July 27, 1937. J. SLEPIAN 2,088,490

POWER TRANSLATING DEVICE

Original Filed Dec. 13, 1923 2 Sheets-Sheet 1

Fig. 1.

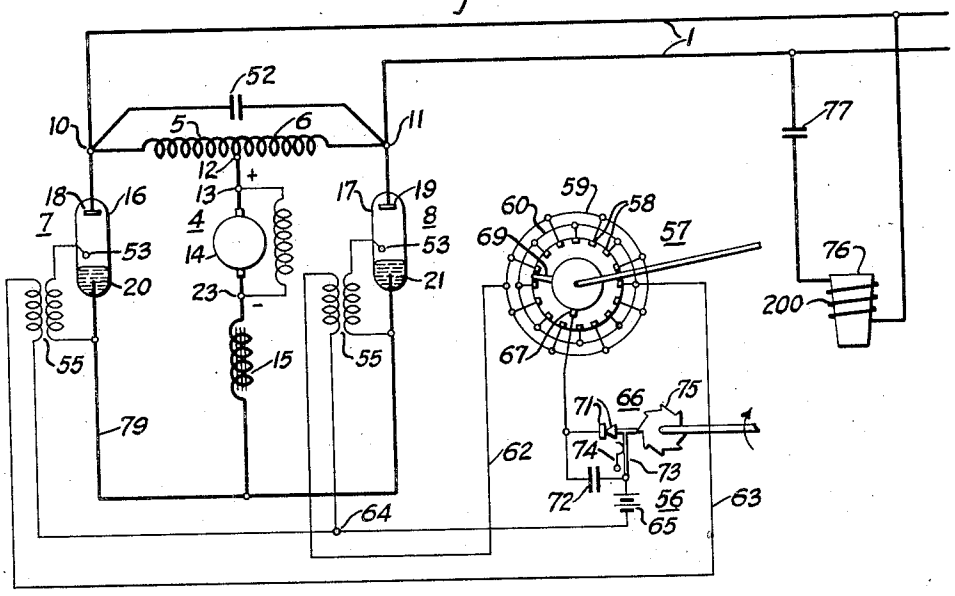
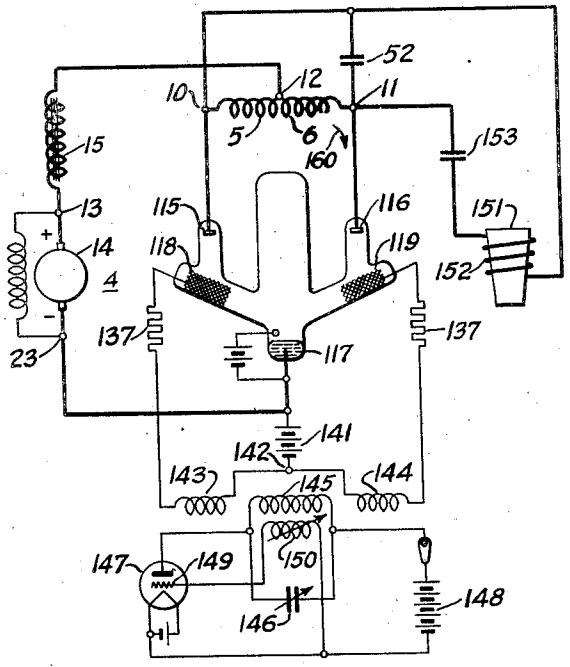


Fig. 2.



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Fig. 3.

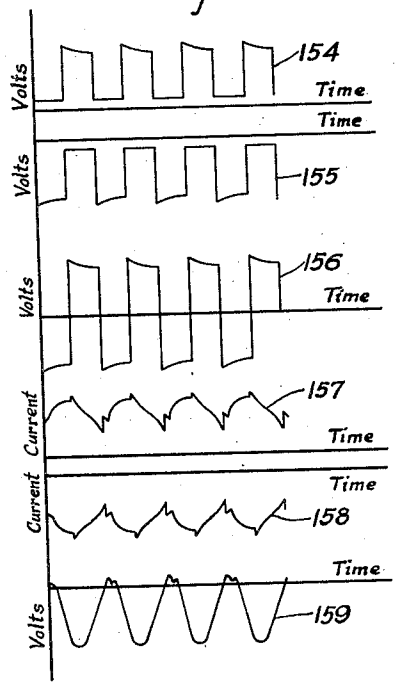
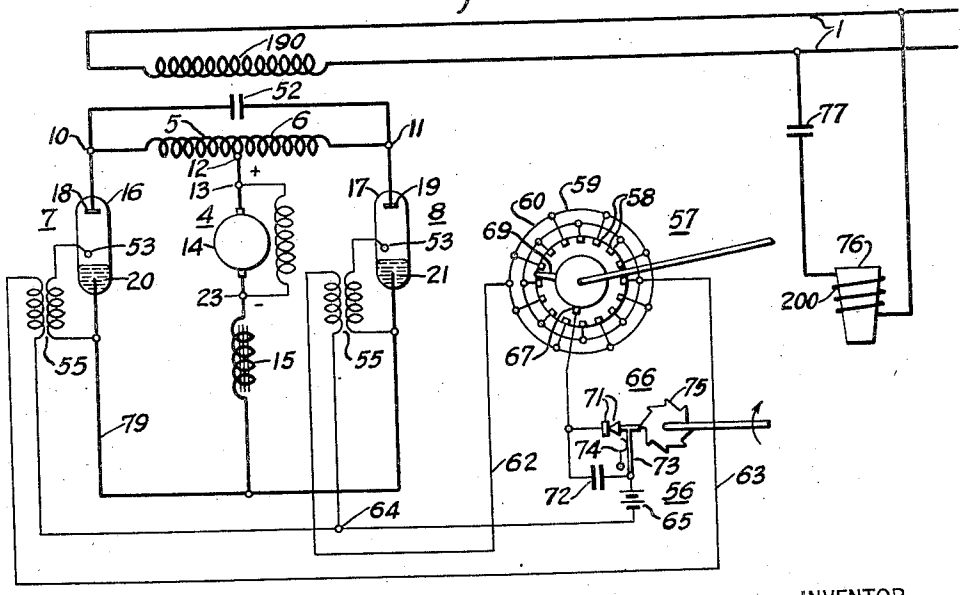


Fig. 4.



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Patented July 27, 1937 2,088,490

UNITED STATES PATENT OFFICE

2,088,490

POWER TRANSLATING DEVICE

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Original application December 13, 1923, Serial No. 680,396. Divided and this application December 14, 1934, Serial No. 757,463

15 Claims. (Cl. 219—47)

My invention relates to electric translating apparatus and it has particular relation to translating apparatus of the type utilized in inductive heating systems.

The present application is a division of my copending application, Serial No. 680,396, filed December 13, 1923.

It is an object of my invention to provide inductive heating apparatus, the energy for which shall be supplied from a direct current power source.

Another object of my invention is to provide inductive heating apparatus, of the type wherein alternating current of a frequency within the intermediate range is supplied to the heating coil, that shall be capable of excitation from a low frequency power source or from a direct current power source.

More specifically stated, it is an object of my invention to provide inductive heating apparatus devoid of mechanical converters wherein the inductive heating coil is supplied with current of intermediate frequency while the power supply is either direct current or of low frequency.

According to my invention I provide inductive heating apparatus in which the direct current or the current of low frequency is converted into alternating current of the proper frequency by the operation of a plurality of mercury arc discharge devices, the excitation of which is controlled by grids or starting electrodes.

With the foregoing and other objects in view, my invention consists in the arrangements, circuits, and methods of operation described and claimed hereinafter and illustrated in the accompanying drawings, wherein,

Figure 1 is a diagrammatic view showing an embodiment of my invention.

Fig. 2 is a diagrammatic view showing a modification of my invention.

Fig. 3 is a diagrammatic view showing curves illustrating the operation of the system shown in Fig. 2; and,

Fig. 4 is a diagrammatic view showing a modification of Fig. 1.

In the apparatus shown in Fig. 1, alternating current is supplied to an inductive heater 76 in the load circuit 1 from a direct current source 4, comprising a shunt excited direct current generator 14, through transformer windings 5 and 6 and mercury arc discharge devices or rectifiers 7 and 8. The transformer windings 5 and 6 are provided with end terminals 10 and 11, respectively, and a common neutral terminal 12. The end terminal 11 is connected to the heating coil 200 of the inductive heater 76 through a capacitor 77, the other end terminal 10 being connected to the remaining terminal of the heating coil. The intermediate terminal 12 is connected to the positive terminal 13 of the direct current source.

A stabilizing inductance 15 may be connected in series with the direct current source 4 to maintain approximately constant current flow from the generator independently of the changes in the circuit relations of the translating apparatus. The stabilizing inductor is connected, in the preferred practice of my invention, between the negative terminal 23 and the common junction point of the cathodes 20 and 21 of the discharge devices 7 and 8. A commutating capacitor 52 is connected between the terminals 10 and 11 of the auto-transformer 5—6.

The mercury arc rectifiers 7 and 8 comprise evacuated envelopes 16 and 17, respectively, having anodes 18 and 19, respectively, and mercury cathodes 20 and 21, respectively. The anodes 18 and 19 are connected to the terminals 10 and 11, respectively, of the transformer windings 5 and 6. Each rectifier 7 and 8 is provided with a starting electrode 53 which is actuated by means of an ignition transformer 55 having a secondary winding connected between the ignition electrode 53 and the mercury cathode of the rectifier and having a primary winding which is connected to a source 56 of pulsating direct current through a distributor 57.

The distributor 57 comprises a plurality of annularly disposed contact members 58 which are alternately connected to two bus conductors 59 and 60, respectively. The latter are connected by means of conductors 62 and 63 to proper terminals of the primary windings of the ignition transformers, the other terminals of the ignition transformers being connected to a common conductor 64 leading to one terminal of a battery 65 constituting the source of supply of the pulsating direct current. The other terminal of the battery 65 is connected, through an interrupter 66 by a brush 67, to a distributor arm 69 which is rotated by a motor not shown in the drawings. The distributor arm 69 alternately makes contact with the several contact members 58 leading to the respective ignition transformers 55 and alternately starts the mercury arc rectifiers 7 and 8.

The interrupter 66 consists of a pair of quick-break contacts 71 shunted by condenser 72. One of the contacts 71 is mounted upon a flexible arm 73 which is biased to an open position by a spring 74. A toothed cam 75 is rotated at a high

speed and closes and releases the quick-break contacts 71 at a high rate.

The alternate closing and opening of the quick-break contacts 71 sends a pulsating direct current through the primary winding of the one or the other of the ignition transformers 55 during the short interval of the engagement of the distributor arm 69 with a contact member 58. The pulsating direct current induces a high potential in the secondary winding of the ignition transformers and impresses upon the starting electrode 53 a high unidirectional potential with respect to the mercury electrode causing a discharge therebetween. The asymmetric or unidirectional quality of the induced potential results from the quick interruption and the relatively slow establishment and building up of the current in the circuit including the interrupter 66.

In the operation of the apparatus illustrated in Fig. 1, the control of the current flow through the rectifiers is effected by the operation of the starting electrode 53. Assume that a current is flowing from the positive terminal 13 of the direct-current source and the rectifier 7 is energized. The current divides at the middle transformer-terminal 12 into two portions, one portion flowing directly through the transformer winding 5, and the other portion flowing through the transformer winding 6 and the load circuit 1 to the end terminal 10. It then flows through the rectifier 7 and the conductor 79 to the negative terminal 23 of the direct-current generator 14. The distributing arm 69 is at the same time in the position shown in the drawings. The commutating condenser 52 is charged to a potential corresponding to the direction of flow of current into the load, that is, opposite to the voltage impressed thereon by the direct-current source 14.

In the course of rotation, the distributing contact arm 69 energizes the ignition transformer of the formerly non-conducting rectifier 8, causing a discharge between the starting electrode 53 and the mercury cathode 21. The rectifier 8 thereupon becomes conducting and the current from the direct-current generator 14 is diverted thereto by the commutating action of the discharge current of the commutating condenser 52, the current through the rectifier 7 being simultaneously reduced to zero. The mercury-arc rectifier 7 thereupon becomes non-conducting and the circuit therethrough is interrupted, while the current now flows through the transformer winding in the opposite direction. This cycle repeats itself alternately in accordance with the operation of the ignition device. By regulating the speed of the distributor 57, the frequency of the generated alternating currents may be controlled.

In the modification shown in Fig. 2 the flow of current through a double wave mercury rectifier is controlled by means of grids disposed in the space current paths of the rectifier. The two anodes 115 and 116 of the rectifiers are connected to the two end terminals 10 and 11 of a transformer having two windings 5 and 6 and provided with a common middle terminal 12 leading to a positive terminal 13 of the direct current generator 14. The mercury electrode 117 of the rectifier is permanently connected to the negative terminal 23 of the direct-current generator 14.

Two grids 118 and 119 are provided in the two rectifier paths leading between the mercury cathode 117 and the two anodes 115 and 116, for so controlling the rectifying action and conductivity of the paths as to utilize the direct current flowing from the direct-current generator 14 to supply power to the inductive heating coil 152 which is connected to the two end terminals 10 and 11 in an analogous manner to the coil 200, the coil 152 being connected to the terminal 11 through a capacitor 153.

The control potential is provided for the discharge device by utilizing a master oscillator. The mercury cathode 117 is connected through a biasing battery 141 to a common terminal 142 of two secondary transformer windings 143 and 144 leading through current limiting resistors 137 to the grids 118 and 119 respectively. The secondary windings 143 and 144 of the grid control transformer cooperate with a primary transformer winding 145 which is included in an oscillating circuit with a condenser 146. A three-electrode tube 147 is connected in a circuit including a source of electromotive force, such as a battery 148, across the condenser 146. The grid 149 of the three-electrode tube 147 is connected, through a feed-back coil 150, to the filament and serves to produce sustained oscillations in the circuit including the transformer winding 145 and the condenser 146.

The system illustrated in Fig. 2 is particularly well adapted for producing high-frequency currents such as are utilized in radio applications or for certain industrial purposes such as induction furnaces. I have illustrated an induction furnace comprising a crucible 151 surrounded by an inducing coil 152 which is connected in series with a condenser 153 across the terminals 10 and 11 of the transformer windings 5 and 6.

To illustrate the operation of the system shown in Fig. 2, I have reproduced, in Fig. 3, oscillographic records obtained during the operation thereof. Curve 154 shows the voltage across the rectifier arm 115 as a function of time; curve 155 shows the voltage across the rectifier arm 116 as a function of time; curve 156 shows the voltage between the anodes 115 and 116 as a function of time; curve 157 shows the current through the transformer winding 5 and curve 158 shows the current through the transformer winding 6 as a function of time; and curve 159 shows the voltage between the grid 118 and the mercury cathode 117 as a function of time. In determining the direction of the voltage in the above diagrams, it has been assumed that the voltage in the direction of the arrow 160 from the middle terminal 12 through the anode 116, cathode 117 and anode 115 back to the neutral terminal 12 is positive. In determining the direction of flow of current it has been assumed that a current flowing in the transformer windings 5 and 6 in the direction from right to left, that is from the end terminal 11 to the end terminal 10, is positive.

As will be seen from the above-described curves, the voltage across the rectifier arms pulsates from a low value, corresponding to the voltage drop of the rectifier when the arm is conducting, to a full value corresponding to the open-circuit conditions. The current in the transformer winding 5 leading to the conducting rectifier arm increases during the period that the arm is conducting, while the current through the transformer winding 6 leading to the non-conducting arm of the rectifier decreases. The voltage which appears across the two terminals 10 and 11 of the transformer windings 5 and 6, and which is also the voltage across the two

rectifier anodes 115 and 116, corresponds to the change in flux attendant upon the increase in the current of one transformer winding and the decrease of the current in the other transformer winding, both effects adding to each other since the direction of the currents are opposite. As seen from the above diagrams the current flowing from the direct-current source is divided into two approximately equal portions pulsating around mean values. The sum of both currents is approximately constant and corresponds to the total current flowing from the direct-current source.

It may thus be seen that only approximately half of the current flowing from the direct-current generator 14 flows into the alternating-current load circuit. The energy corresponding to the other half of the direct-current flow is utilized in raising the potential across the load circuit to approximately twice the potential of the direct-current generator, by a transformer action in the windings 5 and 6. It is to this end that the windings 5 and 6 are preferably arranged in inductive relation to each other although my system would also operate with two separate transformers or coils.

The apparatus shown in Fig. 4 is similar to the apparatus shown in Fig. 1 except that a transformer with separate coils 5—6 and 190 is substituted for the auto-transformer specifically shown in the latter view.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. An electric heating system including an inductor coil, a pair of arc rectifiers inductively coupled together by said inductor coil, means for successively rendering said rectifiers alternately conducting and non-conducting, and a condenser connected between the circuits of said rectifiers for interrupting the current flowing in one rectifier substantially immediately after the other rectifier is made conductive.

2. In an electric induction furnace having an inductor coil the combination of a plurality of grid controlled arc rectifiers, a capacitor, a capacitor charging circuit including one of said rectifiers, a capacitor discharging circuit including another of said rectifiers, and an alternating current circuit including said inductor coil common to said charging and discharging circuits.

3. In an electric induction furnace provided with an inductor coil, the combination of a plurality of arc rectifiers, each provided with a grid for controlling the starting of current between its cathode and anode, a capacitor, capacitor charging and discharging circuits controlled by said rectifiers, means arranged to produce in each of said circuits a countervoltage which is dependent on the current in the other of said circuits, an alternating circuit including said inductor coil common to said charging and discharging circuits.

4. Inductive heating apparatus including the combination of a current conductive means for inducing heating currents, a plurality of electric rectifiers, a capacitor, a capacitor charging circuit including one of said rectifiers, a capacitor discharging circuit including another of said rectifiers, and an alternating current circuit including said current conducting means common to said charging and discharging circuits.

5. Inductive heating apparatus including the combination of an inductor coil for inducing heating currents, a plurality of electric rectifiers, a capacitor, a capacitor charging circuit including one of said rectifiers, a capacitor discharging circuit including another of said rectifiers, and an alternating current circuit including said inductor coil common to said charging and discharging circuits, the said inductor coil inductively coupling together said charging and discharging circuits.

6. In an induction furnace having a charge containing crucible and an inductor coil, the combination of a plurality of grid controlled arc rectifiers inductively coupled together by said coil, a capacitor, connections for connecting said capacitor with said coil to produce a substantially resonant circuit, a variable frequency source of supply for said grids, and means for varying said frequency so as to maintain said circuit substantially resonant.

7. In an induction furnace provided with an inductor coil, the combination of a plurality of arc rectifiers, each provided with a grid for controlling the starting of current between its cathode and anode, means for generating a control voltage for said grids, means for varying the frequency of said control voltage, a capacitor, capacitor charging and discharging circuits controlled by said rectifiers, means arranged to produce in each of said circuits a countervoltage which is dependent on the current in the other of said circuits, an alternating circuit including said inductor coil common to said charging and discharging circuits.

8. Apparatus for heating an element comprising an inductor coil for inducing heating currents in said element, a first discharge device for supplying current pulsations of one polarity to said inductor coil, a second discharge device for supplying current pulsations of the opposite polarity to said inductor coil and means independent of said coil for predetermining the frequency of said pulsations.

9. Apparatus for heating an element comprising an inductor coil for inducing heating currents in said element, a discharge device having a control electrode and a plurality of principal electrodes for supplying current pulsations to said inductor coil and means independent of said coil for impressing potentials between said control electrode and said principal electrodes to predetermine the frequency of said pulsations.

10. Apparatus for heating an element comprising an inductor coil for inducing heating currents in said element, a first discharge device having a control electrode and a plurality of principal electrodes for supplying current pulsations of one polarity to said inductor coil, a second discharge device having a control electrode and a plurality of principal electrodes for supplying current pulsations of the opposite polarity to said inductor coil and means independent of said coil for impressing potentials between the control electrode and the principal electrodes of each of said discharge devices to predetermine the frequency of said pulsations.

11. Apparatus for heating an element comprising an inductor coil for inducing heating currents in said element, a discharge device for supplying current pulsations to said inductor coil and means independent of said coil and including

a master oscillation generator for predetermining the frequency of said pulsations.

12. Apparatus according to claim 10 characterized by that the means for predetermining the frequency of the pulsations includes a master oscillation generator common to both said discharge devices.

13. Apparatus for heating an element comprising an inductor coil for inducing heating currents in said element, a discharge device for supplying current pulsations to said inductor coil and means independent of said coil and including a master oscillation generator of the type incorporating a high-vacuum discharge device for predetermining the frequency of said pulsations.

14. Apparatus for heating an element comprising an inductor coil for inducing heating currents in said element, a discharge device for supplying current pulsations to said inductor coil and means including a master oscillation generator for predetermining the frequency of said pulsations.

15. Apparatus for heating an element comprising an inductor coil for inducing heating currents in said element, a first discharge device having a control electrode and a plurality of principal electrodes for supplying current pulsations of one polarity to said inductor coil, a second discharge device having a control electrode and a plurality of principal electrodes for supplying current pulsations of the opposite polarity to said inductor coil and means including a master oscillation generator for impressing potentials between the control electrode and the principal electrodes of each of said discharge devices to predetermine the frequency of said pulsations.

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