June 23, 1942. A. VANG 2,287,542

ELECTRIC INDUCTION HEATING

Filed Nov. 8, 1940

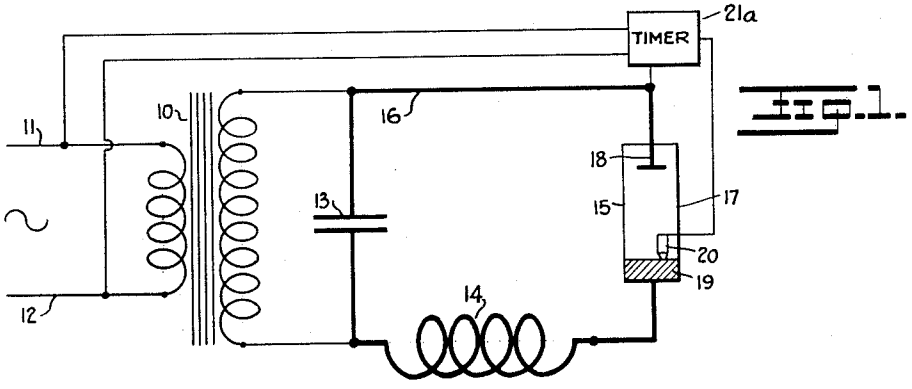


Fig. 1.

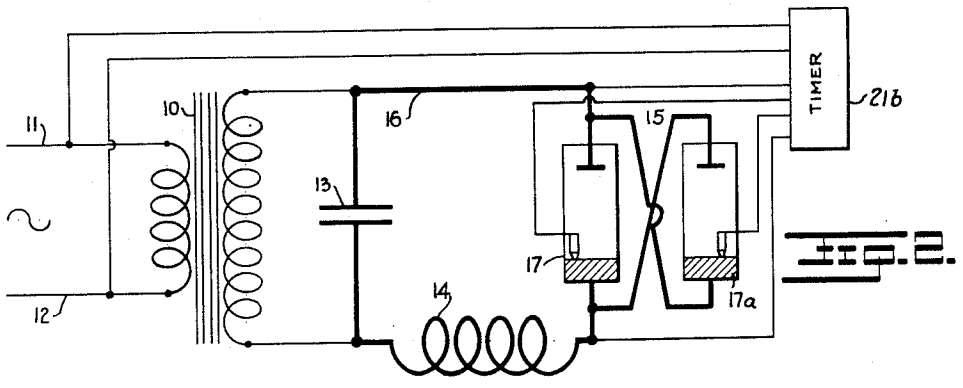


Fig. 2.

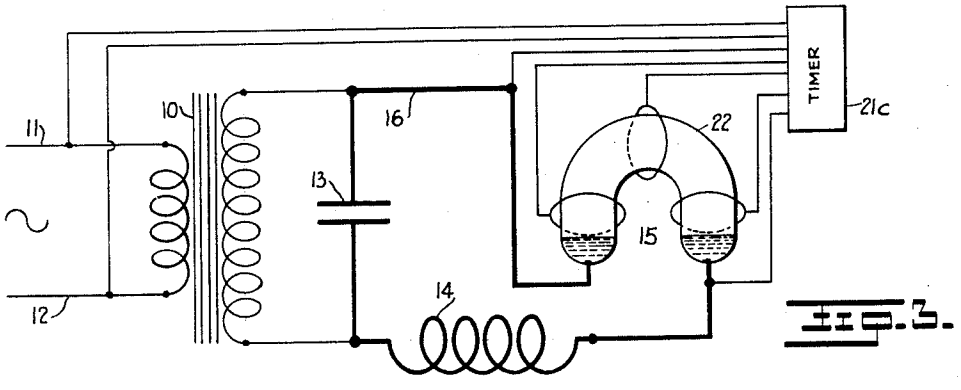


Fig. 3.

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ELECTRIC INDUCTION HEATING

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Application November 8, 1940, Serial No. 364,770

4 Claims. (Cl. 250—36)

This invention relates to electric induction heating, and more particularly to apparatus for translating power from commercial supply lines to high frequency application circuits for absorption in work as heat.

One object of my invention is to provide a power translating circuit which will convert power at commercial frequency to power at high frequency with a minimum of loss in the conversion.

Another object of my invention is to make a simple apparatus of relatively compact dimensions for providing a relatively great amount of high frequency electric power.

An ancillary object of my invention is to provide a low cost source of high frequency electric power.

Another object of my invention is to provide a dependable source of high frequency power which shall be under accurate and flexible control.

A further object of my invention is to provide an apparatus for translating power which will have a minimum rate of deterioration relative to the amount of power translated.

A still further object of my invention is to extend the useful range for employment of induction heating by providing a method for translating power to high frequency, of which practical embodiments can be made economically in a wide range of sizes.

Another object of my invention is to provide a source of high frequency power which will require a minimum of skill to operate.

Other objects and advantages of the invention will become apparent as the specification proceeds.

In the drawing in which similar numerals indicate corresponding parts:

Figure 1 is a wiring diagram of an embodiment of my invention for converting one half of the supply cycle.

Figure 2 is a wiring diagram of an embodiment of my invention for converting both halves of the supply cycle.

Figure 3 is a wiring diagram of an embodiment of my invention employing the discharge tube described in my copending application, Ser. No. 364,701, filed Nov. 7, 1940, for Discharge tubes.

Referring to the drawing, and more particularly to Figure 1, the numeral 10 indicates a transformer for raising the alternating potential of the supply lines 11 and 12 to a predetermined voltage, for charging the condenser 13 with an increment of power, which will be discharged in the form of resilient oscillations at high frequency through the inductance 14 by closing the high frequency switching means 15. The discharge is permitted to reverse itself immediately so that energy which remains in the high frequency circuit after the first passage therethrough, in the form of an opposite charge of the condenser, is permitted to re-circulate, or pass through the switching means in either direction until it is entirely dissipated. This is termed discharge by resilient oscillation, distinguishing the present invention from inverter circuits which terminate the discharge after a single passage. Thus my switching device permits a greater part of the energy to be absorbed in the work than is the case where the switching means operates in a uni-directional manner, either always in the same direction, or serially in different directions. High frequency power may be taken from the high frequency circuit 16 in any conventional manner, as, for example, by inserting metallic objects to be heated into the oscillating field of the coiled inductance 14, or by coupling a secondary high frequency circuit (not shown) with the circuit 16 in any conventional manner.

After the energy of the discharge has been dissipated from the circuit 16, the condenser will charge again, and discharge as before, transferring another increment of energy to the high frequency load. The output wave form is thus similar to that of oscillators for damped wave wireless telegraphy.

The operation of the switching means 15, however, distinguishes the present invention from the circuits used in damped wave wireless telegraphy, in that a controlled ionic discharge through a low pressure gas replaces the conventional spark gap; but it is the spark gap which has limited the use of the damped wave oscillator for induction heating, because the gap has a relatively high resistance, causing a loss of nearly half of the power of the high frequency circuit in the gap itself, which in turn creates a very high local temperature, resulting in a gradual disintegration of the gap. Both of these factors reach seriously detrimental proportions in induction heating, where the amount of power involved is often relatively great.

In the present invention, the power loss is reduced virtually to an insignificance by the use of a switching means employing gas under low pressure as a conducting medium. The gas (preferably mercury vapor) has a relatively high resistance when not ionized, but a relatively very low resistance when ionized, which properties are

consequent upon the reduction of pressure, as is well known in the art.

Thus, the low resistance of the switching means **15** during the conducting period greatly reduces the amount of heat generated within the means, having the simultaneous effects of increasing efficiency and increasing carrying capacity, while reducing deterioration.

A further distinction between my invention and damped wave wireless oscillators lies in the provision of control means, by which ionization may be started at will, independently of the potential across the switching tube. This permits the same apparatus to be used over a very wide power range, wherein the power made available to the high frequency circuit may be varied either by controlling the switching voltage at which discharge will be initiated, thus controlling the size of the condenser energy increment, or by timing the discharge to take place at a given stage of the supply cycle, thus controlling the amount of power taken from the transformer.

Switching means for the circuit, according to my invention, may have a variety of embodiments. One embodiment which has worked well in practice, although it is not ideally suited to this use, is the conventional ignition-controlled cold-cathode mercury vapor rectifier tube, which does not behave as a rectifier in my circuit, because it has a de-ionization time which is longer than one half cycle of the high frequency discharge, causing the tube to "flash back" or continue conducting in either direction until the condenser energy is nearly or entirely dissipated. The tube is illustrated in Figure 1, where **17** is the envelope, **18** the anode, **19** the mercury cathode, and **20** the igniter electrode. The use of this conventional rectifier tube to conduct current in both directions is new in my invention, and constitutes a great improvement in the art. It is wearing, however, upon the particular tube described, and hence a different embodiment can be used to greater advantage, as will be described presently.

To initiate ionization at the proper time, a timer **21***a* is employed to synchronize the initiation of ionization with one half cycle of the supply potential, connections as shown, or of the condenser potential, connections not shown. The timer circuits will necessarily vary with the application, and need not be shown in detail, as they are known, or can readily be devised by anyone skilled in the art.

The low voltage line **11**, **12**, and the transformer **10** can be replaced by a high voltage line, provided suitable impedance is included to protect the line. Also, in the same manner, the low voltage line could be used directly, but then the apparatus would lose efficiency, as the increment of energy absorbed by the condenser would be smaller relative to the ability of the line to deliver power. Hence, it is in general preferable to use a relatively high voltage to avoid excessive cost for condensers.

Figure 2 shows how both halves of the supply cycle can be drawn upon by a circuit otherwise identical with that of Figure 1. To accomplish this, another rectifier tube **17***a* of the same type has been connected in opposed parallel relation to the first. The only other changes necessary are to add to the timer connections **21***b* to accommodate the new tube, and to take customary precautions for the passage of a heavier current through the remainder of the circuit.

As mentioned before, I use the "rectifier" tubes for conducting current in both directions, but with regard to the initiation of ionization they still behave as rectifiers. Thus the circuit shown in Figure 1 operates only on that half of the cycle which causes the mercury electrode **19** to be initially negative, and hence while the circuit is potentially capable of operating on either half of the cycle, actually it only starts on one half.

The circuit shown in Figure 2 provides a symmetrical arrangement, so that whichever side of the switching means is initially negative, one tube will be capable of immediate ionization. Hence the circuit starts on both halves of the cycle, only one tube starting each time, and that tube carrying the discharge in both directions, because it has not had time to de-ionize before the high frequency has reversed itself.

An alternative arrangement is to employ a fast-acting timer circuit which will excite or add to the excitement of the gas in each tube whenever the mercury pool thereof becomes or is about to become negative, thus the high frequency discharge will pass back and forth through the tubes alternately, each tube conducting at least the greater part of the current always in the same direction. This arrangement will prolong the life of the conventional type of rectifier tube, as it will minimize the harmful effect of the "flash back".

It will, of course, be necessary to superimpose a low-frequency timer upon the fast acting timer to render the latter inoperative during the charging period.

In order to obtain still better performance from my invention, I can replace the two rectifier tubes shown in Figure 2 with one of the discharge tubes described in my copending application, Serial No. 364,701, filed November 7, 1940, of which this application is a continuation-in-part, and as shown in Figure 3. Here the timer **21***c* may also include a connection for the grid, to assist in de-ionization, as described in said application. The symmetry of my discharge tube adapts it to operation in the present circuit on both halves of the supply cycle, and the absence of solid electrodes permits a much heavier current to be carried, along with a longer tube life.

It is obvious that changes may be made in the form, construction and arrangement of the several parts, as shown, within the scope of the appended claims, without departing from the spirit of the invention, and I do not, therefore, wish to limit myself to the exact construction and arrangement shown and described herein.

Having thus described my invention, what I claim as new, and desire to secure by Letters Patent of the United States, is:

1. A device for translating electric power, comprising a source of alternating current, a condenser connected across said source, a tube having two liquid electrodes, means for starting an ionized discharge in said tube, and an inductor, said inductor and said tube being connected in series across said condenser, said inductor and said condenser being tuned to a frequency sufficiently high so that said tube conducts at least one discharge in both directions during the de-ionization time of said tube.

2. A device for translating electric power comprising a capacitor, means for charging said capacitor from a source of alternating current, a discharge tube having two liquid electrodes, means for starting an ionized discharge in said tube, and an inductor connected in series with said tube and said capacitor, the de-ionization

time of said tube being longer than one-half cycle of the resonant frequency of the series circuit while said tube is ionized, whereby the tube is adapted to continue conducting alternately in each direction until the energy of the charge of said capacitor is substantially dissipated as output energy.

3. A device for translating alternating electric power from low to high frequency, comprising a capacitor, means for charging said capacitor with power of said low frequency, an inductor, a bi-directional mercury vapor discharge tube having two separated mercury electrodes, a discharge-starting electrode adjacent to each of said mercury electrodes, and a timing device connected to said starting electrodes for starting a discharge in said tube, said mercury electrodes, capacitor and inductor being connected in series to form a series circuit whose natural resonant period is not more than twice the de-ionization time of said tube.

4. A device for translating alternating electric power from low to high frequency, comprising a capacitor, means for charging said capacitor with power of said low frequency, an inductor, a bi-directional mercury vapor discharge tube having two separated mercury electrodes, a discharge-starting electrode adjacent to each of said mercury electrodes for starting a discharge in said tube, said mercury electrodes, capacitor and inductor being connected in series to form a series circuit whose natural resonant period is not more than twice the de-ionization time of said tube.

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