June 8, 1943. P. E. DRAVNEEK 2,321,189

INDUCTION HEATING APPARATUS

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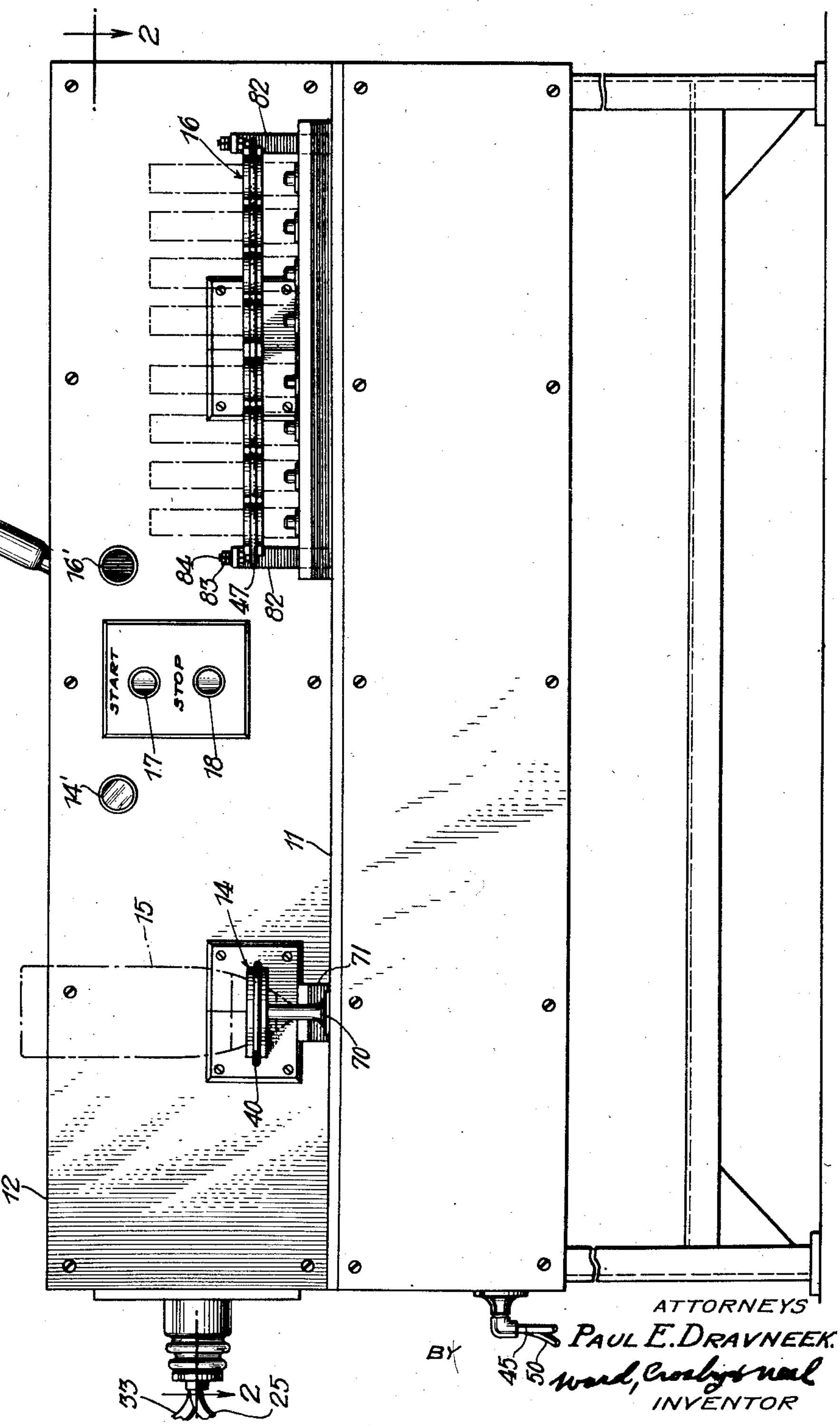

Fig. 1.

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INDUCTION HEATING APPARATUS

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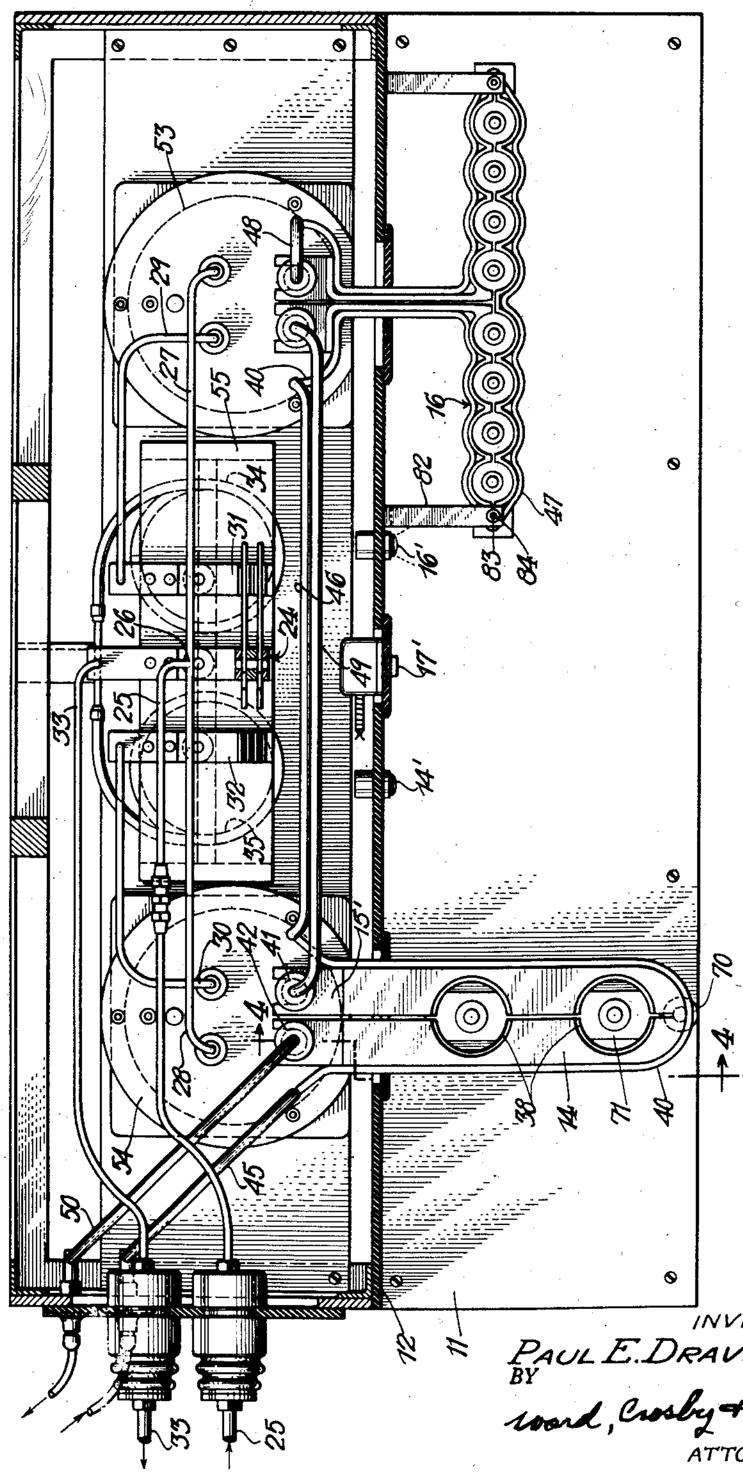
Fig. 2.



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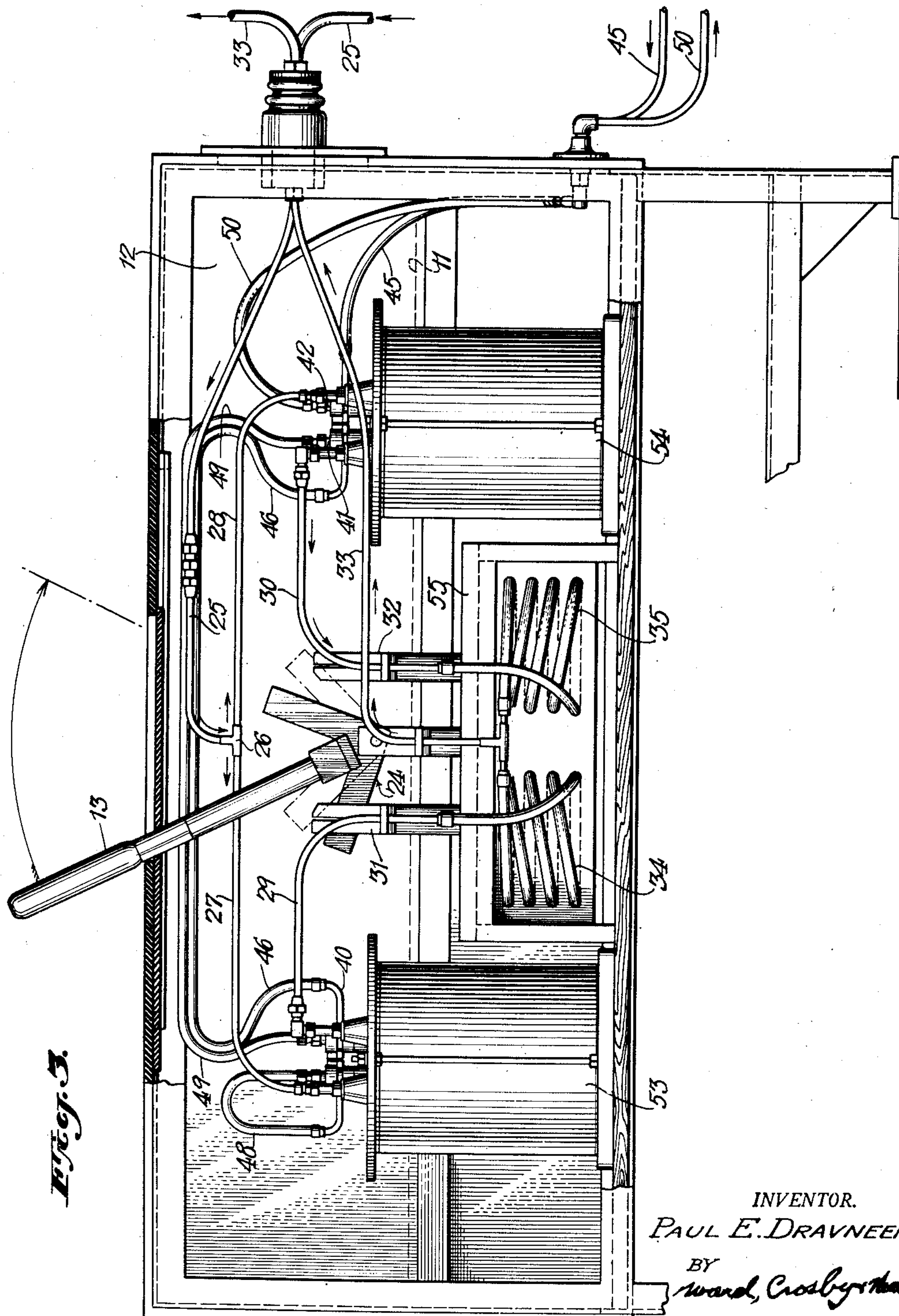

Fig. 3.

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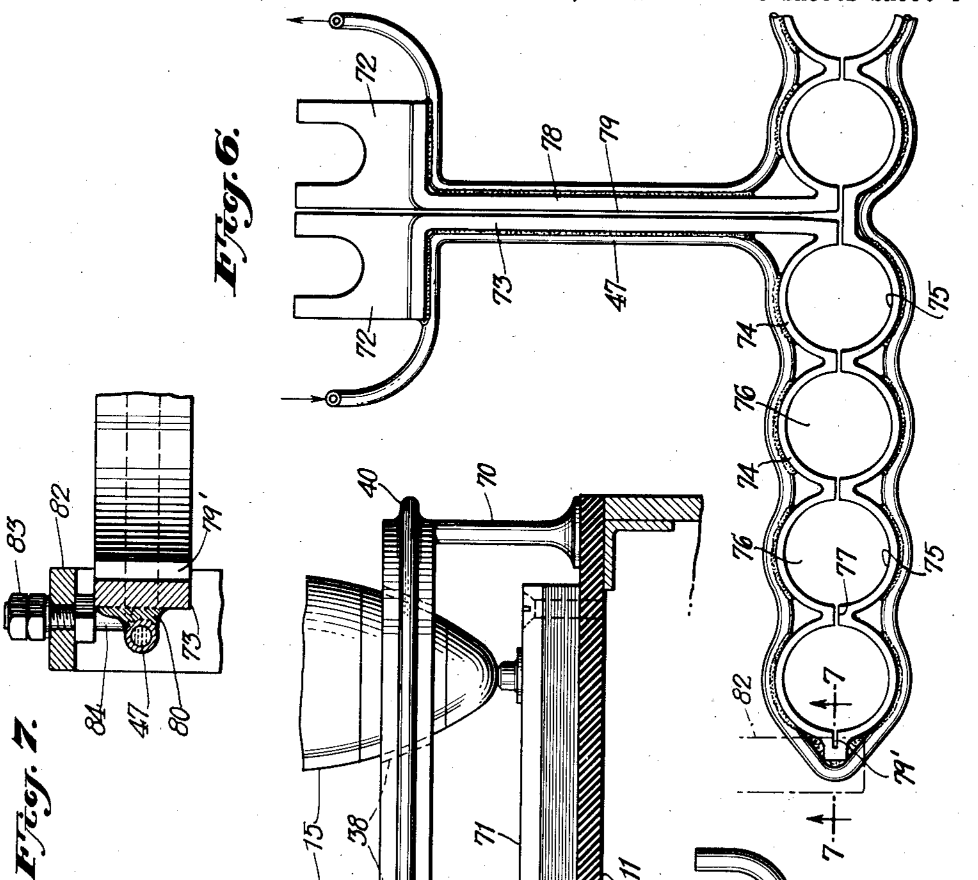

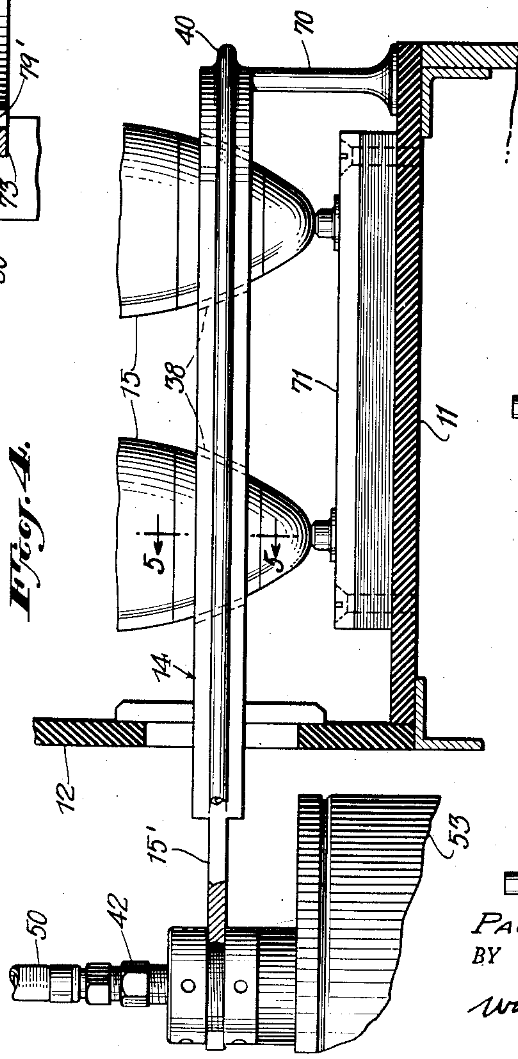

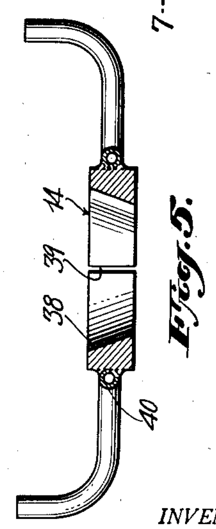

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INDUCTION HEATING APPARATUS

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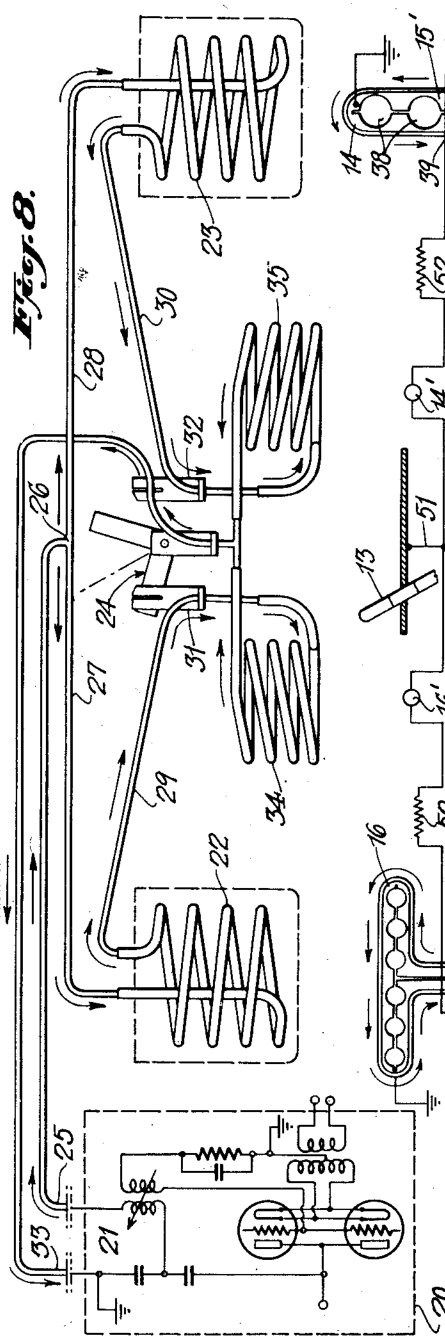

Fig. 8.

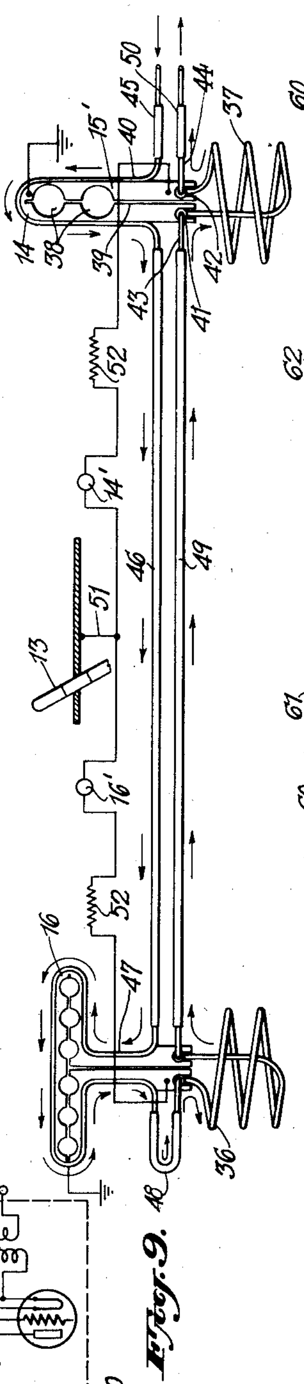

Fig. 9.

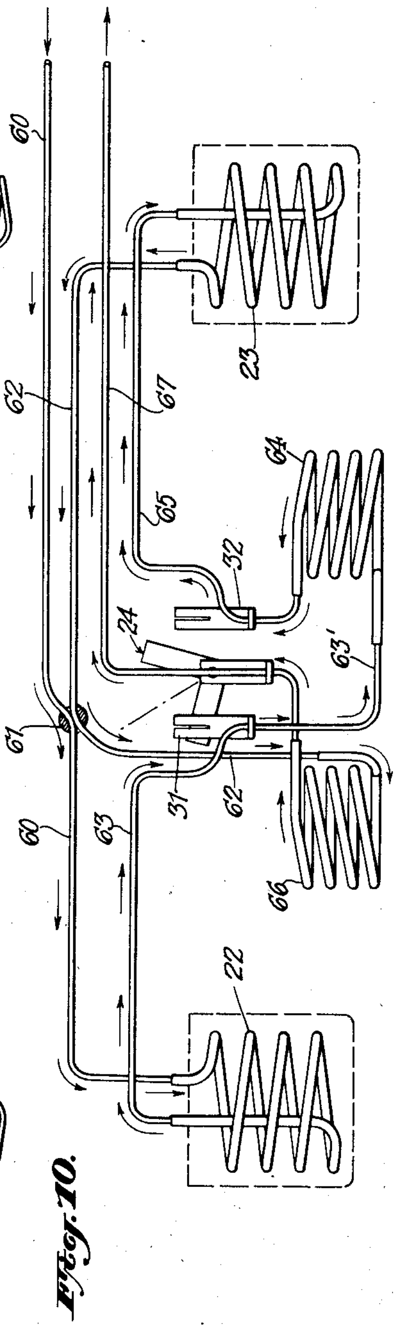

Fig. 10.

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Patented June 8, 1943 **2,321,189**

UNITED STATES PATENT OFFICE

2,321,189

INDUCTION HEATING APPARATUS

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Application December 26, 1942, Serial No. 470,233

8 Claims. (Cl. 219—13)

This invention relates to induction heating apparatus and more particularly to an arrangement whereby two or more high frequency induction heating work coils may be conveniently and efficiently used alternately or in succession in conjunction with a single source of high frequency power.

In the treating of objects by induction heating, it is customary to place an object within or adjacent a work coil while the power is shut off, and to then turn on the power for the predetermined time required for the treatment, whereupon the power is again shut off while the heated object is removed and another put in place. Since with such procedure the high frequency generator is in operation only during a fraction of the elapsed time, it is desirable to provide two or more work coils adapted to be connected alternately or in succession to the high frequency generator, whereby while an object is being heat-treated at one of the coils, the operator may be performing the steps of taking out and replacing other objects at another coil, thus economizing as to the use of the generator as well as the operator's time. With circuits for the generation of powerful currents at frequencies of the order of several hundred thousand cycles as now preferred for many cases of induction heating, it is necessary to maintain streams of cooling fluid through the connections and coils to avoid their being rapidly heated to the point of melting, and hence if the generator is turned on and off at such intervals that it is used for example during less than one-half of the elapsed time, there will be loss of efficiency for the added reason that considerable heat is radiated and wasted because of the abnormal cooling of the equipment during the off intervals. For equipment of this kind, the alternate use of two or more work coils for a single generator is thus particularly desirable.

The use of two work coils alternately with a high frequency generator such as to require constant water cooling of the circuits and coils in use, involves various difficulties. The work coils are operated from step-down transformers at low voltage so as to provide very heavy heating currents. Hence to efficiently conduct these currents from the transformers to the work coils, the connections must be direct and too short to afford space for any convenient switching means therein, while still maintaining the necessary cooling fluid streams throughout. Also the switching connections would have to be too short for the work coils to be adequately spaced apart for convenient use. To avoid the difficulty of changing from one work coil to another by switches in the work circuit, an arrangement according to the present invention is provided having fixed independent work circuits for two work coils respectively, these circuits being energized from two separate high frequency step-down transformers, with the primaries of the transformers adapted through switching means to alternately form a part of a tank circuit of a single oscillator. One difficulty with such an arrangement, however, is that of providing for constantly maintaining a stream of cooling water through the primary coils of both transformers and the electrical connections therefor, while still avoiding short-circuiting of the switch means by the stream of water. Such an arrangement involves certain other difficulties hereinafter explained and which are overcome by various features of the invention.

In accordance with one feature of the invention, the portions of the electrical connections which are common to two transformer primaries, are provided with a single supply of cooling water which enters and leaves through these portions of the connections, but which at intermediate points is divided into two parallel streams running respectively constantly through the two transformer primaries and the respective individual electrical connections therefor. This provides a particularly advantageous arrangement for a number of reasons. The electrical characteristics of the transformer primaries are such that the conduit cavities therein must be relatively restricted, thus limiting the size of the stream which may be passed therethrough at pressures available from ordinary water supplies. Yet since each primary is electrically connected only during a part of the time, the maintenance of the stream of limited size therein, throughout the on and off periods, serves to accomplish the purpose of adequate cooling. The use of parallel streams through the two primaries from a single source also enables the use of the combined amounts of the two streams in such of the connections as are common to both primaries and which therefore need more cooling because of being connected in the electrical circuit twice as long as each primary.

Various further and more specific objects, features and advantages of the invention will appear from the detailed description given below taken in connection with the accompanying drawings which form a part of this specification and illustrate merely by way of example, preferred forms of the invention. The invention consists in such novel features and combinations of parts as may be shown and described in connection with the apparatus herein disclosed.

In the drawings, Fig. 1 is a front view of one form of apparatus embodying the invention;

Fig. 2 is a horizontal sectional view taken substantially along line 2—2 of Fig. 1 and Fig. 3 is a rear view of the same apparatus;

Fig. 4 is a sectional view taken substantially along line 4—4 of Fig. 2 and Fig. 5 is a sectional view taken substantially along line 5—5 of Fig. 4;

Fig. 6 is an enlarged view showing the construction of one type of so-called work coil adapted for use with the invention;

Fig. 7 is a sectional view taken substantially along line 7—7 of Fig. 6;

Fig. 8 is a diagram of the high voltage electrical circuits and water cooling circuit therefor for one embodiment of the invention;

Fig. 9 is a diagram of the low voltage work coil circuits and water cooling circuit therefor according to one embodiment of the invetnion; and

Fig. 10 is a diagram similar to Fig. 8 but showing an alternative embodiment of the invention.

In Fig. 1 a work bench or table is shown at 11, the rear portions of which include an apparatus housing having an insulation front panel 12. At the face of this panel a pair of induction heating work coils are mounted and adapted to be used alternately on throwing a switch handle 13 to one side or the other. These work coils may be the same or of different constructions, depending upon the type of objects to be heated thereby. For example, a one-turn work coil is shown at 14 of the type shown in further detail in Fig. 4, and adapted to simultaneously heat two objects as at 15. The other work coil as shown at 16 is of the type shown in further detail in Fig. 6, and is adapted to be used for simultaneously heating, for example, eight like objects.

The two work coils of Fig. 1 are adapted to be supplied with power from a single high frequency power oscillator which may be started and stopped when desired as by push button switches 17, 18 on the face of the panel 12. That is, these switches through connections now shown, simply serve to turn on or shut off the power supply to the high frequency oscillator. The panel 12 may also be provided with indicator lamps as at 14′ and 16′ for showing when the work coils 14 and 16 respectively are being supplied with high frequency power.

Referring now more particularly to the circuit diagram of Fig. 8, connections for a high frequency vacuum tube power oscillator are indicated at 20. Various known types of circuit connections for the oscilaltor per se may of course be used in connection with the invention, the particular form shown at 20 being according to the principles of the well-known Hartley oscillator circuit, and being further described in connection with Fig. 1 of the copending application of Wallace C. Rudd and Fred Kohler, Ser. No. 465,246, filed November 11, 1942. The oscillator may be designed to supply power up to 20 kilowatts for example, at a frequency of several hundred thousand cycles and at a potential of several thousand volts. The arrangement 20 may conveniently be contained in a high frequency generator cabinet separate from the apparatus forming the subject matter of the present invention. The apparatus in such generator cabinet may include a portion 21 of a tank circuit, the remainder of this tank circuit being embodied in the assembly to the rear of the insulation panel of Fig. 1 and shown diagrammatically in the remaining parts of Fig. 8.

The latter part of this tank circuit may comprise a primary 22 of a high frequency transformer or, alternatively, a primary 23 of another high frequency transformer, a single pole double throw switch 24 being provided and operated by the above mentioned handle 13 for switching either primary into the tank circuit to the exclusion of the other.

One of the electrical terminals to the apparatus of Fig. 1 may comprise a metal pipe 25 which is connected to one side of the portion of the tank circuit 21 in the generator cabinet, and is also connected with a suitable source of supply of cooling water (not shown). As indicated in Fig. 8, the pipe 25 may extend to a junction point 26 where it is connected to metal pipes 27, 28 running respectively to primaries 22 and 23. These primaries as indicated may comprise hollow metal tubing, communicating with the pipes 25, 27, 28. The outlet terminals of the primaries respectively may be connected by metal pipes 29 and 30 to the two opposite terminals 31, 32 of the switch 24. The center terminal of the switch 24 may be connected by metal pipe 33 running back to the other side of the portion of the tank circuit 21 within the generator cabinet and also to a suitable point of discharge (not shown) for the cooling water.

In order to maintain the streams of cooling water through both primaries regardless of the position of the switch 24, and yet without short-circuiting either side of this switch when open, the pipes 29 and 30 respectively, are brought into communication with the return pipe 33 by insulation conduits 34, 35. These conduits may for example be in the form of coiled tubing formed of rubber or of a fusible plastic insulation material. Each should be of a length sufficient so that when filled with a stream of water of the degree of purity customarily available with city water supplies, there will be no material amount of the high voltage high frequency current conducted across either side of the switch 24 when open. Ordinarily about 7 ft. of 3/8″ tubing are found to be suitable for each of the conduits 34, 35. With water supplies having unusually large amounts of dissolved salts, etc., the water should be treated before use in the apparatus.

Referring now to Fig. 9, a pair of transformer secondaries 36, 37 are shown which are adapted to cooperate respectively with the transformer primaries 22, 23. As shown, the secondary 37 is connected in series with work coil 14, which has a single "turn" and is constructed in the form of a bar or strip of metal 15′ with apertures as at 38 for receiving the objects to be heated, and the bar being formed with a sawcut as at 39 for separating electrically one side of the "turn" from the other. A metal cooling fluid conduit 40 is soldered around the periphery of the bar 15′. The electrical terminals are provided as at 41, 42 including metal cooling fluid conduit terminals as at 43, 44 communicating respectively with the terminals of the secondary 37. The construction of the work coil 16 which may also comprise a single "turn," is similar in principle to that of work coil 14. Also the secondary 36 may have electrical and cooling fluid terminals similar to the secondary 37.

Cooling fluid to the circuits of Fig. 9 may be supplied through an insulation conduit 45 to pipe 40, thence through an insulation pipe 46 into a metal pipe 47 embracing work coil 16, thence through an insulation connection 48, into and through secondary 36, back through an insulation conduit 49, into and through secondary 37, and finally through an insulation outlet connection 50. Thus a single stream of cooling fluid may be conducted continuously in series through substantially all parts of both secondary circuits, while these circuits are kept electrically independent for alternate use.

As further shown in Fig. 9, the indicator lamps 14' and 16' may each have one terminal grounded as at 51, the other terminals respectively being connected through suitable resistances as at 52 to the work coils 14 and 16.

The physical arrangement of the various parts above referred to in connection with Figs. 8 and 9 are shown in further detail in Figs. 2 and 3. The transformers embodying the above mentioned primaries and secondaries are here shown at 53 and 54, the same being preferably of the type disclosed in the copending application of Wallace C. Rudd, Ser. No. 447,002, filed June 15, 1942. As shown, these transformers are respectively preferably located to the rear of the insulation panel 12 at positions such that the work coil structures may extend through the insulation panel and be directly mounted upon the transformer secondary terminals. This arrangement makes it possible for the low voltage heavy currents in the high frequency work circuits to follow a short direct path free of losses to substantially the maximum possible degree. Since for convenient use, the two work coils must be mounted at opposite end portions of the work table and thus be separated to a substantial extent with consequent separation of the transformers, the switch 24 may be conveniently mounted in the space between the transformers at the rear of the panel. With the switch in this position, the electrical connections to the two transformer primaries may be made relatively short and of the same length, so that the natural frequency of the tank circuit will not be altered on throwing either primary into the circuit. The switch 24 may be mounted on a somewhat elevated insulation platform or box structure 55 so that its terminals may be connected as directly as possible to the transformer primary terminals. The coils of insulation pipe 34, 35 may be conveniently housed beneath or within the box or platform structure 55.

The blades at the two sides of the switch 24 as best shown in Fig. 3, should be arranged at such an angle that in throwing the switch, the connections to one of the transformer secondaries will be maintained until after the other secondary is connected in circuit. This will insure against an open circuit condition at any time in the tank circuit of the power oscillator. This is important since if the power supply should happen to be turned on to the oscillator when the tank circuit is open, dangerous potentials may be established therein sufficient to cause arcing and destruction of the apparatus. Ordinarily, the power supply to the generator cabinet will be shut off by the stop switch whenever the switch 24 is thrown. However, if the generator should accidentally be operating when the switch 24 is thrown, then the two transformer primaries will be connected in parallel in the same tank circuit. If this results in overloading the equipment, the power supply circuit breaker will open and no damage will be done to the equipment, particularly since both transformer primary circuits are being constantly water-cooled.

In Fig. 10 an alternative arrangement of the water-cooling circuit for the transformer primaries is shown. In this case the water inlet is through a metal pipe 60 acting also electrically as a part of the tank circuit. This pipe is joined electrically at 61 to a pipe 62 hereinafter referred to. The pipe 60 is extended on as a fluid conductor and electrical connection through primary 22, thence through a pipe 63 running to one side of the switch 24, then through a pipe 63', through an insulation conduit 64. Fluid from the conduit 64 is conducted through contact 32 of the switch, thence through pipe 65 and through primary 23. From primary 23 the electrical and fluid connection extends through pipe 62 to the electrical connection 61, the pipe 62 extending on to an insulation conduit 66. From conduit 66 the fluid is conducted through the center contact of the switch and thence through a metal pipe 67 running back to the generator cabinet and point of discharge for the water.

The connections of Fig. 10 thus provide an arrangement in which the stream of cooling water is constantly conducted through both transformer primaries in series and through the electrical connections therefor, while at the same time provision is made for switching either primary into circuit to the exclusion of the other. This series connection of the water conduits is desirable in cases such as where the load and the consequent heating is greater for one transformer than for the other. That is, the cold water then may be passed first through the primary which is subject to the greatest load.

Reference to Figs. 4 and 5 will show further details of construction of the work coil 14 and the manner in which same may be supported directly from the transformer secondary terminals as at 42 and so as to extend through the insulation panel 12 outwardly in a position above the table 11. The outer end of the construction may be carried by a supporting post as at 70. Suitable jig or fixture means may be provided as at 71 for supporting the objects 15 which are being heated within the apertures 38 of the work coil.

Further details of the construction of the particular form of work coil 16 will be apparent from Figs. 6 and 7. This may comprise a pair of lugs as at 72 adapted to be supported directly from the transformer secondary terminals. A heavy bar or strip of metal 73 has one end formed integral with or welded to one of the lugs 72, this bar 73 then extending outwardly over the work bench and then extending along in a series of semi-circular portions as at 74 and a return series of such semi-circular portions as at 75, thus providing circular apertures as at 76 for receiving the objects to be heated. As is apparent in Fig. 6, the portions of the bar 73 on opposite sides of each aperture may be separated by narrow spaces as at 77 and the portion of the bar 78 which returns to the other lug 72 may be similarly separated by a narrow space 79 from contact with the outgoing portion of the bar. As is apparent in Fig. 6, the bar 73 may be extended outwardly in both directions from its supporting portions to provide for example, a total of eight or more of the apertures. In order that the heating within the end apertures will be substantially the same as within other apertures, a sawcut or narrow space as at 79' should be provided. As in the case of the work coil 14, the coil 16 and its supporting arms are embraced by a metal cooling fluid conduit as at 80, portions of which are soldered or brazed along opposite sides of each of the apertures 76. If desired, the outer end portions of the work coil 16 may be supported in the manner shown in Fig. 7 and also Figs. 1 and 2. That is, supporting brackets as at 82 may be mounted upon the insulation panel and adapted to carry movable bolts as at 83, the lower ends of the bolts being soldered or brazed as at 84 to the ends of the work coil structure.

While the invention has been described in detail with respect to certain preferred examples, it will be understood by those skilled in the art after understanding the invention that various changes and modifications may be made without departing from the spirit and scope of the invention, and it is intended therefore in the appended claims to cover all such changes and modifications.

What is claimed as new and desired to be secured by Letters Patent is:

1. In induction heating apparatus adapted to be operated with current from a high frequency power oscillator, the combination of two tank circuit output transformer primary coils for respectively alternately energizing two work circuits, electrical connections and switch means for alternatively connecting said coils to form a part of a tank circuit of the oscillator, said connections and coils including cooling water conduits of metal for carrying a cooling stream along one of the electrical connections common to the two coils, thence dividing to provide parallel streams respectively through the two coils and their respective individual electrical connections, and insulation conduits for bringing the parallel streams thereafter together to flow along a return electrical connection common to the two coils, said insulation conduits serving to simultaneously conduct said parallel streams respectively across said switch means, whereby the cooling streams are maintained through both coils and connections therefor regardless of the opening of the circuit by the switch means to either coil, said insulation conduits being of sufficient length whereby no material amount of the operating current is conducted through the water in either, when the accompanying switch means is open.

2. Induction heating apparatus adapted to be supplied with power from a high frequency generator, comprising two coils, electrical connections and double throw switch means for alternatively connecting said coils to the generator, said connections and coils including cooling fluid metal conduits for carrying a cooling fluid stream extending along one of the electrical connections from the generator, thence dividing to provide parallel streams respectively through the two coils and their respective electrical connections, the parallel streams being thereafter brought together to flow along the other of the electrical connections from the generator, insulation conduits being provided for simultaneously conducting said parallel streams respectively across the two sides of said double switch means, whereby cooling streams are maintained through both coils regardless of the throwing of said switch.

3. In induction heating apparatus adapted to be operated with current from a high frequency power oscillator, the combination of two tank circuit output transformer primary coils for respectively alternately energizing two work circuits, electrical connections and switch means for alternatively connecting said coils to form a part of a tank circuit of the oscillator, said connections, coils and switch means being constructed and arranged to provide a tank circuit of substantially the same frequency through either coil, said connections and coils also including cooling fluid metal conduits for carrying a cooling stream along one of the electrical connections common to the two coils, thence dividing to provide parallel streams respectively through the two coils and their respective individual electrical connections, and insulation conduits for bringing the parallel streams thereafter together, to flow into a return electrical connection common to the two coils, said insulation conduits serving to simultaneously conduct said parallel streams respectively across said switch means, whereby the cooling streams are maintained through both coils and connections therefor regardless of the opening of the circuit by the switch means to either coil.

4. In induction heating apparatus adapted to be operated with current from a high frequency power oscillator, the combination of two tank circuit output transformer primary coils, electrical connections and switch means for alternatively connecting said coils to complete a tank circuit of the oscillator, said connections and coils all including communicating cooling fluid conduits of metal, and insulation conduits communicating therewith and for bridging said switch means, to maintain cooling streams through both coils regardless of the opening of the circuit by the switch means to either coil.

5. In induction heating apparatus adapted to be operated with current from a high frequency high voltage power oscillator, the combination of two tank circuit output transformer primary coils, electrical connections and double throw switch means for alternatively connecting said coils to complete a tank circuit of the oscillator, said switch means being so constructed and arranged that upon throwing the switch, the circuit of one coil is maintained until after the circuit of the other coil is established, said connections and coils all including communicating cooling fluid conduits of metal, and insulation conduits communicating therewith and for bridging said switch means, to maintain cooilng streams through both coils regardless of the opening of the circuit by the switch means to either coil.

6. In induction heating apparatus adapted to be operated with current from a high frequency power oscillator, an insulation panel, a pair of induction heating work coils mounted in spaced positions at the face of said panel, a pair of high frequency step-down transformers mounted adjacent the rear surface of said panel in positions adjacent said work coils respectively and with their secondaries respectively directly connected to said work coils, a double throw switch mounted between said transformers, electrical connections for the primaries of said transformers and said switch for alternatively connecting upon operation of said switch, said primaries to complete through either, a tank circuit of the oscillator, and conduit means for maintaining streams of cooling fluid through said primaries and connections independently of the operation of said switch, said conduit means beirg constructed and arranged to conduct streams flowing in each primary as parallel branches of a single supply of fluid entering and leaving the apparatus through electrical connections common to the two primaries.

7. In induction heating apparatus adapted to be operated with current from a high frequency power oscillator, the combination of two tank cir-

cuit output transformer primary coils, electrical connections and double throw switch means for alternatively connecting said coils to complete a tank circuit of the oscillator, said connections and coils all including communicating cooling fluid conduits of metal, and insulation conduits communicating therewith and for bridging said switch means, to maintain cooling streams through both coils regardless of the opening of the circuit by the switch means to either coil, said conduits being constructed and arranged to provide a fluid path along one of the connections from the oscillator thence through one of said coils to one of of the two alternative poles of said double throw switch means, thence through one of said insulating conduits to the other alternative pole of said switch means, thence through the other of said coils and through another of said insulating conduits to the center pole of said switch means, and thence along the return connection to the oscillator.

8. In induction heating apparatus adapted to be operated with current from a high frequency power oscillator, the combination of two tank circuit output transformer primary coils, electrical connections and switch means for alternatively connecting said coils to complete a tank circuit of the oscillator, said connections and coils all including communicating cooling fluid conduits of metal, and insulation conduits communicating therewith and for bridging said switch means, to maintain cooling streams through both coils regardless of the opening of the circuit by the switch means to either coil, said conduits being constructed and arranged to maintain a series fluid path through said two coils while either coil is alternatively electrically connected in the tank circuit.

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