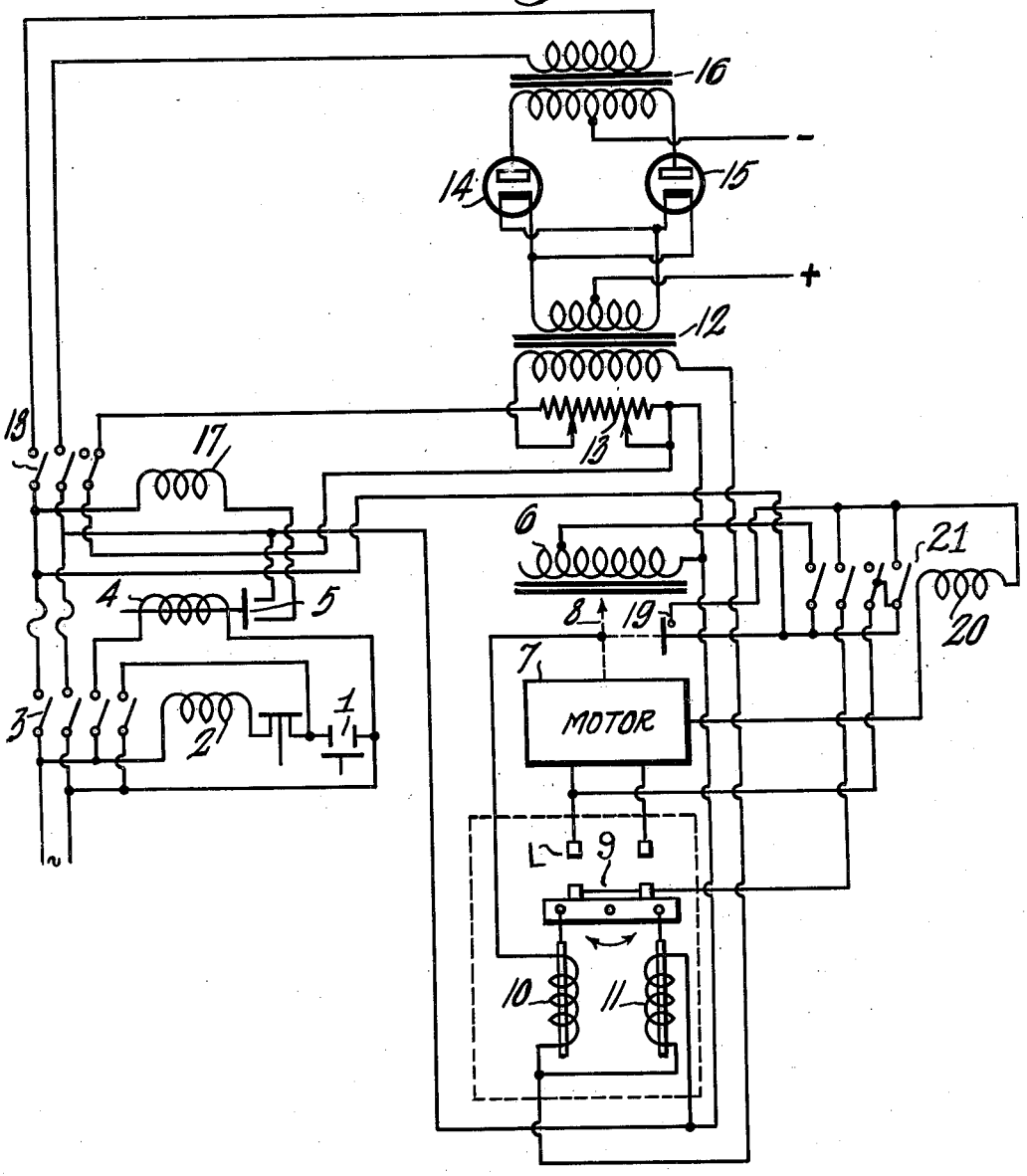
Feb. 7, 1950 C. W. HANSELL 2,496,717

MEANS AND METHOD FOR IMPROVING FILAMENT LIFE

Filed June 13, 1949 2 Sheets-Sheet 1

Fig. 1.



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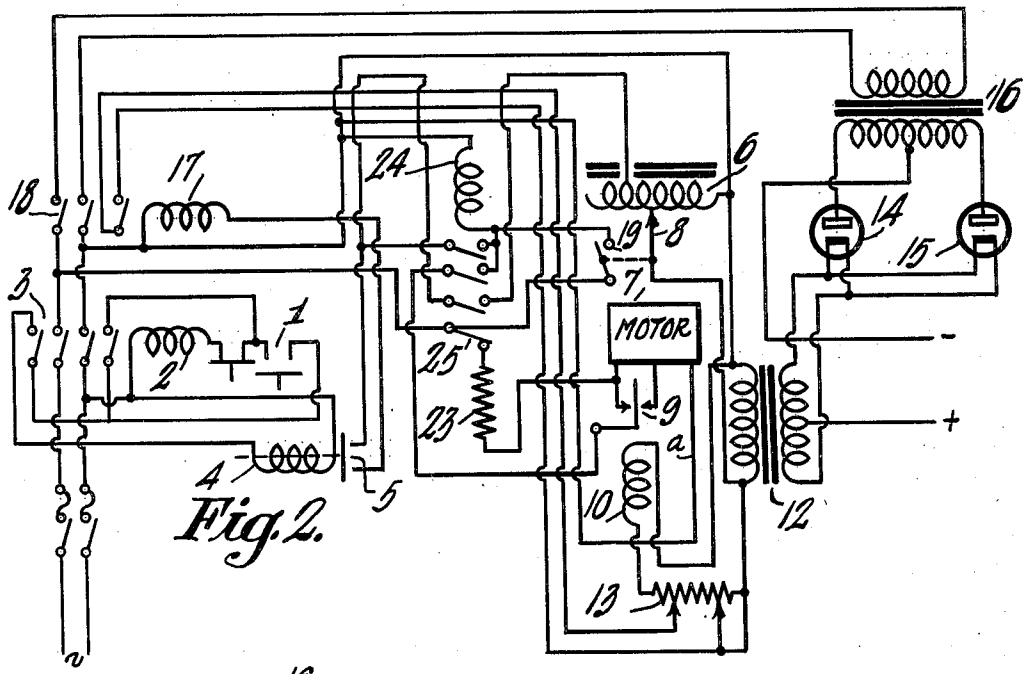
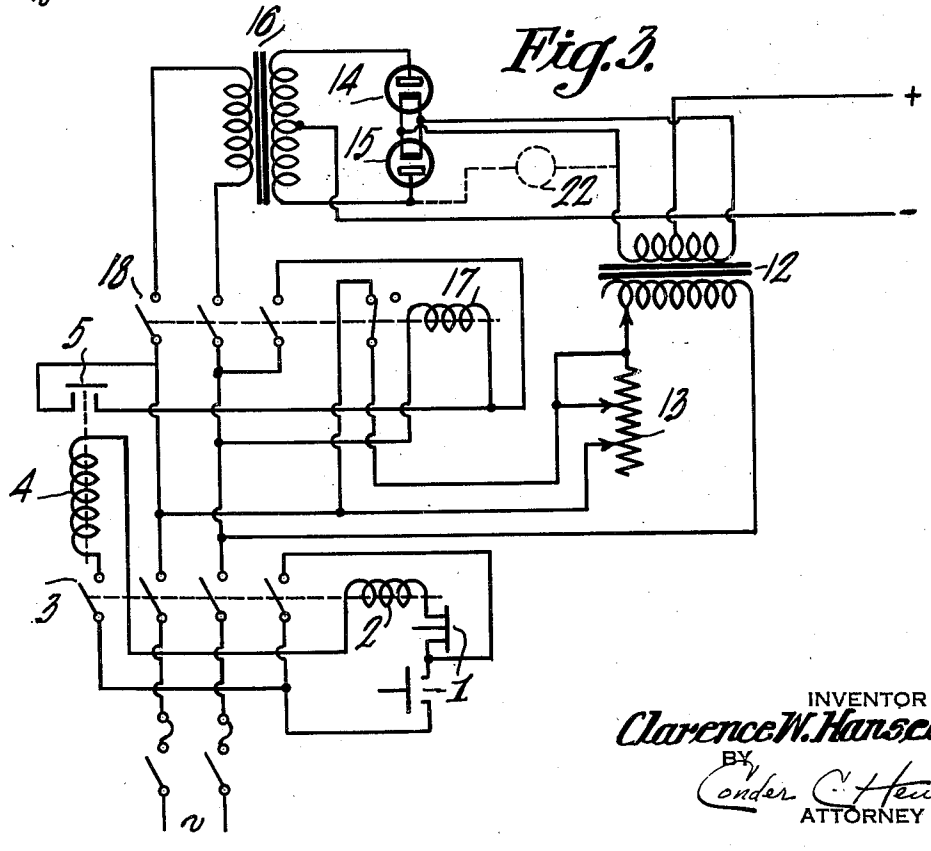


Fig. 2.

Fig. 3.



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MEANS AND METHOD FOR IMPROVING FILAMENT LIFE

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This invention relates to the art of increasing filament life in thermionic tubes, and more particularly to a means and method for keeping filament temperature constant.

In electronic equipment employing thermionic devices I have recognized that the life of the thermionic cathodes is very substantially reduced by improper conditions of operation. That the conditions of operation are improper has not previously been recognized so far as I am aware and the improper conditions exist under standard practices of equipment design and operation.

In order that long life be obtained from thermionic cathodes it is necessary that the cathodes be operated at or not far from the minimum temperatures at which adequate electron emission is obtained to supply the required peak emission currents. That this is true has been generally recognized but still the designers and operators of equipment have generally failed to fulfill this required condition. What they have failed to take into account is that, before emission current is drawn from the cathodes, the cathode temperatures must be raised by their heating currents up to values high enough to provide the required electron emission and then, after emission currents are being drawn, in operation of the equipment, the cathode temperatures do not remain at the correct initial values but, in many cases, rise to values greatly in excess of the correct ones.

As an illustration, consider the usual conditions of operation for hot cathode mercury vapor rectifiers. Before anode current is applied to these tubes the cathodes should be raised to such a temperature that electron emission is equal to, or greater than, the peak values of anode current. Otherwise there will be limiting of the emission current, the potential drop through the tubes, produced by anode current, will rise, and destructive sputtering of the cathode due to ion bombardment will take place. It is a common observation that the rectifier tubes often fail, or arc-over, when anode circuit power is first applied and quite often, if not generally, this can be attributed to insufficient cathode emission, due to too low cathode temperatures, at the time of starting.

If the tubes get through the starting period without complete and permanent destruction they may then function satisfactorily for long periods of continuous service. This is because the losses in the tube due to flow of anode current will raise the cathode temperature and usually will thereby provide adequate, or even excess, electron emission.

If the cathode heating power were made greater, assuming it is on long enough before plate circuit power is applied, adequate electron emission might be available before the plate

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power is applied and there would be no cathode sputtering due to ion bombardment at the time of starting. In this case, however, the rise in cathode temperature after starting would result in a great excess of electron emission due to too high temperature. This is bad for tube life because the rate of evaporation of cathode materials is very sensitive to cathode temperature and the life is very greatly reduced by relatively small temperature increase. Because, in most cases, the net evaporation of cathode material is made up of the difference between evaporation and electrical back pumping effect of the electron current, the cathode life is very sensitive to any substantial increase in temperature beyond the temperature required to produce adequate electron emission. I have observed, in one case, that reducing the heater power in mercury vapor rectifiers to about 85% of a customary value, increased tube life in a ratio of at least 20 to 1.

It would now seem obvious that, an extra power is dissipated in the tubes, after anode current is applied, the cathode heating power should be reduced so that the cathode temperature will remain nearly constant and electron emission only moderately in excess of the required value will be provided. This has not been done in practice, undoubtedly because the observations and reasoning presented above have not previously occurred to those "skilled" in the art, who have been designing and operating equipment.

Having recognized this situation the present invention is designed to correct it. I propose, in accordance with the invention, to make the cathode temperature, and therefore the electron emission, remain constantly close to the optimum value at all times while anode current is being drawn and to compensate for variations in power loss in the tubes which otherwise would cause the temperature and electron emission to fluctuate excessively.

It is accordingly an object of my invention to provide a means by which cathode temperature may be kept substantially constant.

A further object of my invention is to provide means compensating for increases in cathode temperature caused by emission current flow.

Another object of my invention is to provide a method of utilizing thermionic tubes by which filament life may be increased.

A still further object of my invention is to provide means by which destructive sputtering of the cathode is retarded during the warm-up period.

Other objects and advantages of my invention will be made clear in the following discussion.

The above objects of my invention together with other objects and advantages will become apparent upon consideration of the following de-

tailed description of an embodiment of my invention taken in conjunction with the accompanying drawing wherein like reference characters designate similar parts in the several views and in which:

Figs. 1, 2 and 3 represent schematically circuits in which my invention is embodied.

A common cause for inconstant cathode temperatures is that there are power losses either at the cathode, or in surrounding and adjacent other electrodes, which change the cathode temperature when anode currents are turned on and off due to starting and stopping equipment, keying or modulating it, and changing the power level. Other causes are inconstant load circuits, power voltage variations, etc.

In almost all cases the cathode heating current supplied to the tubes flows through the metallic resistance of a filament of heater wire which may be of a material the resistance of which varies with variation of temperature. Therefore, one form of the present invention provides a system to control the heater power, and to keep the heater resistance constant to a fair degree of approximation, by holding constant cathode temperature and cathode electron emission.

Continuing with the hot cathode rectifier tubes as an example, not forgetting that a similar situation exists in high vacuum thermionic tubes, one simple expedient which I would propose is that, when rectifier equipment is placed in service, the usual means be employed for applying cathode heating power for a prescribed amount of time before anode circuit power is applied. The amount of heating power, and the time delay, will be so adjusted that adequate, but no great excess, of electron emission is available when the plate power is applied. Then, when plate power is applied, assuming this also applies the plate current, the cathode heating power will be reduced automatically to such a value that the cathode temperature will remain nearly constant. One very simple way of doing this is to employ an auxiliary contact on the last contactor to close, to apply plate voltage and current, which auxiliary contact will open to insert resistance in series with the cathode heating circuit. The value of the resistance will then be adjusted to obtain nearly the same cathode temperature or more accurately nearly the same electron emission, which may require some temperature change, with plate power on as obtained just before the plate power was applied. In the case of power on-off keyed radio transmitters where current does not always flow when plate voltage is on, a relay operated by the current may be used to control the amount of heater power. This provision of a contact means to reduce cathode heating current when anode current is started in rectifiers, to make the electron emission more closely match requirements at all times is the simplest example of my invention, which is expected to have most universal application and to provide very great economic advantages.

To illustrate another form of the invention note that there are available as standard equipments, obtainable from electrical manufacturers, types of relays which are operated by differences in the value of two alternating currents. One form, made by the Westinghouse Electric Company, has two A.-C. solenoids which pull on opposite ends of a beam or lever which is supported at the middle. The beam or lever bears a pair of contacts, one of which opens and one of which closes as the beam is tilted in one direction. An opposite opening and closing of contacts occurs if the beam is tilted in the opposite direction.

If now one coil of such a relay, suitably designed as to turns and resistance, is energized with a current proportional to the voltage of a cathode heater circuit and the other is energized with a current proportional to the current in the cathode heater circuit, then it is possible to have the two coils exert equal forces on the tilting contact arm and both contacts will remain open so long as voltage and current of the heater circuit are in correct proportion. This correct proportion corresponds to the cathode heater resistance at its correct temperature, assuming that the heater is one of the refractory metals which changes resistance with change of temperature, which at present may not be the case in commercial tubes whose heaters may be made of alloys which do not change resistance with change of temperature.

If now the cathode temperature should rise the heater current will diminish relative to the voltage and the relay arm will tip in one direction. A decrease in cathode temperature will have an opposite effect. Tipping of the relay arm in one direction or the other, in response to changes in cathode temperature will close one contact or the other, which in turn can cause a small motor to run in one direction or the other to correct the cathode temperature by changing the voltage and current delivered to the heater.

This principle of operation is used in the circuit shown in Fig. 1 which is explained as follows:

When the rectifiers, 14 and 15, are de-energized, the power is simultaneously removed from the motor 7 so the position of brush 8 is that for normal full filament voltage. As it is not good practice to start filaments on large powerful tubes on full voltage it is necessary to change the position of brush 8 to a low voltage position. In order to eliminate the errors of forgetfulness on the part of the operator this reduction of voltage is made automatic.

Push-button 1 energizes winding 2, which closes the four-blade contactor 3 applying voltage to the windings of the time delay relay 4 and to terminal L on motor 7, which moves the brush 8 to a low voltage position, closing the momentary contact switch 19. Closing switch 19 energizes the winding 20, which closes contactor 21. Contactor 21 simultaneously gives control of the motor to relay 9 and its two windings 10 and 11; applies voltage to auto transformer 6; and disconnects terminal L on motor 7 from power other than that which is controlled by relay 9. Filament voltage is now raised by motor 7, under control of relay 9, by moving brush 8 to a higher voltage position. Winding 10 is a current winding carrying the current passing through the primary windings of filament transformer 12 and winding 11 is a voltage winding which is connected across the primary of the filament transformer 12. The windings 10 and 11 are designed so that the pulls they exert on their armatures just balance when the filament heating current is such that the temperature of the filaments is just a little above that below which emission limiting of electron current would occur. The exact adjustment of the balance may be controlled by appropriate shunt resistance across coil 10, resistance in series with coil 11, or spring or weight or air gap adjustment of relay 9, these being not shown but well known in the art.

As explained above, losses in tube elements

adjacent to and surrounding the filaments cause heat to be radiated to the filaments when the tubes draw plate current. More important, cathode bombardment by ions in the case of gas discharge rectifiers, particularly when shielded cathodes are used, raises the cathode temperature and electron emission. To compensate for this difference in temperature, and in available electron emission which is normal at the end of starting warm-up and that which would exist during full load, a resistor 13 is inserted in series with the primary winding of the filament transformer when the plate contactor 18 is closed by the actuation of the time delay relay 5, thus decreasing the voltage applied to the transformer, at the balance condition of the voltage control relay with its windings 10 and 11. Normally the amount of voltage and power change produced at resistor 13 by closing of contactor 18 will be adjusted to compensate for the extra cathode heating of tubes 14 and 15 due to flow of anode current, so that no compensation by running of motor 7 is required when plate power is put on or taken off.

A material change in filament temperature causes an unbalance in the pull exerted by windings 10 and 11 and this causes the motor to make a compensating change in the voltage applied to the filament transformer so as to restore a fixed relation between voltage and current at the primary winding of the filament transformer, which corresponds to a constant effective resistance.

Of course regulation would be slightly better if the balance relay coil current and voltage were that directly applied to the filaments but in most cases this would involve difficulties in circuit insulation. The filaments may often be at high D.-C. potential.

In transmitters having automatic control of cathode heating current by means of motor driven variable ratio transformers, where a voltage sensitive relay is used to control the cathode heater voltage, the contactor which applies anode power may insert resistance either in series with the cathode heater circuit as previously described, or it may alternatively insert resistance or reactance in series with the control coils of the voltage sensitive relay so that the relay will cause the motor driven variable voltage transformer to hold a lower value of cathode heater voltage after plate power is applied.

This operation is described as follows in conjunction with the circuit shown in Fig. 2:

Push button, 1, energizes winding, 2, which closes the four-blade contactor, 3, which starts the time delay relay, 4. Power through contactor, 3, flows to motor, 7, directly through lead *a* and through contactor, 25, and resistor, 23, which has the same ohmic resistance as winding 24. The energized motor, 7, runs in such direction that brush 8 of variable voltage autotransformer, 6, moves toward the low voltage position. When the brush 8 approaches a predetermined low voltage position, it, through mechanical linkage with momentary contact switch 19, energizes winding 24 which closes four-blade contactor 25, interrupting the current through resistor 23 to the motor, simultaneously energizing winding 6 of the autotransformer and winding 10 of voltage sensitive relay 9 which has two contacts which control the direction of rotation of the motor 7. At the same time winding 10 is energized the primary of the filament transformer 12 is energized and the filaments of the rectifier tubes, 14 and 15, draw current. Starting to heat, the filaments present a gradually rising resistance which voltage sensitive winding 10, connected in series with a variable resistance 13, "sees" as a low voltage and causes its relay 9 to make contact with that contact which will cause the motor to rotate in the direction to move brush 8 to a higher voltage position. Thus the filament voltage is raised slowly and steadily until the filaments have developed full normal temperature, which "satisfies" the voltage sensitive relay winding 10 and it moves the relay 9 to an intermediate position, stopping the motor 7. Time delay relay 4, having a delay time sufficient to permit the foregoing operations to be completed, will now close and its contacts 5 closes the circuit to energize winding 17 of three-blade plate contactor 18, which in turn causes plate transformer 16 to be energized.

Now, when plate current is drawn by tubes, 14 and 15, which are assumed to be gas discharge rectifiers, the cathodes will be bombarded by ions due to the cathode fall of potential and will rise in temperature. At the same time, though less of a factor, the plates of these tubes will develop a high temperature caused by the impingement of electrons. The heated plates will radiate heat to the filaments, thus also tending to let the temperature rise, causing a wasteful excess of electron emission, evaporation of filament coating and activating material, and less effective back pumping of evaporated material by the discharge. This will shorten the useful life of the tubes. To compensate for the heating of the filaments caused by flow of anode current, one contact on plate contactor 18 short circuits a predetermined part of resistor 13. Now the voltage sensitive winding 10 "sees" a voltage which is too high and promptly lowers the filament voltage by its control over motor 7, so that the temperature of the filaments will be held at the optimum temperature in keeping with longest life and satisfactory operation of the tubes.

Fig. 3 shows a simplified diagram of a system embodying my invention which operates as follows:

Push-button 1 energizes winding 2, which closes four-blade contactor 3, by which the filament transformer 12 is energized through a contact on relay 17 shunting the variable resistance 13. Time delay relay 4 permits the filaments of the tubes, 14 and 15, to heat to their normal operating temperature before closing contacts 5, which energizes the winding 17, which closes the four-blade contactor 18, one contact being the plate contactor which energizes the plate transformer 16.

In order to compensate for the overheating of the filaments resulting from the flow of current from the plates of the tubes to the cathodes, one blade of plate contactor 18 opens the circuit, which, during the warm-up period before time delay relay 4 had closed its contacts 5, had been serving as a short circuiting jumper across part of the variable resistance 13, thus inserting part of resistance 13 in series with the primary windings of the filament transformer 12. This resistance carrying the primary current introduces an IR drop in the primary circuit of the transformer 12 producing a lower primary voltage, hence a lowered filament current and lowered filament heating.

Instrument 22 for measuring forward voltage drop when anode current flows, may be used to indicate the proper adjustment of resistance 13

both before the plate voltage is applied to the tube anodes and also after the tubes have started to draw normal load. Usually this special instrument will be connected only for short periods of actual observation.

It is thus clear that my invention provides a system whereby tube life may be greatly prolonged by operating the emission surfaces at a nearly constant temperature or at any rate a nearly constant electron emission not too greatly in excess of the emission actually used. An essential feature of this system is reducing filament heat power upon application of plate current in an amount which compensates for heat dissipation in the tube due to current flow.

While I have shown and described the preferred embodiments of my invention, it will be understood that various modifications and changes will occur to those skilled in the art without departing from the spirit and scope of this invention. I therefore claim:

1. Apparatus for prolonging the life of thermionic tubes comprising in combination; a tube having a thermal electron emission surface; a voltage supply; means connected to said voltage supply thermally heating said surface; a differential relay having two windings and two contact sets operated by respective energization of said windings, one of said windings being energized by current from said heating means, the other of said windings being energized by voltage across said heating means, said contacts being adjusted so that one contact set is closed when heating power drops below a certain predetermined value thus causing less than required emission from said surface and the other contact set is closed when heating power exceeds a corresponding value; and circuits connected between said contact sets and said voltage supply correspondingly increasing or decreasing said heating power in accordance with said contact closing in a direction causing said heating power to remain constant.

2. Apparatus for prolonging tube life comprising in combination, a tube having a thermionic emission surface and an anode, a circuit completing the discharge path of said anode and surface, a voltage supply, means connected to said supply providing heat for said thermionic surface, means for delaying completion of said discharge path until said thermionic surface is heated to emission temperature and a circuit connected to said means reducing said voltage upon said completion in an amount sufficient to keep said surface at a substantially constant temperature.

3. Apparatus as described in claim 2 wherein said surface is a tube filament the resistance of which changes with change of temperature and said voltage is constantly variable by means including a motor which is directed by a circuit connected to contacts of a differential relay having one winding proportional to filament current, and the other winding proportional to filament voltage, said relay windings proportioned such that the resulting voltage change will keep filament temperature substantially constant.

4. In combination, a thermionic tube having a filament and anode; a supply voltage source; a circuit connecting said voltage to said filament; a voltage dropping device for said circuit; a second circuit connecting said voltage to provide a discharge path for said tube, said second circuit having a time delay sufficient to allow said filament to come to optimum operating potential; means operating with said time delay connecting said voltage dropper in said filament circuit; and motor controlled means for varying said filament voltage in inverse proportion to any temperature change in said filament.

5. Apparatus as described in claim 4 in combination with means for varying said motor controlled means to a point corresponding to low filament voltage when first connecting said supply voltage source, a means connecting said filament voltage when said low voltage point is reached, and means for keeping said filament voltage connected until said supply source is interrupted.

6. A circuit for maintaining filament temperature constant comprising in combination, a thermionic tube having a filament and anode, a relay connecting a supply voltage to said filament, time delay means operated by said relay connecting said supply to said anode, and a voltage dropping means connected to said filament supply circuit in a fixed time relation with said anode supply connection.

7. Apparatus for increasing filament life comprising in combination; a thermionic tube having a filament and anode; a supply voltage source; a transformer connected to said filament having mechanical means for voltage variation; a reversible motor adapted to said mechanical means to vary said transformer voltage; a circuit connecting said supply to said motor; means causing said motor to reduce said filament transformer winding to a low voltage position when said transformer is in an unenergized position; a switch actuated when said filament winding reaches a low voltage position connecting filament voltage to said transformer and accordingly connecting means to said motor whereby said filament voltage is varied inversely proportional to the filament temperature in such an amplitude that filament temperature is kept substantially constant; and time delay means connecting said supply to said anode after said filament voltage attains said constant amplitude.

8. Apparatus as described in claim 7 in combination with means to decrease filament voltage when said anode supply is connected, said filament voltage decrease being of such amplitude as to cause the filament temperature to remain constant when said tube is conducting.

9. The method of increasing life of a thermionic tube having a filament and an anode comprising the steps of applying filament voltage adjusting said filament voltage to a level providing rated emission output, and decreasing said voltage to a value causing said filament emission to remain constant simultaneously upon drawing anode current from said tube.

10. The method of increasing life of a thermionic tube comprising the step of maintaining cathode temperature constant at a value substantially equal to that required to provide rated cathode emission.

11. Apparatus as described in claim 7 in combination with means connected to said motor to vary said filament voltage transformer upon application of anode potential in an amount keeping the filament temperature substantially constant upon flow of plate current.

12. The method of increasing filament life in a thermionic tube comprising the steps of increasing filament voltage gradually to the value causing filament temperature to become substantially constant at that temperature required to provide rated cathode emission, varying filament voltage inversely with changes in cathode

temperature in such amplitude as to maintain the cathode temperature constant taking said emission current from said tubes and simultaneously reducing said filament voltage in an amount causing said emission to remain constant upon taking said emission current.

13. In devices employing hot cathode gaseous discharge tubes, automatic means to supply heat to the cathodes to bring them up to a temperature such that electron emission from the cathode is sufficient to provide a required anode current, in combination with means to apply the anode current and simultaneously to reduce the heat supplied to the cathodes to compensate for the

effect of anode current upon the electron emission.

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