42 within the lower aperture 50 of the shorting bar. The two collets are secured to the control bar 52, as for example, by the threads 78, 78, and nuts 80, or by any other appropriate means, while the portions of the collets within the apertures 48, 50 of the shorting bar are composed of spaced segments. The two apertures 48, 50 are of frusto-conical configuration and the segmental portions of the two collets are of the similar configuration (Figs. 3 and 4).

When, therefore, operation of the control knob 62 causes the shorting bar 46 to move away from the control bar 52, the segmental portions of the collets 74, 76 are wedged into the apertures 48, 50 respectively. Radial pressure is thus exerted on the shorting bar and also on the conductors 40, 42, thereby insuring a tight and effective electrical connection between the shorting bar and the conductors and preventing movement of the conductors with respect to the shorting bar. Conversely, when the control knob 62 is rotated even slightly in the opposite direction, so that the shorting bar moves towards the control bar, the radial pressure is reduced and the whole assembly of the control and shorting bars and their associated apparatus may be slid along the conductors to any desired position. The assembly may then be locked in that position merely by a slight turn of the knob 62.

By this means the reactions of the two conductors 40, 42 and the shorting bar 46 may be varied to any desired extent within the limits of the length of the two conductors. The reactance, which is almost entirely of an inductive character and has only a negligible capacitive component, is at a minimum when the shorting bar is nearest the terminal blocks 26, 36 and at a maximum when the shorting bar is furthest from those blocks. The power transferred to the load is a function of the current induced in the load, which in turn depends on the current in the output circuit 18. Variation of the reactance of this circuit alters the current flowing in it, and hence the power output of the heater.

Fig. 8 is a graph showing the relation of the power output of a high frequency induction heater employing a reactor according to the invention to the distance of the shorting bar from the terminal blocks 26, 36. The results recorded were taken with a generator operating at a frequency of 400 kc. per second and with an output circuit which carried a current of from 700 to 1000 amperes. The tubular conductors were each 9" long, and had an outside diameter of 3/8", and walls .060" thick. It will be seen that it was possible to vary the power output over a range of from 4 to 11.8 kilowatts.

Figs. 1 to 6 show the reactor of the invention connected in series between the secondary member 20 and the work coil 24. It is also possible, as illustrated in Fig 7, to connect the reactor in parallel with these two circuit elements, although the series connection has hitherto produced more satisfactory results. With the parallel connection, although the reactance of the output circuit varies as in the case of the series connection, the power output is at a maximum when the shorting bar is nearest the terminal blocks 26, 36.

In a practical application the control knob 62 may be connected with safety interlock means for cutting off the supply of power to the heater in response to operation of the knob, although the voltages applied to the device are low.

There has thus been described a simple, compact and inexpensive device for varying the power output of a high frequency inductive heater. The device is distinguished by the ease of the control which it permits and is capable of carrying and controlling heavy currents as indicated. In its simplest form the device comprises a variable reactor connected in the output circuit of the heater and constituted by a pair of conductors arranged in spaced parallel relation with each other, together with means for short-circuiting any desired portion of the conductors and means permitting the continuous passage of coolant through the device. While the invention has been described by way of illustration in connection with a high frequency induction heater, it will be apparent that it may be used to control the power output of any type of high frequency generator or to tune any type of high frequency device.

We claim as our invention:

1. A device for electrically connecting a pair of spaced parallel conductors at selectable points comprising a pair of collets having an axial aperture adapted to slidably receive said conductors respectively, one end of each collet having spaced segments whose outer surfaces have a frusto-conical configuration; a shorting bar provided with a pair of frusto-conical apertures, the segmented ends of said collets lying within the apertures of said shorting bar; a control bar parallel to and spaced from said shorting bar and rigidly holding said collets in relatively fixed relation, a control shaft rotatably mounted in said control bar and containing an eccentric cam portion; and link means connecting said shorting bar and said control bar and movable in response to a rotation of said control shaft cam to vary the spacing between said bars.

2. A device for electrically connecting a pair of spaced parallel conductors at selectable points comprising a pair of collets having an axial aperture of uniform cross-section adapted to slidably receive said conductors respectively, one end of

each collet having circumferentially spaced longitudinal segments whose outer surfaces have a frusto-conical configuration; a shorting bar provided with a pair of complementary frusto-conical transverse apertures, the segmented ends of said collets normally lying loosely within the apertures of said shorting bar longitudinally with respect to said collets to exert radial pressure inwardly on said segments so as to firmly grip said conductors, said means comprising a control bar parallel to and spaced from said shorting bar and rigidly mounted on said collets, a control shaft rotatably mounted in said control bar, an eccentric cam rotated by said control shaft, and link means engaging said cam, longitudinally movable by rotation of said shaft, and connected to said shorting bar.

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