Dec. 6, 1932. W. K. KEARSLEY 1,890,330

APPARATUS FOR AND METHOD OF OPERATING RECTIFYING LOAD DEVICES

Filed Feb. 6, 1930

Fig. 2.

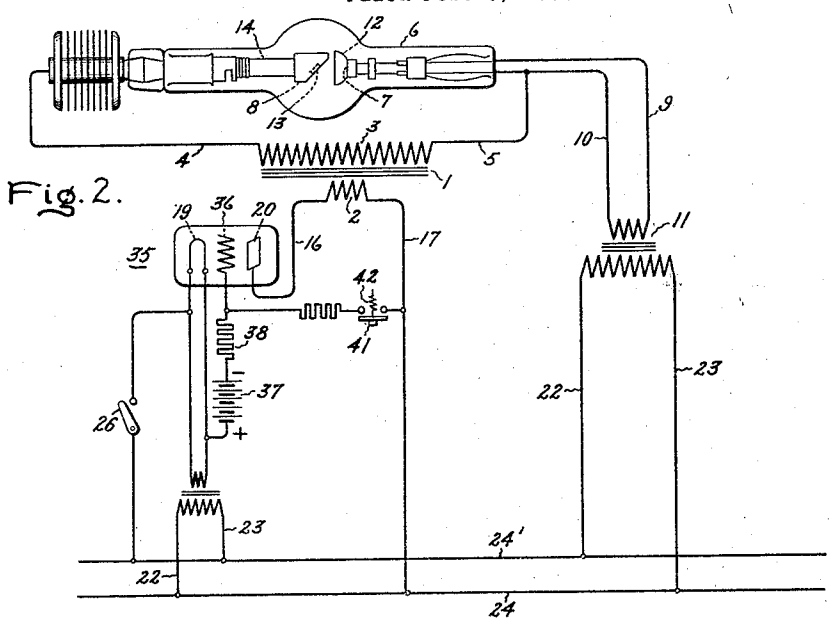


Fig. 1.

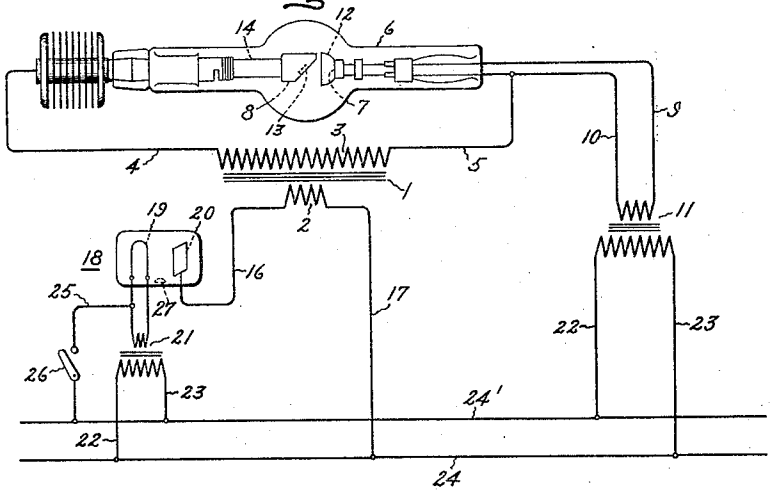
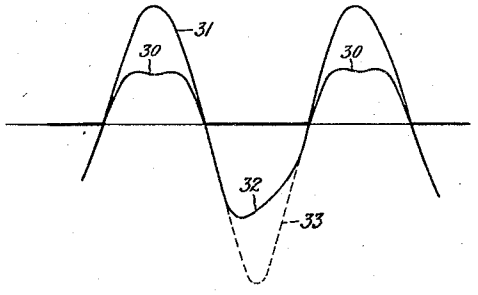


Fig. 3.



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UNITED STATES PATENT OFFICE

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APPARATUS FOR AND METHOD OF OPERATING RECTIFYING LOAD DEVICES

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The present invention relates to alternating current, apparatus containing a transformer and a load device, such as an X-ray tube, which is unilaterally conducting, or rectifying.

It is the object of my invention to provide means for so operating such a transformer and rectifying load that the high open-circuit or inverse voltage which tends to occur during the half wave intervals when the load is non-conductive to current is materially reduced.

In accordance with my invention I have provided a system wherein a unilateral load device which is operatively connected to an electromagnetic supply source, such as a transformer, is combined with means whereby the flow of magnetizing current in the primary circuit of such source is prevented during the half wave intervals when no current is flowing through the load device because of its rectifying character.

My invention will be more fully understood by reference to the accompanying specification taken in connection with the accompanying drawing in which Fig. 1 represents an X-ray system embodying my invention and containing an incandescent cathode X-ray device; Fig. 2 illustrates a modification in which the rectifying device in the primary circuit of the transformer acts also as a switch for controlling the flow of current in the system; and Fig. 3 is a graph showing the relation of current to voltage in the primary circuit of the transformer.

Referring to Fig. 1, the system described comprises a transformer having as usual a magnetic core 1, a primary circuit 2 and a secondary circuit 3. The transformer illustrated is of the step-up type, that is, has a low voltage primary and a high voltage secondary, having a greater number of turns than the primary. Connected to the secondary conductors 4, 5 is an X-ray tube 6 of the well known form known as the Coolidge tube. Briefly, such an X-ray tube comprises a highly evacuated bulb in which are sealed electrodes comprising a cathode 7 and anode 8. The cathode comprises a filament (not shown) connected by conductors 9, 10 to a source of current, whereby the filament may be heated to incandescence, as represented by the low voltage secondary of a transformer 11. The filamentary cathode is surrounded by a focusing cup 12 whereby a thermionic discharge from the filament is caused to be focused and directed upon a target of refractory metal 13 which is embedded in the anode 8. The main portion of the anode 8 and the anode stem 14 consists of a metal of high heat conductivity, such as copper, whereby the heat may be carried away to an external radiator from the target 13 during operation. An X-ray tube such as described is conductive to current only in one direction or polarity, that is, is conductive only for half waves of current of such polarity as to make the cathode negative. The construction and operation of an X-ray tube of this type is well understood by those skilled in the X-ray art.

When an alternating current is supplied by the primary conductors 16, 17 to the primary 2 of the transformer, (that is, without a rectifier) then the transformer will be excited by current flow both during the so-called useful half-wave impulses when the polarity of the current waves on the secondary circuit are such as to cause the flow of electron current through the X-ray tube, and also during the opposite half wave impulses.

During the opposite half waves when no current flows in the X-ray tube a high voltage is generated in the secondary circuit of the transformer and is impressed upon the X-ray tube through the conductors 4 and 5. The voltage during this period of no current flow is commonly called the inverse voltage. This inverse voltage is always higher than the useful voltage during the periods of current flow and the greater the current drawn by the X-ray tube the greater the difference between the useful voltage and the inverse voltage. It is undesirable that the X-ray tube should be subjected to higher voltage strains during the inverse half wave intervals than are required for the production of X-rays during the intervals of useful current flow through the X-ray tube. A high inverse voltage may cause electrical breakdown of the X-ray tube or the transformer.

In accordance with my invention a rectifier 18 is provided in the primary circuit of the transformer 1. The particular rectifier illustrated in Fig. 1 is of the thermionic type and comprises a sealed envelope containing a cathode 19, which is adapted to be maintained at incandenscence by a separate flow of current therethrough, and thus being adapted to function as a source of electrons. The anode 20 commonly consists of a plate, or mass of metal which is adapted to remain relatively cool during the operation of the rectifier, that is, below the temperature at which appreciable electron emission can occur. The envelope preferably should contain a filling of monatomic gas, such as argon or other rare gas or mercury vapor. A drop of mercury in the evacuated envelope is indicated at 27. In the case of mercury vapor the usual pressure is within the limits of about 5 to 50 microns of mercury. Higher pressures may be used in some cases. In place of the hot cathode type of rectifier illustrated in Fig. 1 other well known forms of valve devices, such as a mercury cathode arc rectifier, may be employed.

Fig. 1 shows the cathode 19 connected to the low voltage secondary of the transformer 21 whereby the cathode may be maintained at incandescence. The primaries of both the cathode heating transformers 11 and 21 are connected respectively by the conductors 22 and 23 to alternating current supply mains 24, 24′. The anode 20 of the rectifier 18 is connected to the supply conductor 16 of the transformer 1, the supply circuit for the transformer 1 being completed through the conductor 25 to the mains 24, 24′. A hand operated switch for the circuit 25 has been diagrammatically indicated at 26. By the unilateral conducting property of the rectifier 18 sufficiently high impedance is introduced into the circuit 17 during the periods of inactivity of the X-ray tube to prevent the flow of magnetizing current through the primary circuit 2 of the transformer 1 during these periods, thereby reducing the inverse voltage impressed on the X-ray tube 6.

In Fig. 3 the flow of current during alternating half wave impulses in the primary circuit 2 is represented by the current wave 30. During the flow of load current through the rectifier in the primary circuit 16, 17 of the transformer a current of opposite polarity flows in the secondary circuits 4, 5 and through the X-ray tube. The primary voltage of this useful current is represented by the curve 31; the secondary voltage is not shown. When the polarity in the primary circuit reverses, the half wave of current which would flow except for the presence of the rectifier is suppressed. Some inverse voltage is still impressed by the transformer upon the X-ray tube during this period of no current flow in the primary circuit due to the collapse of the magnetic field of the core of the transformer. However, this inverse voltage, the primary counterpart which is represented by the curve 32, is very much lower than an inverse voltage produced by a flow of magnetizing current through the primary of the transformer. The curve 33, shown in dotted lines, represents visually the high inverse voltage which would occur if the rectifier 18 were not present. It will be observed that the peak of the inverse voltage 32 is less than the peak of the useful voltage 31. If the rectifier were not present the peak of inverse voltage would be materially higher than the peak of the useful voltage 31, as indicated. For example, in the case of an X-ray outfit operating with a useful voltage of eighty-five thousand volts and a current of thirty milliamperes, such undesired inverse voltage may be seven thousand volts higher than the useful voltage, thus correspondingly endangering the X-ray tube and transformer. In a system containing a rectifier as described above about eighty milliamperes can be drawn by the X-ray tube with even less inverse voltage than when thirty milliamperes are drawn without it.

In the system illustrated in Fig. 2 the rectifier in the primary circuit 16, 17 is represented by a three element gaseous discharge device 35. In addition to an incandescent cathode 19 and an anode 20 this device also has a grid or control electrode 36. A discharge device of this character is described in an article by Dr. A. W. Hull published in the General Electric Review, vol. 32, (1929), pages 312–323 incl. and pages 390–399 incl. As described by Dr. Hull in this article, current flow through the gas-filled thermionic device is prevented when the grid electrode 36 is negatively charged with respect to the cathode. Means for producing such a negative charge is diagrammatically represented in Fig. 2 by a battery 37, the negative pole of which is connected to the control electrode 36 through a resistance 38. Assuming the hand-operated switch 26 to have been closed, when the switch 41 is closed, by the compression of the spring 42, and thereby the control electrode 36 is connected to the positive side of the circuit, current flow occurs through the rectifier 35, and the X-ray tube is energized as above described. Current flow, however, can occur only during the half wave impulses when the X-ray tube 6 is conducting load current. During the opposite half wave impulses the flow of magnetizing current through the transformer is prevented as described in accordance with Fig. 1. As soon as pressure is released from the spring operated switch 41, the control electrode becomes negative and stops the flow of current through the rectifier at the next zero point of current wave thereby deenergizing the transformer.

An X-ray outfit in which the inverse voltage rose to a permissible maximum value with an observed non-rectified primary current input, could be operated in accordance with my invention with a rectified primary current input of three times the observed value of this non-rectified primary current, without exceeding the permissible maximum inverse voltage.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An alternating current system comprising a transformer having primary and secondary circuits, a unilaterally conducting load device in a secondary circuit, and valve means in a primary circuit constructed and connected to conduct current continuously in said circuit during the half wave intervals of useful current flow in said load device and preventing flow of a magnetizing current in said primary circuit during the half wave intervals when said device is non-conductive.

2. An X-ray system comprising a transformer, a rectifying X-ray device connected to receive current from the secondary circuit of said transformer, and a rectifier in the primary circuit of said transformer connected to continuously supply current thereto during half wave intervals of load current flow in said X-ray device and being non-conductive to current flow during half wave intervals of opposite polarity when no flow of load current occurs through said X-ray device.

3. An X-ray system comprising a transformer, a thermionic X-ray tube connected in a secondary circuit of said transformer, a source of alternating current connected to supply a primary circuit of said transformer, and a gas ionization rectifier connected in said primary circuit to uninterruptedly conduct current during useful half wave intervals when said X-ray tube conducts current and to prevent current flow during the inverse intervals when said X-ray tube is non-conductive.

4. The method of reducing undesired inverse voltages in a rectifying load device connected to a transformer which consists in supplying current continuously to a primary circuit of said transformer during operative intervals of said load device and introducing sufficiently high impedance in said primary circuit during the opposite intervals of no current flow in said device to suppress the flow of current in said primary circuit.

5. An X-ray system comprising an electric transformer having a primary and a secondary circuit, an X-ray tube connected to said secondary circuit of said transformer, a thermionic rectifier connected in series with the primary circuit of said transformer to uninterruptedly transmit current during half wave intervals when said X-ray tube is operating and to prevent current flow during intervals of opposite potential when said X-ray tube is non-operative.

In witness whereof, I have hereunto set my hand this 5th day of February 1930.

WILLIAM K. KEARSLEY.