May 9, 1933. W. D. COOLIDGE 1,907,508

THERMIONIC APPARATUS

Filed Nov. 4, 1929

Fig. 1.

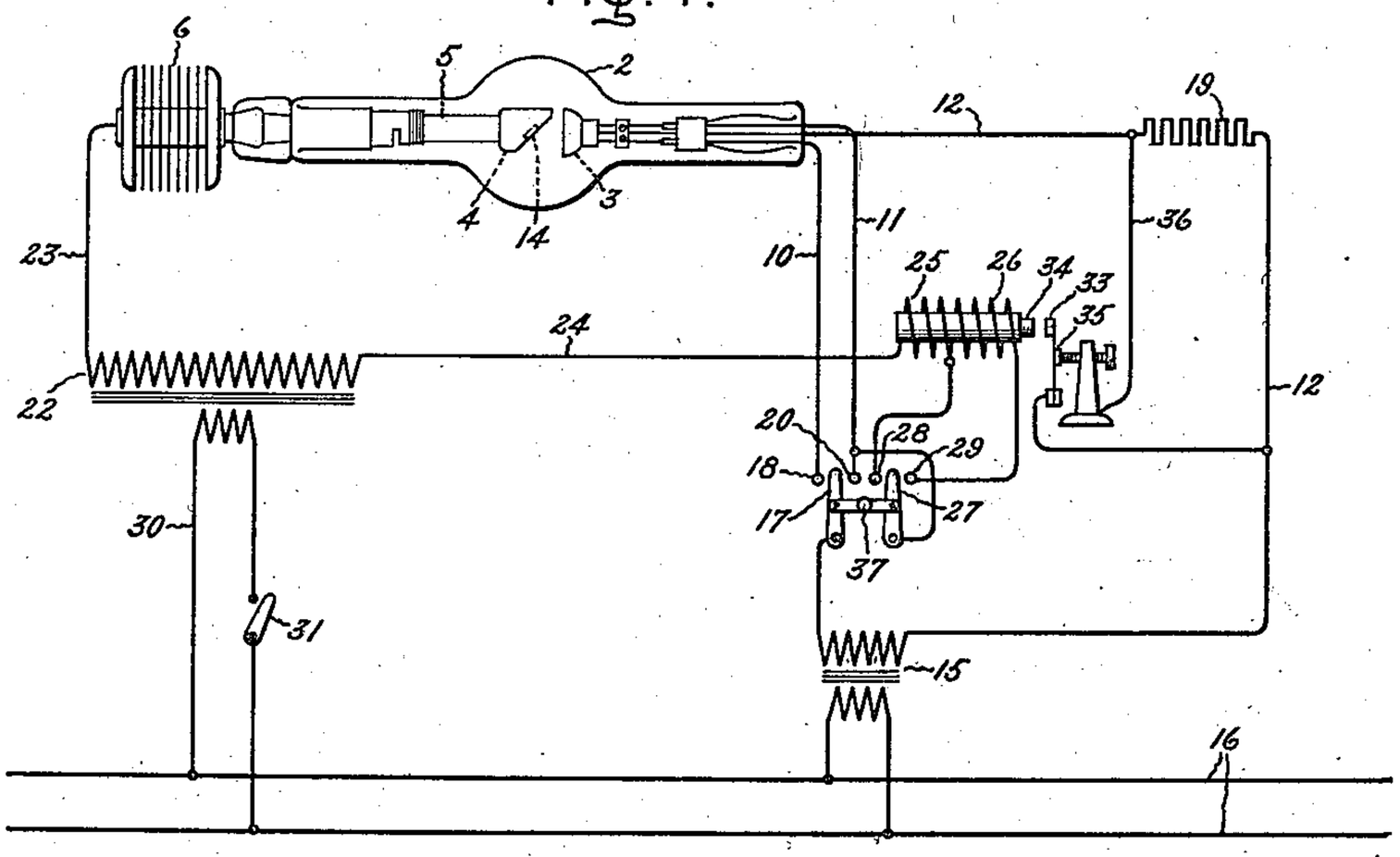


Fig. 2.

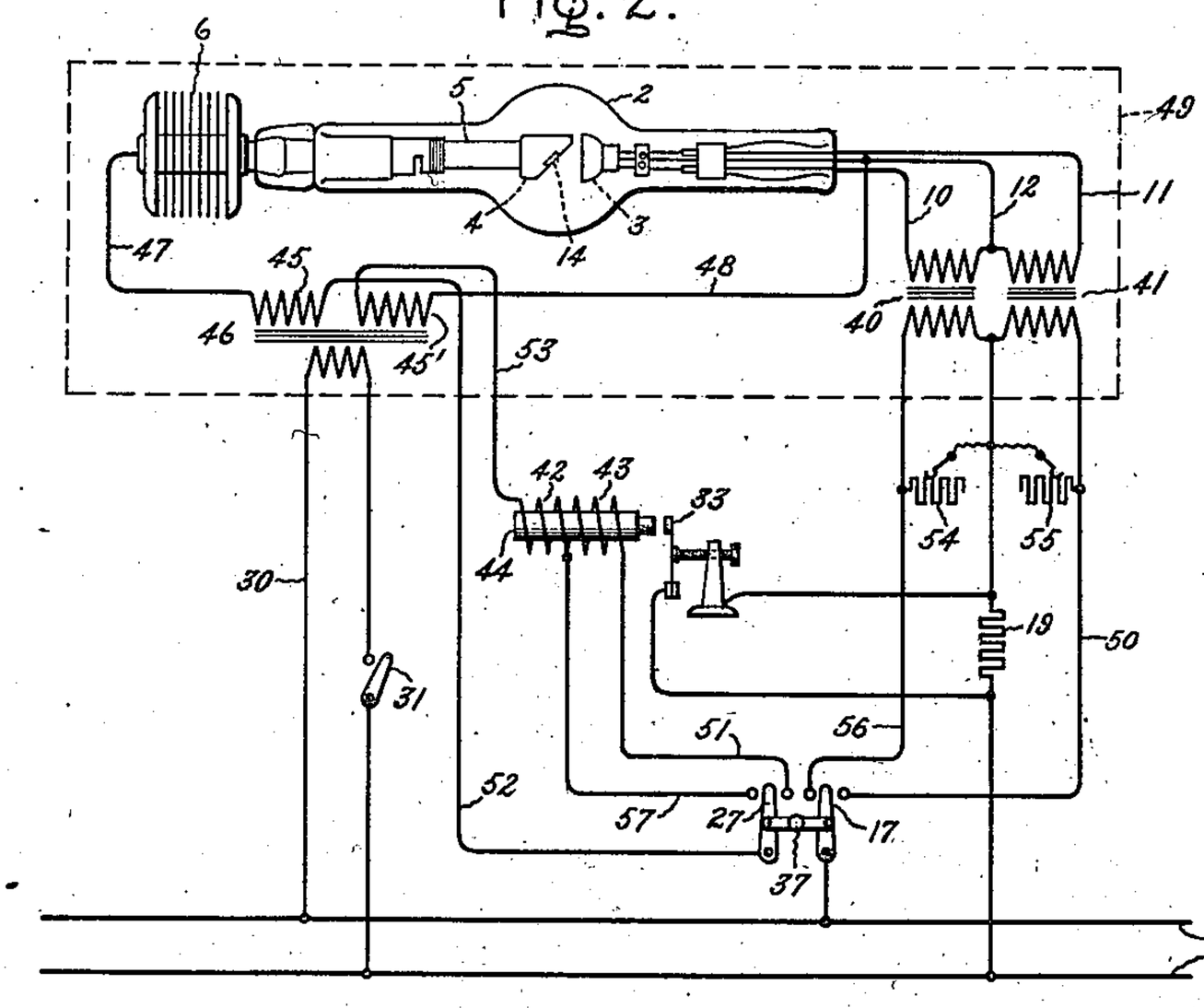
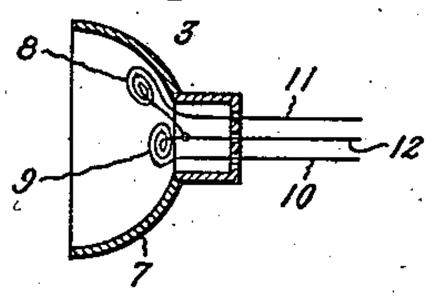


Fig. 3.



Inventor:
William D. Coolidge,
by Charles E. Mullen
His Attorney.

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UNITED STATES PATENT OFFICE

WILLIAM D. COOLIDGE, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

THERMIONIC APPARATUS

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The present invention relates to thermionic devices, such, for example, as X-ray tubes, provided with a plurality of cathodes, which are capable of being used interchangeably. In X-ray tubes to which my invention is particularly applicable, said cathodes may be caused to project a beam of cathode rays or electrons on focal spots of different area. One cathode may be caused to project a beam of electrons on a focal spot of small area permitting sharp definition in radiographs and another cathode may be caused to project a beam of electrons of greater current value on a focal spot of correspondingly larger area with some sacrifice of definition in order to avoid overheating of the target at the focal spot.

In such an arrangement serious disturbances and damage may occur by overheating the focal area of the anode should the temperature, and hence the emissivity, of the cathode be altered inadvertently during operation.

In accordance with my invention means are provided for controlling the current in the heating circuits of the respective cathode circuits of an X-ray tube, or other thermionic device, the setting of said control means being so interlocked with switching means for selectively exciting the cathodes of the discharge tube that a change from one cathode to another automatically fixes the setting of regulating means for the cathode selected for operation.

The novel features of my invention will be set forth with greater particularity in the appended claims. For a more complete understanding thereof reference may be had to the accompanying drawing taken in connection with the accompanying description.

Fig. 1 of the drawing shows somewhat diagrammatically an X-ray apparatus embodying my invention; Fig. 2 illustrates a modification adapted particularly for operation in connection with oil-immersed X-ray devices, and Fig. 3 is a detail view of a cathode structure which is employed in an X-ray tube used in my improved apparatus.

The system illustrated in Fig. 1 includes a thermionic X-ray device comprising a bulbous container 2, containing a cathode structure 3 and an anode or target 4, stem 5 of which leads to an external radiator or heat dissipator 6. The cathode structure 3, as shown in Fig. 3, comprises a cup-shaped focusing device 7 in which are provided spirally wound filaments 8 and 9. These filaments have separate supply conductors 11 and 10 respectively and a common return conductor 12. The filaments are so positioned within the focusing device 7 that when either filament is heated to an electron-emitting temperature, that electrons emitted by it, (also known as cathode rays) will be projected upon a target 14 of highly refractory metal, such for example as tungsten, which forms part of the anode 5. The electrons emitted from either of the filaments 8 or 9 are caused to impinge upon a focal spot on the target, the size of the focal spots depending upon the position of the filaments 8 and 9 within the focusing cup 7. The size and excitation of the filaments 8 and 9 are so chosen that a relatively small electron current is caused to be emitted by the filament 8 and a larger current is caused to be emitted by the filament 9, thus permitting different X-ray outputs to be obtained from the X-ray tube. The electrostatic focusing effect of the device 7 causes the cathode rays from the respective filaments to be focused on focal spots of correspondingly different areas. To secure maximum definition the focal spot should be as small as practicable without overheating the anode metal at the focal spot during a normal period of operation.

Heating current for the cathode filament is obtained from the secondary of the transformer 15, the primary of which is connected to the supply mains 16. Either one of the filaments 8 or 9 may be connected in circuit with the transformer 15 by a selector switch 17, that is, when the selector switch is moved to the left to the contact 18 so as to complete the circuit of the conductor 10, heating current will flow from the secondary of the transformer 15, through the conductor 10, through the filament 9, returning through the conductor 12,

which includes a resistance 19, to the opposite terminal of the secondary of the transformer 15. When the switch 17 is moved to the right to the contact 20, then the circuit of the cathode 8 is energized through the conductors 11 and 12, in series with the resistance 19. High potential current for generating X-rays is furnished by the secondary of the step-up transformer 22, through the conductors 23 and 24 in series with one or both of the windings 25 and 26 of a regulator, the winding 25 only being energized when the regulator circuit switch 27 makes contact with the conductor 28 and both windings being energized when the switch 27 makes contact with the conductor 29. Current for energizing the transformer 22 is drawn through the conductors 30 from the main 16, a hand-operated switch 31 being provided to open and close the circuit.

The resistance 19 is caused to be short-circuited periodically by the vibrations of a magnetic member or armature 33 which is juxtaposed to the core 34 of the windings 25 and 26. The vibrations of this armature opens and closes contacts 35 in a circuit 36 shunting the resistance 19. The relative periods of make and break of the contacts 35 determine the effect of the resistance 19 in the respective cathode circuits. A regulator of the form here shown is more fully described in U. S. Letters Patent No. 1,653,102 issued to William K. Kearsley on December 20, 1927. By means of the operation of such a regulator the electron-emissivity of the cathode and hence the space current of the X-ray tube is maintained substantially constant regardless of variations of voltage of the power supply.

The switches 17 and 27 are connected to one another by an interlock member 37 which prevents switch 17 being operated without at the same time operating the other switch 27.

It will be observed that in the described outfit when the switch blade 17 is moved to the left into contact with the conductor 10 to energize the filament 9, then at the same time the switch 27 must be moved to the left into contact with the conductor 28 thereby energizing only the winding 25 of the regulator. When the switch 17 is moved to the right in contact with the conductor 11 it energizes the cathode 8 which is intended for operation with a smaller heating current. Through the simultaneous movement of the switch 27 into contact with the conductor 29, both windings of the regulator will be energized thereby increasing the relative duration of the break periods during which the resistance 19 is included in the heating circuit of the cathode and thus decreasing the effective value of the heating current. As a consequence of the interlock of the switches 17 and 27, the setting of the X-ray tube can be shifted from one setting to another with the assurance that whenever the focus of the X-ray is changed to provide a smaller focal spot for sharper definition or for any other reason that the space current in the X-ray tube at the same time will be decreased and maintained at a lower value.

In the arrangement shown in Fig. 2 the regulator is connected in the primary circuit of transformers 40 and 41, the secondary circuits of which are respectively connected to the cathode supply conductors 10, 11 and 12. The windings 42 and 43 of the regulator 44 are connected in series with the secondary windings 45 and 45′ of the transformer 46 which supplies high potential operating current by the conductors 47 and 48 to the X-ray device. A regulable resistance 54 may be inserted in shunt with the primary winding of transformer 40 to permit of hand adjustment of the value of the heating current. A similar resistance 55 is inserted in shunt with the primary winding of the transformer 41. The arrangement shown in this figure is particularly suitable for operation with a device in which the X-ray tube as well as the high potential transformer 46 and the low potential filament transformers 40 and 41 are all contained within an enclosure or tank 49 which contains a body of oil, or other suitable insulating fluid.

When the selector switch 17 of the outfit shown in Fig. 2 is moved to the right in contact with a conductor 50 in the primary circuit of the transformer 41 the switch 27, which is interlocked with the regulator circuit switch 17 must also be moved to the right in contact with the conductor 51 thereby connecting the windings 42 and 43 into circuit with the secondary windings 45 and 45′, the circuit being completed through the conductors 52 and 53. The cathode filament 8 then is supplied with heating current. The vibrations of the armature 33 causes the resistance 19 to be inserted and withdrawn in the primary winding of the transformer 40, the relative duration of the periods of insertion and withdrawal of this resistance being so proportioned that the effective value of the heating current supplied to the filament 8 maintains this filament at the desired temperature.

When the switch 17 is moved to the left in contact with a conductor 56, the cathode heating transformer 40 is energized, thereby suppling heating current to the cathode filament 9. This movement of the switch 17, by the action of the interlock 37, simultaneously causes the switch 27 to close the circuit 57, thereby energizing only the windings 42 of the regulator. This causes the duration of the periods during which the resistance 19 is short-circuited in the primary of the transformer 40 to be longer as com-

pared with the duration of the periods during which such resistance had been included in the transformer 40, thus supplying heating current of greater effective value to the cathode filament 9. As is the case in the arrangement described above in connection with Fig. 1, the focal spot on the target on which cathode rays from cathode filament 9 are projected being larger overheating of the metal will not occur.

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

1. The combination of an X-ray tube having an anode and a plurality of cathodes arranged to deliver electron discharges upon unlike focal areas of said anode, a plurality of circuits connected to respectively energize said cathodes, a resistor common to both of said circuits, a regulator having a winding and contacts operated thereby to intermittently short circuit said resistor in response to variations of current between one of said cathodes and said anode, a source of electric energy, switching means for selectively connecting said cathode circuits to said source, and means interlocked with said switching means for changing the excitation of the winding of said regulator to maintain the excitation of said cathodes at different current values.

2. The combination of an electrical discharge device having charge-receiving means and a plurality of cathodes arranged in said device to deliver electron discharges upon unlike focal areas of said means, means for controlling the electron emissivities of said cathodes, separate circuit connections arranged to energize either of said cathodes, and means for simultaneously changing the setting of said control means by a selection of energizing circuits whereby the output of the cathode selected is maintained at a predetermined value.

3. The combination of a thermionic discharge device having a plurality of cathodes, energizing circuits respectively connected to said cathodes, a regulator for maintaining the current in said circuits substantially constant at different selected values, and means for automatically changing the setting of said regulator whenever a change in the excitation of said energizing circuits is effected.

4. The combination of an X-ray tube provided with a target and a plurality of cathode elements constructed to project upon said target cathode rays of unlike energy and sharpness of focus, electric supply circuits for said cathode elements, switching means for shifting the energy input from one supply circuit to another, means for regulating the energy delivered to said cathode elements and means for automatically changing the setting of said regulator by the operation of said switching means.

5. The combination of an X-ray tube which is provided with a plurality of cathodes constructed to project electron streams upon focal spots of unlike area, a plurality of cathode energizing circuits, means for selectively energizing said supply circuits, a regulator for controlling the energy delivered to said X-ray tube, and means interlocked with said selective energizing means for changing the setting of said regulator.

6. The combination of an electric device which is operable with focussed electron discharges of different focal settings, circuit means including a selector switch for creating in said device electronic discharges of unlike values for different focal settings, a regulator for maintaining such electronic discharges substantially constant at selected values, and means including a selector switch interlocked with said first-mentioned switch for changing the setting of said regulator to correspond with a selected electronic discharge.

7. The combination of an electric device which is operable with a plurality of focussed electron discharges of unlike focal settings, means for maintaining in said device unlike electronic discharges of substantially constant value for each such focal setting, and a switch for selecting focal settings, said switch being interlocked with a member of said maintaining means whereby the setting of said maintaining means is altered automatically by a change of focal setting.

In witness whereof, I have hereunto set my hand this 1st day of November, 1929.

WILLIAM D. COOLIDGE.