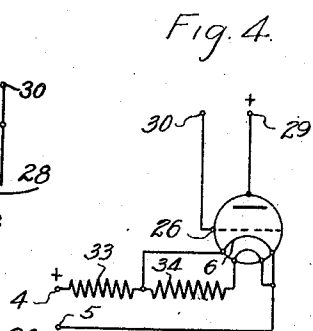
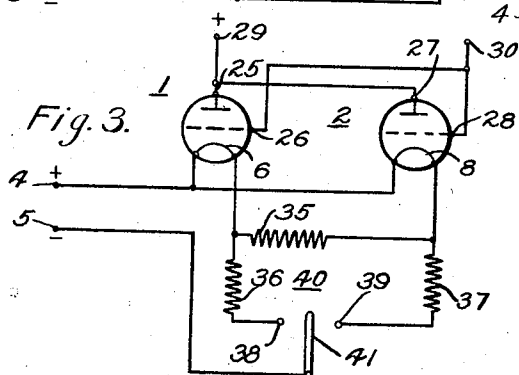
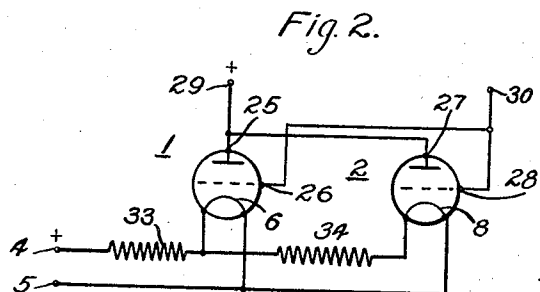
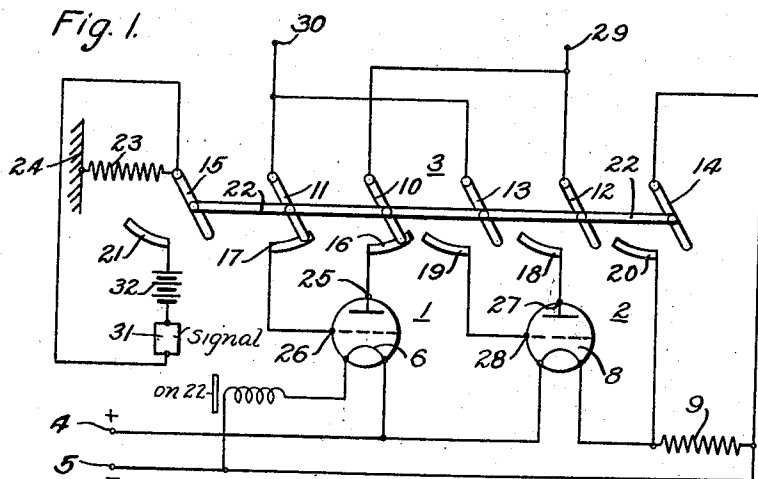


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VACUUM ELECTRIC TUBE DEVICE

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UNITED STATES PATENT OFFICE.

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VACUUM ELECTRIC TUBE DEVICE.

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This invention relates to vacuum electric tube devices of the hot cathode type and has for its object to provide automatic means whereby in the event of the cathode such as a filament of a valve being burnt out during operation another cathode will be brought into operation in place thereof. The other cathode may be located in the valve in which case the same valve will continue in service; or an auxiliary valve may be used and similarly brought into service. A further object is to provide automatic means of the above indicated character whereby when, upon the failure of a cathode, another cathode or valve is brought into operation, practically no interruption of service will take place and the resulting disturbance will be small or negligible.

In order that no appreciable interruption of service and only a negligible disturbance shall take place it is essential that the anode current and consequently the electron emission should not fall below a certain value whilst the automatic changeover is taking place. The anode of the second or auxiliary valve, when such is employed, may obviously be connected permanently to a source of potential and the grid thereof may be likewise permanently connected to an input circuit but if the cathode of said valve is cold before being brought into operation, an interval of time must elapse before the said cathode attains its normal working temperature whereby an appreciable interruption of the anode current must occur. Now it is well known that the electron emission of a heated cathode and the evaporation thereof changes comparatively rapidly with variations of temperature and that there is for a given cathode material a temperature above which evaporation and electronic emission takes place freely whilst below said temperature the evaporation and emission is negligible which may be defined as the critical temperature.

According to the invention the second or spare cathode or the cathode of the auxiliary valve, is normally maintained at a relatively high stand-by temperature which is just below the critical temperature for electron emission and means governed by the operativeness of the main cathode are provided for automatically increasing the temperature of said second or spare cathode above the

critical temperature thereof when the main cathode burns out or becomes inoperative. In this manner the interruption due to the substitution of the new cathode for the original one and the consequent disturbance is small and may in some cases be negligible.

The automatic increase of the temperature of the second or spare cathode may be effected in various ways but according to a further feature of the invention this is effected without the use of switching devices in a manner to be hereinafter described. A relay or other electrically operated device may be included in the system and so controlled in accordance with the operativeness of the valves as to operate an indicator or warning signal when the cathode burns out.

Furthermore the electrodes such as the anode and grid of the second or spare valve when such is used may be permanently connected in parallel with the main or working valve as previously herein stated, or alternatively they may be connected by means of automatic switches immediately on failure of the main valve, and according to another feature such electrodes of the main valve may be disconnected by automatic switching devices when the changeover is effected. Such automatic switching devices may be controlled for example by changes in the cathode current.

In order that the invention can be fully understood it will now be described with reference to the accompanying drawings in which Fig. 1 is an electrical diagram illustrating a main and an auxiliary valve together with an automatic switch for their anode and grid circuits; Fig. 2 is an electrical diagram of a main and an auxiliary valve arranged to operate without the switching means, and Fig. 3 is a modification of this arrangement. Fig. 4 is a modification of the invention employing a single tube with two cathodes.

Referring to Fig. 1 the main valve is shown by 1 and the auxiliary valve by 2. The automatic switch for effecting the alternative connections of the two valves is shown by 3. The cathode supply current is obtained from the terminals 4 and 5. The cathode 6 of the valve 1 is connected across the supply terminals through the operating coil 7 of the automatic switch, and the cathode 8 of the valve 2 is similarly connected

across the terminals 4 and 5 through a resistance 9.

The automatic switch 3 is of the 6-pole two-way type and comprises a plurality of pivoted switch arms 10 to 15 inclusive which are adapted to engage respectively with the contact segments 16 to 21 inclusive. The switch arms are all linked to a rod 22 and are thereby adapted to be operated simultaneously. The switch is biased to one of its two operative positions by means of a spring 23 attached to a rigid support 24. A magnetizable member (not shown in the drawing) is provided on the switch to co-operate with the coil 7. The contact segments of the switch are so arranged that the switch arms 12, 13, 14 and 15 are out of engagement with their corresponding segments when the switch arms 10 and 11 are engaged, and vice versa. The anode 25 of the valve 1 is connected to the contact segment 16 and the grid 26 to the segment 17. Similarly the anode 27 of the valve 2 is connected to the contact segment 18 and the grid 28 to the segment 19. The switch arms 10 and 12 are connected to the anode supply terminal 29 and the switch arms 11 and 13 to the grid supply terminal 30. The switch arm 14 is connected to one terminal of the resistance 9 and its corresponding contact segment 20 is connected to the other terminal of resistance 9. The switch arm 15 is connected to its corresponding contact segment 21 through a warning device 31, such as an electric bell, and an operating battery 32 for the bell.

When the arrangement is in operation the values of the resistance 9 and of the voltage applied across the terminals 4 and 5 are adjusted so that the cathode 6 of the valve 1 is at its normal operating temperature, while the cathode 8 of the valve 2 is at the maximum permissible temperature below its normal operating temperature such that evaporation of the cathode is negligible. The operating coil 7 of the switch 3 is then energized, and by means of its cooperating magnetic member maintains the switch in one operative position against the action of the biasing spring 23. That is to say, the switch arms 10 and 11 alone make contact with their corresponding segments. When the cathode 6 of the valve 1 burns out the switch operating coil 7 is deenergized and the switch is pulled into its other operative positions through the action of the spring 23. That is to say, the switch arms 12, 13, 14, and 15 then engage their corresponding contact segments. The anode and grid supplies are thereby switched from the valve 1 to the valve 2, the resistance 9 is short-circuited to bring the temperature of the cathode 8 of the valve 2 to its normal operative value, and the electric warning bell 31 is rung.

In Fig. 2 an arrangement is illustrated in which the changeover from the main valve 1 to the auxiliary valve 2 on failure of the main valve cathode is effected without switching means. In this arrangement the cathode current supply is obtained from the terminals 4 and 5, and the cathode 6 is connected in series with the resistance 33 across the terminals 4 and 5 while the cathode 8 of the valve 2 is connected in series with the resistance 34 in parallel with the cathode 6 of the valve 1. The anodes 25 and 27 of the valves 1 and 2 respectively may both be connected directly to the anode supply terminal 29 and the grids 26 and 28 connected to the grid supply terminal 30.

A relay may be included in the circuit and arranged to operate an indicator or warning signal when the current through it decreases owing to one of the filaments being burnt out, or the said relay may be arranged in series with the filament and arranged to operate when the current ceases to flow there-through owing to the filament being burnt out. Instead of a separate warning signal or indicator the bulb of the spare valve may be coloured or placed behind a coloured screen to give visual warning when the changeover from valve 1 to valve 2 takes place.

Alternatively the arrangement shown in this modification of the invention can be associated if desired with the switching means described with reference to Fig. 1. Also in a further modification a single valve can be provided with a plurality of auxiliary cathodes which can be maintained at temperatures below their normal operating temperature and successively switched into or otherwise included in the main circuits on failure of the successive main cathode.

In the operation of the arrangement of Fig. 2 the values of the main resistances 33 and 34 and of the voltage applied across the terminals 4 and 5 are adjusted so that the cathode 6 of the main valve 1 is maintained at its normal operating temperature while the cathode 8 of the auxiliary valve 2 is maintained at a temperature below its normal operating temperature such that emission and evaporation of the cathode is negligible.

The correct values for the resistances 33 and 34 and for the electromotive force applied between the terminals 4 and 5 can be found experimentally, or alternatively can be calculated from the formulæ obtained by the following mathematical analysis.

When the arrangement shown in Fig. 2 is in operation let E represent the value of the voltage applied across the terminals 4 and 5, and X and Y represent the respective values of the resistances 33 and 34, which have to be calculated. Let I_1 represent the known value of the cathode current in the main

valve 1 giving normal electron emission and E_1 the corresponding voltage applied across the cathode; and let I_2 represent the known maximum permissible cathode current in the auxiliary valve 2 giving negligible electron emission and E_2 the corresponding applied voltage.

The following equations hold respectively for valves 1 and 2—

$$E = E_1 + X(I_1 + I_2) \text{-----} (1)$$

$$E_1 = E_2 + I_2 Y \text{-----} (2)$$

When the cathode of valve 1 burns out the current through the cathode of valve 2 must be increased from I_2 to I_1 . Therefore the following new equation then holds for valve 2—

$$E = E_1 + I_1(X + Y) \text{-----} (3)$$

It follows from equation (2) that—

$$Y = \frac{E_1 - E_2}{I_2} \text{-----} (4)$$

from equations (1) and (3) that—

$$\begin{aligned} (I_1 + I_2)X &= I_2(X + Y) \\ I_2X &= I_1Y \\ X &= \frac{I_1Y}{I_2} = \frac{I_1(E_1 - E_2)}{I_2^2} \text{-----} (5) \end{aligned}$$

and from equations (1) and (5) that—

$$E = E_1 + \frac{I_1(I_1 + I_2)(E_1 - E_2)}{I_2^2} \text{-----} (6)$$

Since the numerical values of I_1 and E_1 ; I_2 and E_2 are known the appropriate numerical values of Y , X and E can be calculated from equations (4), (5) and (6) respectively.

In the arrangement described with reference to Fig. 2 it is necessary to replace a burnt out main valve 1 by a new one which automatically takes up the load. Thus the auxiliary valve 2 is brought into operation at each failure of the main valve 1 and is never replaced. In time it naturally fails also and no automatic operation of the arrangement is then possible. In order to avoid this difficulty the modification shown in Fig. 3 can be employed. In this arrangement one terminal of each of the cathodes 6 and 8 is connected to the cathode current supply terminal 4. The other two cathode terminals are connected together through the resistance 35 and are also connected respectively through resistances 36 and 37 to the contacts 38 and 39 of a two-way switch 40. The switch 40 is provided with an operating arm 41 which is connected to the cathode current supply terminal 5 and can be operated either manually or electrically from an auxiliary circuit. The anode and grid terminals of the valves can be connected directly to their corresponding supply terminals or alternatively can be associated with a

switching device such as is described with reference to Fig. 1. Also suitable warning devices can be provided.

When the switch arm 41 engages with contacts 38 the arrangement of Fig. 2 is exactly reproduced, that is to say, the valve 1 is the main valve and valve 2 auxiliary. When the switch arm 41 engages with the contact 39 the valve 2 becomes the main valve and valve 1 auxiliary. Thus by changing over the switch arm 41 each time a failure occurs the load between the two valves can be evenly distributed and the replacement of each one in turn assured.

It is to be understood that various modifications can be made in the arrangements described without departing from the scope of the invention.

We claim as our invention:—

1. In a vacuum-tube device, a plurality of cathodes, means for maintaining one of said cathodes at a temperature so high that it will render the device operative, and means for maintaining another cathode at a temperature below that required to render the device operative, said last named temperature being so high that the time required to raise said other cathode to a temperature which will render the device operative is too short to noticeably interrupt the operation of the device.

2. In a vacuum-tube device, two cathodes in parallel and a resistance in series with only one of said cathodes, said resistance being sufficient to keep the current through its cathode below the value necessary to produce an effective electron emission from said cathode and insufficient to prevent said current reaching said value when the circuit through the other cathode is open.

3. In a vacuum-tube device two cathodes, a source of heating current for said cathodes, means for so proportioning the current from said source that one cathode is above and the other below the temperature which is just sufficient to render the vacuum-tube device operative, said proportioning means admitting sufficient current to the cooler cathode to heat it nearly to said temperature and upon failure of the hotter cathode admitting additional current to the other cathode.

4. In a vacuum-tube device, a pair of vacuum tubes, a cathode in each vacuum tube, a source of heating current common to said cathodes, a resistance connected between said cathodes, a pair of resistances connected on opposite sides of said resistance, and a switch for connecting either member of said pair of resistances in series with said source.

In testimony whereof we have hereunto subscribed our names this 12th day of September, 1924.

ERNEST YEOMAN ROBINSON.
WALTER JOHN BROWN.