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CONTROL APPARATUS

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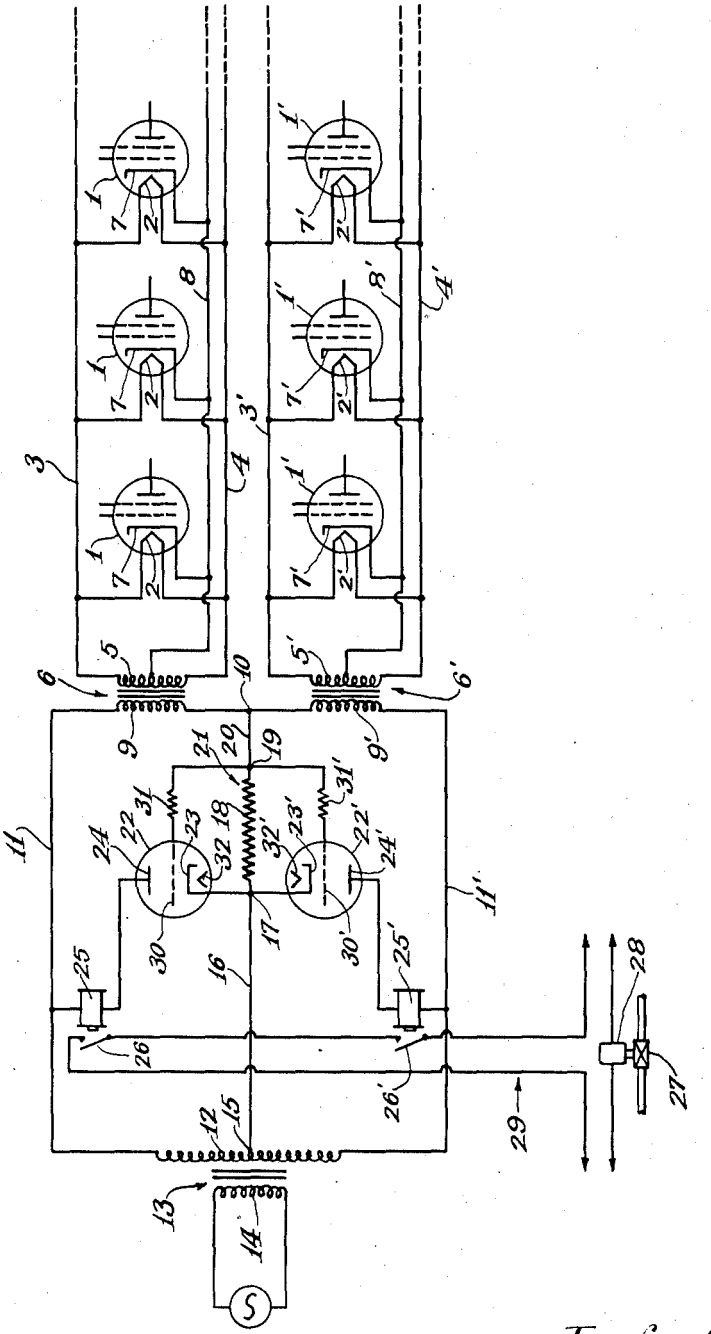

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CONTROL APPARATUS

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8 Claims. (Cl. 250—27)

This invention relates to electronic control apparatus and particularly to safety control apparatus of the character in which electron tubes are adapted to be maintained in a nonconductive state during normal operation of the equipment with which the control apparatus is associated, and where these tubes are arranged to become conductive only in the event an unsafe condition arises with respect to the equipment or in the control apparatus itself.

In apparatus of the character to which the present invention pertains it is, of course, essential that when a tube is called upon to pass current through its plate or anode circuit that it should be capable of so doing; which is to say, that the conductivity of the tubes should not become so impaired that any tube remains in a permanently nonconductive state. In order to insure that the tubes are at all times capable of functioning as desired it is customary to regularly check the tubes and replace any which have become defective. However, where this is done manually there is always the likelihood that a proper check will not be made and that defective tubes will be allowed to remain in use, thereby giving rise to a hazardous situation because of the possible failure of the control apparatus to react safely in an emergency. Hence, an object of the present invention is to enable the control apparatus to automatically detect failure of one or more electron tubes and to cause it to function in a safe manner if and when such a condition arises, and inasmuch as one of the chief causes of tube failure is burning out of the filament or heater of the tube, the present invention is particularly designed to detect the occurrence of an unsafe condition of this character.

In the copending application of Robert E. Yates, Serial No. 245,173, filed December 12, 1938, it has been proposed to automatically detect failure of a filament in any of a plurality of electron tubes by connecting all of the filaments in a series circuit which includes a device responsive to an interruption in the flow of current through the series circuit to cause the apparatus to react as though to an unsafe condition. While this scheme is applicable where vacuum tubes are being employed, it is not equally feasible where the electron tubes are of the gas-filled type because if the filaments of these tubes are connected in series with each other electrical stresses are apt to be set up between the cathodes and filaments and this may in some instances cause disruptive discharges to take place within the tubes. Hence, where gas-filled tubes are used it is advisable to connect the filaments thereof in parallel to the voltage supply source, with the cathodes of the tubes so arranged as to be electrically at the midpoints of their respective filaments, or else to provide a separate voltage supply source for each filament.

In the copending application of Donald E. Richardson and Robert E. Yates, Serial No. 400,332, filed June 28, 1941, there is disclosed a control apparatus utilizing gas-filled tubes which are arranged to be maintained in a non-conductive state so long as a fuel burner or like system with which the control apparatus is associated is in normal operation, such tubes becoming conductive only in the event of an emergency requiring functioning of the control apparatus. This particular apparatus includes means for automatically checking the conductivity of each tube as a condition precedent to operation of the system, and if each tube is capable of conducting current the system is then conditioned for operation. It may be desirable to augment this initial conductivity test by making provision for a continuous check on the condition of the tube filaments all the time the control apparatus is being utilized, and hence it is another object of the present invention to afford such a check while the system is in operation without the necessity of connecting the filaments of the various tubes in series.

A more specific object is to match the impedances of two or more equally divided groups of filaments and to control the operation of the apparatus in dependence upon whether or not the impedances are evenly balanced electrically. An ancillary object is to provide a novel balancer system of transformers having a neutral connection through which the flow of current is regulated according to the relative loads on two or more of the transformers, where each transformer load comprises the combined impedance of a group of tube filaments, and to cause the control apparatus to function as though in response to an unsafe condition whenever a substantial current flow is set up in the neutral connection as a result of an unbalancing of load impedances indicative of a filament failure.

While the present invention is described herein as being particularly adapted for use in conjunction with a control apparatus for a fuel burner or like system, it will be understood that it is capable of more extensive applications wherever electronic control apparatus is employed, and hence it is to be understood that the invention is not limited to the exact use herein disclosed.

Other and further objects of the present invention will be apparent from the following description and claims and will be understood by reference to the accompanying drawing which, by way of illustration, shows a preferred embodiment and the principle thereof and what I now consider to be the best mode in which I have contemplated applying that principle. Other embodiments of the invention embodying the same or equivalent principle may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

The accompanying drawing is a diagrammatic illustration of my invention.

Referring to the drawing, the various electron tubes included in an electronic control apparatus are in the present instance shown divided into two groups, the tubes in one group being designated by the reference character 1 and those in the other group by the reference character 1'. The filaments 2 of the tubes 1 are connected in parallel by a pair of conductors 3 and 4 to the secondary 5 of a filament voltage supply transformer 6. Likewise, the filaments 2' of the tubes 1' are connected in parallel across the conductors 3' and 4' which lead to the secondary 5' of a filament voltage supply transformer 6'. An equal number of tube filaments are arranged to be supplied with voltage by the transformers 6 and 6', and if it should happen that there is an odd number of tubes in the apparatus, a balancing resistance is connected in parallel with the filaments in the group having the lesser number, the object being to equalize the loads on the transformers 6 and 6'. The cathodes 7 of the tubes 1 are preferably connected by a common conductor 8 to a center tap on the secondary 5 so that these cathodes will be electrically at the midpoints of the filaments 2. Similarly, the cathodes 7' of the tubes 1' are connected by a common conductor 8' to a center tap on the secondary 5'.

One end of the primary winding 9 of the transformer 6 is joined at junction 10 to one end of the primary winding 9' of the transformer 6', while the opposite ends of the primaries 9 and 9' are connected by conductors 11 and 11', respectively, to the ends of a secondary 12 of a transformer 13. The primary 14 of this transformer 13 is adapted to be energized from a suitable source of alternating current for operating the apparatus. The secondary 12 has a center tap 15 from which a conductor 16 leads to a junction or terminal 17 of a resistor 18, the other terminal 19 of the resistor 18 being connected by a conductor 20 to the junction 10 of the primaries 9 and 9'. The conductor 20 and the resistor 18 together constitute a neutral path or connection generally designated 21 extending between the junctions 17 and 10. Normally when the loads on the filament transformers 6 and 6' are substantially equally balanced, the secondary 12 of the transformer 13 supplies alternating current solely through the conductors 11 and 11' to the series-connected primary windings 9 and 9' of the transformers 6 and 6', and substantially no current flows through the path 21. However, if a filament in one of the tubes burns out, for example, a filament 2 in a tube 1, the load impedance on the secondary side of the corresponding filament transformer as 6 becomes greater than the impedance on the secondary side of the other transformer as 6', producing an unbalanced load condition, and under these circumstances current flows through the path 21. The phase relation of this current with respect to the impressed voltage depends upon which of the transformers 6 and 6' has the heavier load, as will be explained in greater detail presently.

In order to detect an unbalanced load condition, a pair of electron tubes 22 and 22' are arranged with their cathodes 23 and 23' connected in common to the terminal 17 of the resistor 18, while the anodes 24 and 24' of these tubes are respectively connected through the windings of relays 25 and 25' to the conductors 11 and 11'. In this manner the tubes 22 and 22' are adapted to be alternately rendered conductive to pass current through the windings of the relays 25 and 25' during alternate half-cycles of the impressed voltage. The relays 25 and 25' are of the alternating-current type and are provided with contacts 26 and 26' which are normally open when the relays are deenergized but which are maintained closed so long as the relays are energized by the currents in the anode circuits of the tubes 22 and 22'.

The control apparatus to which my invention pertains is particularly adapted to be used in combination with a fuel burner system as disclosed in the aforesaid copending application, Serial No. 400,332. Such a system includes a fuel valve 27 which is operated by a solenoid 28 for enabling fuel to be supplied to the burners in the system. Whenever an abnormal condition such as failure of combustion arises, however, the solenoid 28 is adapted to be deenergized by the control apparatus to enable the fuel valve 27 to close. For the purpose of enabling the operation of the solenoid 28 to be controlled in part according to the condition of the tube filaments, the relay contacts 26 and 26' are embodied in the circuit 29 through which the solenoid 28 is energized, this circuit extending through the contacts 26 and 26' in series when both of these contacts are closed. Since the relays 25 and 25' are both maintained energized under normal load conditions, the contacts 26 and 26' thereof remain closed so that there is no interruption of the circuit 29 insofar as these contacts are concerned.

The tubes 22 and 22', which are preferably of the gas-filled type, have control grids 30 and 30' which are connected through protective resistors 31 and 31' to the terminal 19 of the resistor 18. It will be recalled that the cathodes 23 and 23' are connected to the opposite terminal 17 of this resistor. Hence, if any current flows through the resistor 18 the control grids 30 and 31' may become biased with respect to their cathodes 23 and 23' due to the voltage drop in the resistor 18. The filaments 32 and 32' of the tubes 22 and 22' have been fragmentarily represented in the drawing but it is to be understood that these filaments will be supplied by voltage from a suitable source which may be independent of the transformers 6 and 6'. In this connection it should be noted that inasmuch as the tubes 22 and 22' are adapted to be normally maintained in a conductive condition when the filament loads are evenly balanced (each tube being rendered nonconductive only when there is a filament failure in the corresponding group of filaments 2 or 2' as will be explained presently) it is not essential that the conductivity of the tubes 22 and 22' should be continually checked in the manner in which this is done in the case of the tubes 1 and 1', because if a tube 22 or 22' becomes per-

manently nonconductive it immediately causes the holding circuit for the solenoid 28 to be broken so that the apparatus fails safely. However, to avoid providing extra filament transformers for the tubes 22 and 22' it may be desirable to connect the filaments 32 and 32' in parallel with the filaments 2 and 2', respectively, in order that they may be supplied with current by the transformers 6 and 6'. In this event the filaments 32 and 32' are included in the load impedances which are to be matched against each other, but of course this is only incidental to the purpose of minimizing the number of transformers which are required.

As an example of the manner in which the apparatus operates, it will be assumed that one of the filaments 2 of the tubes 1 burns out, thereby rendering its tube permanently nonconductive. As a result of this the total load impedance on the secondary 5 of the filament transformer 6 increases in value, producing an unbalanced load condition. During those half-cycles of the alternating current in which the conductor 11 is positive with respect to the conductor 11', current flows through the path 21 in a direction away from the junction 17 toward the junction 19. By reason of the voltage drop in the resistor 18 the terminal 19 becomes negative with respect to the terminal 17 during these half-cycles of the alternating current, thereby causing a negative bias to be applied on the control grid 30 of the tube 22. This is effective to prevent the tube 22 from conducting current, so that the relay 25 thereupon deenergizes and opens its contact 26. The circuit 29 for the solenoid 28 is thus broken, causing the solenoid 28 to deenergize and the fuel valve 27 to close and thereby interrupt the operation of the burners in the system. The tube 22' is unaffected under the conditions just assumed because during the half-cycles in which the conductor 11' is positive with respect to the conductor 11, current flows through the path 21 in a direction toward the junction or terminal 17. This produces a voltage drop in the resistor 18 of such polarity as to impart a positive bias to the control grid 30' so that the tube 22' is not prevented from conducting current.

If a filament 2' of one of the tubes 1' should burn out to thereby produce an unbalanced load condition, current flows through the path 21 in a direction away from the junction 17 during those half-cycles of the alternating current in which the conductor 11' is positive with respect to the conductor 11, that is to say, during those half-cycles during which the tube 22' is normally rendered conductive. Because of the voltage drop produced in the resistor 18 by the current flowing through the path 21, the junction 19 becomes negative with respect to the junction 17 and thereby a negative bias is impressed upon the control grid 30' of the tube 22'. The tube 22' is thus rendered continuously nonconductive and the relay 25' thereupon deenergizes to open its contact 26' and thus break the circuit 29, with the aforesaid effects. The tube 22 continues to conduct current during those half-cycles when the conductor 11 is positive with respect to the conductor 11' because the phase of the current flowing through the path 21 is such that the control grid 30 receives a positive bias due to the voltage drop in the resistor 18.

It will thus be seen from the foregoing that whenever a filament in any of the tubes 1 or 1' becomes defective so that its conductivity is impaired, either one or the other of the tubes 22 or 22' will cease to conduct current and thereby deenergize its relay 25 or 25' to break the circuit 29. The control apparatus may be so arranged that even a momentary interruption of the circuit 29 is sufficient to permanently disable this circuit even though a balanced load condition is restored, this being common practice in the art and hence not disclosed in detail herein. This is of utility in the event, for example, that one of the filaments 2 burns out, producing an unbalanced load condition, and shortly thereafter a filament 2' burns out to again equalize the loads. The possibility that there will be a simultaneous failure of an equal number of filaments 2 and 2' while the apparatus is in operation is so remote that for practical purposes it need not be considered. The tubes 22 and 22' react safely in the event a filament 32 or 32' burns out, inasmuch as this causes the tube to cease conducting and deenergize its relay 25 or 25' to thereby open the circuit 29.

Where the number of tubes 1 and 1' in the apparatus becomes quite large, it may be advisable to have more than two groups of tubes, in which event the various groups can be paired together and the filament loads balanced against each other in a manner similar to that explained hereinabove.

Another advantage of the illustrated apparatus is that it enables the operator to readily ascertain in which group the defective filament may be found. Thus, if there is a burned-out filament in one of the tubes designated 1, the tube 22 lights; whereas if the filament burn-out had occurred in one of the tubes designated 1', then the tube 22' would light. It will be understood, of course, that it is not essential to use electron tubes as 22 and 22' for detecting current flow in the neutral connection 21, any current-responsive means being suitable for this purpose.

Thus, while I have illustrated and described a selected embodiment of my invention, it is to be understood that it is capable of variation and modification and I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. In an electronic apparatus adapted to be operated from a source of electric current for controlling the operation of associated equipment and including a plurality of electron tubes adapted to be nonconductive when said equipment is operating normally and to become individually conductive in response to abnormal conditions arising with respect to corresponding parts of said equipment, each of said tubes including a filament adapted when energized to condition its tube for the conduction of current, the combination therewith of means electrically connecting the filaments of a group of said tubes in parallel to thereby afford a first load impedance, means electrically connecting the filaments of a group of tubes equal in number to the first-named group in parallel to afford a second load impedance, means individually coupling said load impedances in a circuit with said source of current for thereby energizing all of said filaments, said circuit extending through the coupled load impedances in series, means providing a neutral connection between said source of current and a point in said series circuit electrically intermediate the coupled impedances;

said load impedances, said circuit and said neutral connection being so constituted and arranged as to afford a normally balanced network in which said neutral connection normally conducts substantially no current, said network becoming unbalanced to enable said neutral connection to conduct current only when said impedances are of unequal value due to failure of a filament in any of said groups of tubes; and means responding to a flow of current in said neutral connection for indicating the fact that a tube has been rendered permanently nonconductive by reason of the aforesaid filament failure.

2. In an electronic apparatus adapted to be operated from a source of electric current for controlling the operation of associated equipment and including a pair of electron tubes adapted to be nonconductive when said equipment is operating normally and to become individually conductive in response to abnormal conditions arising with respect to corresponding parts of said equipment, each of said tubes including a filament having a predetermined impedance and adapted when energized to condition its tube for the conduction of current, the combination therewith of means individually coupling said filament impedances in a circuit with said source of current for thereby energizing said filaments, said circuit extending through the coupled impedances of said filaments in series, means providing a neutral connection between said source of current and a point in said series circuit electrically intermediate the coupled impedances; said impedances, said circuit and said neutral connection being so constituted and arranged as to afford a normally balanced network in which said neutral connection normally conducts substantially no current, said network becoming unbalanced to enable said neutral connection to conduct current only when said impedances are of unequal value due to failure of a filament in either of said tubes; and means responding to a flow of current in said neutral connection for indicating the fact that a tube has been rendered permanently nonconductive by failure of its filament.

3. In an electronic apparatus adapted to be operated from a source of alternating current for controlling the operation of associated equipment and including a pair of electron tubes adapted to be nonconductive when said equipment is operating normally and to become individually conductive in response to abnormal conditions arising with respect to corresponding parts of said equipment, each of said tubes including a filament having a predetermined impedance and adapted when energized to condition its tube for the conduction of current, the combination therewith of a pair of transformers each having primary and secondary windings, means connecting the primary windings of said transformers in series with each other and in circuit with said source of current, means individually connecting the secondary windings of said transformers respectively to said filaments for thereby enabling said filaments to be energized by said source of current, means providing a neutral connection between said source of current and the junction of said primary windings; said transformers, said series circuit means and said neutral connection being so constituted and arranged as to afford a normally balanced network in which said neutral connection normally conducts substantially no current, said network becoming unbalanced to enable said neutral connection to conduct current only when said impedances are of unequal value due to failure of a filament in either of said tubes; and means responding to a flow of current in said neutral connection for indicating the fact that a tube has been rendered permanently nonconductive by failure of its filament.

4. In an electronic apparatus adapted to be operated from a source of alternating current for controlling the operation of associated equipment and including a plurality of electron tubes adapted to be nonconductive when said equipment is operating normally and to become individually conductive in response to abnormal conditions arising with respect to corresponding parts of said equipment, each of said tubes including a filament adapted when energized to condition its tube for the conduction of current, the combination therewith of means electrically connecting the filaments of a group of said tubes in parallel to thereby afford a first load impedance, means electrically connecting the filaments of a group of tubes equal in number to the first-named group in parallel to afford a second load impedance, a pair of transformers each having primary and secondary windings, means connecting the primary windings of said transformers in series with each other and in circuit with said source of current, means individually connecting the secondary windings of said transformers respectively to said load impedances for thereby enabling said filaments to be energized by said source of current, means providing a neutral connection between said source of current and the junction of said primary windings; said transformers, said series circuit means and said neutral connection being so constituted and arranged as to afford a normally balanced network in which said neutral connection normally conducts substantially no current, said network becoming unbalanced to enable said neutral connection to conduct current only when said impedances are of unequal value due to failure of a filament in any of said groups of tubes; and means responding to a flow of current in said neutral connection for indicating the fact that a tube has been rendered permanently nonconductive by reason of the aforesaid filament failure.

5. In an electronic apparatus adapted to be operated from a source of alternating current for controlling the operation of associated equipment and including a plurality of electron tubes adapted to be nonconductive when said equipment is operating normally and to become individually conductive in response to abnormal conditions arising with respect to corresponding parts of said equipment, each of said tubes including a filament adapted when energized to condition its tube for the conduction of current, the combination therewith of means electrically connecting the filaments of a group of said tubes in parallel to thereby afford a first load impedance, means electrically connecting the filaments of a group of tubes equal in number to the first-named group in parallel to afford a second load impedance, a pair of transformers for individually coupling said load impedances in a circuit with said source of current to thereby energize all of said filaments, and means cooperating with said transformers and said source to afford a balancer network effective to compare the values of the coupled load impedances, said network being arranged to remain in a neutral state so long as said load impedances have like values and responding to an unbalanced load condition caused by filament

failure in either of said groups of tubes to give an indication of an unsafe condition of said apparatus.

6. In an electronic apparatus adapted to be operated from a source of alternating current for controlling the operation of associated equipment and including at least two electron tubes adapted to be nonconductive when said equipment is operating normally and to become individually conductive in response to abnormal conditions arising with respect to corresponding parts of said equipment, each of said tubes including a filament having a predetermined impedance and adapted when energized to condition its tube for the conduction of current, the combination therewith of a pair of transformers for individually coupling said filament impedances in a circuit with said source of current to thereby energize each of said filaments, and means cooperating with said transformers and said source to afford a balancer network effective to compare the values of the coupled impedances, said network being arranged to remain in a neutral state so long as said load impedances have like values and responding to an unbalanced load condition caused by filament failure in either of said tubes to give an indication of an unsafe condition of said apparatus.

7. In an electronic apparatus adapted to be operated from a source of alternating current for controlling the operation of associated equipment and including a plurality of electron tubes each including a filament effective when energized to condition its tube for the conduction of current, said tubes being adapted to be nonconductive when said equipment is operating normally and to become individually conductive in response to abnormal conditions arising with respect to corresponding parts of said equipment, the combination therewith of a first transformer having a primary winding connected to said source of current and including a secondary winding provided with a center tap and two end taps, second and third transformers having equal transformer ratios and each including a primary winding and a secondary winding, means connecting the primary windings of said second and third transformers in series with each other in a circuit extending between the end taps of said first transformer, means separately connecting the secondary windings of said second and third transformers to respectively associated groups of said tube filaments for thereby enabling said filaments to be energized by said source of current, said groups of filaments being so arranged as to afford equal load impedances, means providing a neutral connection between the center tap of said first transformer and the junction of the primary windings of said second and third transformers; said transformers, said connecting means and said neutral connection being so constituted and arranged as to afford a normally balanced network in which said neutral connection normally conducts substantially no current; and control means responsive to a flow of current in said neutral connection whenever said load impedances become unbalanced due to the failure of a filament in either of said groups for effecting a control operation with respect to said equipment.

8. An apparatus as set forth in claim 7, in which said neutral connection embodies a resistor and wherein said control means comprises a pair of electron tubes arranged to be biased in dependence upon the voltage drop set up in said resistor when current flows through said neutral connection, such biasing voltage serving to render at least one of said pair of tubes nonconductive, and means responsive to said pair of tubes and operating when either tube is rendered nonconductive to interrupt operation of said equipment.

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