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ELECTRON DISCHARGE DEVICE

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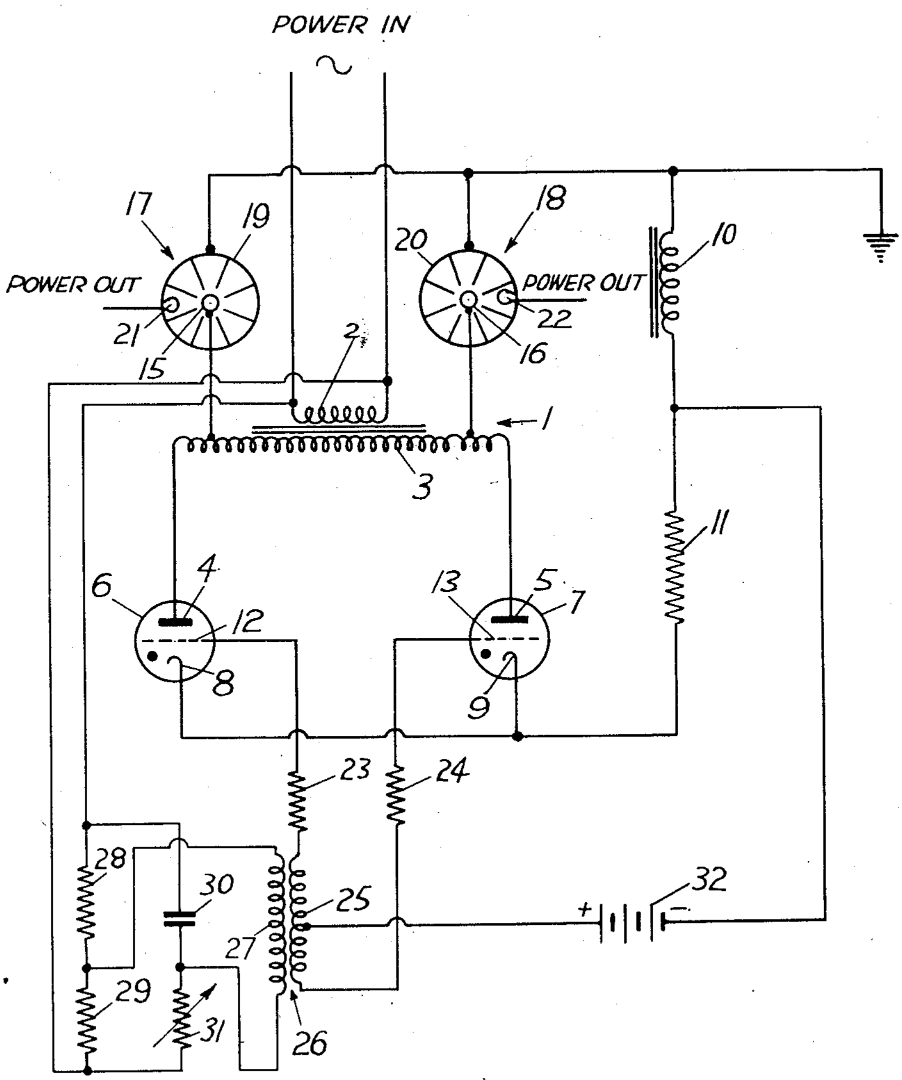

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ELECTRON DISCHARGE DEVICE

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5 Claims. (Cl. 250—27)

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This application relates to electron discharge circuits and more particularly to apparatus for energizing magnetrons from an alternating current source.

In commercial microwave devices, such as electronic cookers, it is necessary to provide a source of microwave energy which is inexpensive and reliable. This has led to the use of magnetrons energized directly from an alternating current supply through a suitable step-up transformer. This method of operation, however, has certain disadvantages, one of which is the large inverse peak voltage which is applied across the magnetron on the opposite half of the cycle from that which feeds power into the magnetron. This inverse peak voltage which will exceed the forward peak voltage across the magnetron may cause an arc discharge within the tube and thus destroy the cathode. Further, when the magnetron is exposed to radio frequency excitation, as generated by another magnetron, while thus exposed to this high inverse peak voltage, then bombardment-induced emission of the anode may result in the flow of inverse current, thus overheating the tube to destruction.

Applicant has discovered that, by connecting a pair of magnetrons from the ends of a transfromer secondary to a common terminal, for example ground, and a space discharge tube substantially in parallel with each magnetron, the inverse peak voltages across the magnetrons may be substantially eliminated. Further, by use of a pair of space discharge devices of the controllable type, for example thyratrons, the current through the magnetrons and hence the power output thereof may be controlled.

It is desirable, however, that current through a magnetron and the voltage across the magnetron remain relatively constant during the portion of the cycle, or pulse, when the magnetron is generating microwave power, since the voltage and current for optimum operation of the magnetron at a given frequency are relatively critical. Therefore, applicant has devised a circuit wherein a large choke is placed in series with the space discharge circuit of the magnetrons, the effect of said choke being to resist changes in current. The result is that the current through the conducting magnetron will remain relatively constant even though the voltage generated by the transformer has dropped considerably below the value necessary to maintain this current, the voltage necessary to maintain the magnetron current being developed by the collapsing magnetic field in the choke. This condition con-

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tinues until the transformer voltage has reversed in polarity and built up until there is a sufficient voltage across the alternate magnetron at which a control signal applied to the alternate thyratron will cause the alternate magnetron and thyratron to conduct. Thereupon the first magnetron and thyratron are extinguished, and, as the transformer voltage builds up, the voltage across the choke reverses. This results in substantially square-topped positive voltage waves being applied between the anode and cathode of the magnetron then operating.

However, during the time that current is increasing in the active magnetron, so far as the large choke will allow, the voltage across this choke is of such polarity as to be applied in an inverse sense to the inactive magnetron and in an undesirable large amount.

Applicant has discovered that by tapping the magnetrons down on the transformer from the ends thereof, the tapped portions of the winding will act as auxiliary sources of alternating current whereby the inverse peak voltages produced across the magnetrons by the choke may be neutralized by the voltages developed between the ends and the taps of the transformer, and thereby may be substantially reduced or indeed eliminated.

Thus it may be seen that applicant has produced a relatively inexpensive, reliable structure whereby microwave energy may be efficiently generated using an alternating current source of power.

The particular manner whereby these advantages may be obtained will now be described in detail, reference being had to the accompanying drawing wherein the single figure illustrates a schematic diagram of an apparatus utilizing this invention.

Referring now to the drawing, there is shown a transformer 1 having a primary winding 2 which may be connected to any desired alternating current source, such as 220 volts, 60 cycles. The secondary 3 of transformer 1 has its ends connected to plates 4 and 5 of a pair of space discharge tubes 6 and 7 which may be, for example, thyratrons. The cathodes 8 and 9 of tubes 6 and 7 are connected together and through a resistor 11 and choke 10, in series therewith, to ground.

The grids 12 and 13 are connected through grid current-limiting resistors 23 and 24 to the opposite ends of a transformer secondary winding 25 of transformer 26 which has a center tap connected through a battery 32 to the junction between resistor 11 and choke 10. The primary winding 27 of transformer 26 is connected through a phase-shifting network to the alternating current source which feeds the primary winding 2 of transformer 1. The phase-shifting network comprises a pair of resistors 28 and 29 connected in series across the alternating current source, and a condenser 30 and variable resistor 31 connected in series across the alternating source. The junctions between resistors 28 and 29 and condenser 30 and variable resistor 31 are connected to opposite ends of the transformer primary winding 27.

This network causes the voltage developed across transformer winding 27 to lag the voltage developed across transformer primary winding 2 by a predetermined amount which may be varied by varying resistor 31. This signal voltage is applied to the grids 12 and 13 to cause tubes 6 and 7 to fire alternately. By varying the amount of the phase shift, the amount of current passed by tubes 6 and 7 may be varied. The details and advantages of this particular phase-shifting grid control circuit are described in more detail in copending application Serial No. 712,-471, filed November 27, 1946, now abandoned.

In addition, the center tap of the transformer secondary winding 25 is connected through battery 32, whose voltage may be, but is not necessarily larger than the voltage drop across resistor 11, to the junction between resistor 11 and choke 10. If the battery voltage is greater than the voltage drop across resistor 11, the average potential of grids 12 and 13 will be positive with respect to cathodes 8 and 9, due to the current flow through resistor 11, by a certain average amount. This amount will vary as a function the average current flow through the tubes 6 and 7 and will increase with an increase in current. A decrease in the average positive grid potential will cause the tubes 6 and 7 to fire later during their respective conductive half cycles, resulting in a lowering of the average current. Thus it may be seen that the firing time of the thyratrons is varied in response to the average current through the thyratrons, thereby maintaining the average current substantially constant for a given setting of phase shift resistor 31.

Connected to taps on the secondary winding 3 adjacent the ends thereof are the cathodes 15 and 16 of a pair of magnetrons 17 and 18, whose anode structures 19 and 20 are connected to ground. Magnetrons 17 and 18 are of the microwave type well known in the art which will, upon the application of a suitable potential between the cathodes and anodes and in the presence of a suitable magnetic field, produce microwave energy. This energy is fed by any desired means, such as coupling loops 21 and 22 attached to the anodes 19 and 20 to the utilization circuit which may be, for example, the oven of an electronic cooker.

With a voltage applied to the primary 2, a large secondary voltage appears across the secondary 3, for example, 7½ kilovolts R. M. S. During the half cycle, wherein plate 4 of thyratron is negative and plate 5 positive, a positive control signal is applied to grid 13 of tube 7, causing tube 7 to conduct, whereby electron current flows through resistor 11, choke 10, tube 7, the secondary winding 3 and magnetron 17. On the opposite half, cycle plate 4 of tube 6 will be positive and plate 5 of tube 7 will be negative, and during this portion of the cycle a firing pulse will be fed by control circuit 14 to grid 12 of tube 6, thereby firing tube 6. Electron current will then flow from ground through resistor 11, choke 10, tube 6, transformer secondary 3 and magnetron 18 to ground. Thus it may be seen that, on alternating half cycles, the magnetrons 17 and 18 are alternately energized to produce microwave energy.

Due to the action of choke 10, whose tendency is to maintain constant current flow at all times, current will continue to flow through the conducting magnetron, for example magnetron 17, after the voltage across the secondary has dropped to zero and indeed reversed in polarity, the requisite voltage to maintain current flow through magnetron 17 being produced by the collapsing magnetic field in choke 10. When the voltage across transformer secondary 3 has reversed in polarity, a pulse applied to grid 12 of tube 6 will fire tube 6, since the voltage across tube 18, being the sum of the voltage developed by choke 10 and the major part of transformer secondary 3, is greater than the voltage developed across magnetron 17, whose voltage is the voltage developed by choke 10 minus the major part of the voltage developed by transformer secondary 3. Magnetron 18 will conduct and magnetron 17 will be extinguished, thereby extinguishing thyratron 7, since the plate 5 thereof becomes negative with respect to its cathode 9. However, when the voltage in transformer secondary 3 builds up to a point where magnetron 18 will conduct more heavily than the current passing through choke 10, the magnetic field of choke 10 is expanded, thereby producing a voltage across choke 10 in series opposition to the secondary voltage. This voltage which drives cathode 8 of tube 6 positive with respect to ground causes the end of transformer secondary 3 which is connected to the anode 4 of tube 6 to become positive with respect to ground. This positive voltage would be applied to cathode 15 of magnetron 17 as an inverse peak voltage if said cathode were connected directly to the anode 4 of tube 6. However, by tapping cathode 15 down from the end of transformer 3, a portion of the transformer secondary voltage will be subtracted from the positive voltage developed by choke 10, thereby reducing the inverse peak voltage applied to cathode 15. If the tap is moved far enough toward the center of secondary winding 3, a point will be reached where transformer secondary 3 will be at zero potential with respect to ground, and, if cathode 15 were tied to this point, no inverse peak voltage would be developed across magnetron 17. By way of example, when the voltage generated between plate 4 and cathode 15 is 1.3 kilovolts R. M. S., an inverse peak voltage of approximately 1500 volts is developed across the magnetron. If the R. M. S. voltage developed between cathode 15 and plate 4 were increased to approximately 2.5 kilovolts, substantially no inverse voltage would be developed across magnetron 17.

Thus it may be seen that applicant has provided a circuit whereby substantially constant voltage and current may be maintained through the magnetrons during their conducting periods and substantially no peak inverse voltage will be applied across said magnetrons during their periods of non-conduction.

This completes the description of the species of the invention illustrated herein. However, many modifications thereof will be apparent to persons skilled in the art without departing from the spirit and scope of this invention. For example, other discharge devices, such as rectifiers, may be used in place of thyratrons 6 and 7, and other means may be utilized to control the power output of the magnetrons, such as varying the magnetic field applied to the magnetrons to produce a substantially constant average magnetron current. Therefore, applicant does not wish to be limited to the particular details of the embodiment of the invention illustrated herein except as defined by the appended claims.

What is claimed is:

1. An electron discharge circuit comprising a pair of space discharge devices, each of said space discharge devices having at least a pair of electrodes consisting of an anode and a cathode, a first of said electrodes of one tube being connected to a similar first electrode of the other tube, a source of alternating current connected between a second electrode of one tube and a similar second electrode of the other tube, switching means for alternately connecting a second of said electrodes through an inductance to said first electrodes, and means for reducing the inverse peak voltage across said devices comprising auxiliary sources of alternating current connected between said second electrodes and said switching means.

2. An electron discharge circuit comprising a first pair of space discharge devices, each of said space discharge devices having at least a pair of electrodes, a first of said electrodes of one tube being connected to a similar first electrode of the other tube, a source of alternating current connected between a second electrode of one tube and a similar second electrode of the other tube, switching means for alternately connecting a second of said electrodes through an inductance to said first electrodes comprising a second pair of space discharge devices connected in circuit with opposite ends of said alternating current source, said inductance, and said first electrodes, and means for reducing the inverse peak voltage across said first devices produced by said inductance comprising auxiliary sources of alternating current connected between said second electrodes and said switching means.

3. An electron discharge circuit comprising a first pair of space discharge devices, each of said space discharge devices having at least a pair of electrodes consisting of an anode and a cathode, the anode of one tube being connected to the anode of the other tube, a source of alternating current connected between the cathode of one tube and the cathode of the other tube, switching means for alternately connecting said cathodes through an inductance to said anodes comprising a second pair of space discharge devices connected in circuit with opposite ends of said

alternating current source, said inductance, and said anodes, and means for reducing the inverse peak voltage across said first devices produced by said inductance comprising auxiliary sources of alternating current connected between said second electrodes and said switching means.

4. An electron discharge circuit comprising a pair of space discharge devices, each of said space discharge devices having at least a pair of electrodes consisting of an anode and a cathode, the anode of one tube being connected to the anode of the other tube, a source of alternating current connected between the cathode of one tube and the cathode of the other tube, switching means for alternately connecting said cathodes through an inductance to said anodes, said switching means comprising a pair of thyratrons connected in circuit with opposite ends of said alternating current source, said inductance, and said first electrodes, and means for reducing the inverse peak voltage across said devices produced by said inductance comprising auxiliary sources of alternating current connected between said cathodes and said switching means.

5. An electron discharge circuit comprising a pair of space discharge devices, each of said space discharge devices having at least a pair of electrodes, a first of said electrodes of one tube being connected to a similar first electrode of the other tube, a source of alternating current connected between a second electrode of one tube and a similar second electrode of the other tube, switching means for alternately connecting a second of said electrodes through an inductance to said first electrodes, said switching means comprising a pair of thyratrons connected in circuit with opposite ends of said alternating current source, said inductance, and said first electrodes, means varying the firing time of said thyratrons in response to variations of the current therethrough, and means for reducing the inverse peak voltage across said devices produced by said inductance comprising auxiliary sources of alternating current connected between said second electrodes and said switching means.

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