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PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION.

Improvements in Ionic Relays.

We, WILLIAM HENRY ECCLES, City and Guilds Technical College, Leonard Street, E.C. 2, Professor of Electrical Engineering, and FRANK WILFRED JORDAN, City and Guilds Technical College, Leonard Street, E.C. 2, Electrician, do hereby declare the nature of this invention to be as follows :—

The relay is designed to produce a large and permanent change in the current flowing in an electrical circuit by means of a small electrical stimulus received from outside. In its simplest form it consists of two three-electrode ionic tubes with resistances. It is well-known that when the potential of the grid electrode relative to the filament is increased and decreased within certain limits, the current that can be sent through the tube from anode to filament by means of a battery of constant voltage increases and decreases correspondingly. In what follows the circuit comprising the space in the tube between anode and filament, the external conductors and the source of E.M.F. will be called the plate circuit and the current flowing in it the plate current. The circuit comprising the space in the tube between the grid and the filament, external conductors and a source of E.M.F. will be called the grid circuit and the current flowing in it the grid current.

The principle of the relay is most easily explained when two tubes, each with resistances and battery in its plate circuit and with a resistance and battery in its grid circuit, are used and interconnected in the following manner :—

The electrical stimulus from outside which it is desired to detect is applied in the grid circuit of the first tube so as to make the grid transiently more positive in potential relative to the filament. This causes an increase of current in the plate circuit of the first tube and consequently an increase of the potential difference between the terminals of the plate circuit resistance. This increased potential difference is transferred to the grid circuit of the second tube in such a manner that the grid becomes more negative than before relative to its filament. Consequently the plate current of the second tube decreases and the potential difference between the terminals of its plate circuit resistance decreases also. This decrease of potential difference is now transferred to the grid circuit of the first tube in such a manner that it tends to make the grid more positive relative to the filament. The result of these processes is that a positive stimulus from outside given to the grid of the first tube initiates a chain of changes, which result finally in the plate current of the first tube attaining the highest value possible under the E.M.F. of its battery and the plate current of the second tube falling to its lowest possible value. This condition persists after the disappearance of the initial stimulus. In the initial condition with the two-tube arrangement just described the plate current of the first tube is made very small and that of the second tube large; after the reception of the outside stimulus on the grid of the first tube the final condition is a large plate current in the first tube and a small plate current in the

second tube. Either the decreases or the increases of plate current can be used for indicating. In order to restore the initial conditions it is necessary to interrupt for an instant the linkage between the tubes or to stop the operation of one or both of the tubes, as for instance by dimming its filament.

In the above described arrangements only two tubes have been used. More than two tubes may be used, and when more than two are used inductance and capacity transformers may be utilised as essential parts between tubes in addition to resistances.

Dated this 21st day of June, 1918.

H. G. LAW,
Agent for the Applicants.

COMPLETE SPECIFICATION.

Improvements in Ionic Relays.

We, WILLIAM HENRY ECCLES, Professor of Electrical Engineering, and FRANK WILFRED JORDAN, Electrician, both of City and Guilds Technical College, Leonard Street, City Road, London, E.C. 2, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement :—

The relay is designed to produce a change in the current flowing in an electrical circuit or in the voltage between two points of an electrical circuit in response to a small electrical stimulus received from outside. In its simplest form it consists of two three-electrode ionic tubes with resistances and batteries. It is well known that when the potential of the grid electrode relative to the filament is increased and decreased within certain limits, the current that can be sent through the tube from anode to filament by means of a battery of constant voltage increases and decreases correspondingly. In what follows the circuit comprising the space in the tube between anode and filament, the external conductors between anode and filament and any source of E.M.F. in the conductors will be called the anode or the plate circuit and the current flowing in it the anode or the plate current. The circuit comprising the space in the tube between the grid and filament, external conductors between grid and filament and any source of E.M.F. in the conductors will be called the grid circuit and the current flowing in it the grid current.

Now in the simplest form just alluded to, the anode circuit of the first tube contains a source of voltage and a resistance and from this resistance a tapping is taken through a battery to the grid of the second tube. The filament of this second tube is connected to the filament of the first tube. The anode circuit of the second tube also contains a source of voltage and a resistance, and from this resistance a tapping is taken through a battery to the grid of the first tube. If therefore a small voltage be applied between the grid and filament of the first tube a change is produced in the current flowing through the second anode circuit and the variation of the potential difference or a part of it arising along the resistance in the anode circuit of the second tube is passed back to the grid of the first tube. It is easy to show that if the batteries be suitably chosen the system is stable or unstable according as G1. G2. R1. R2 is less or greater than (R1 + S1) (R2 + S2) where G1, G2 are the voltage factors of the tubes, R1, R2 the resistances tapped off in the plate circuits, and S1, S2 the resistances of the tubes together with the external resistances not tapped off. That is to say if G1, G2, R1, R2 is less than (R1 + S1) (R2 + S2) the relay will operate in a state of stability, while if G1, G2, R1, R2 is greater than (R1 + S1) × (R2 + S2) the relay will operate in a state of instability and any change initiated by the voltage applied even temporarily to the first grid will be permanent. It is clear from this that by suitably varying the magnitudes of the resistances, or of the voltage factors of the tubes, a relay giving a permanent response to a transient stimulus or one giving a non-permanent response can be designed as desired. It is found that a very good permanent response can be obtained by having the above mathematical greater inequality barely satisfied and using the relay with the currents in the two tubes initially very unequal; and on the other hand that a self restoring relay can be obtained by satisfying the lesser inequality and using currents in the two tubes normally nearly equal.

The principle of the relay is most easily

explained by reference to Figure 1 accompanying this specification, where two tubes each with resistances and battery in its anode circuit and with a resistance and battery in its grid circuit, are used. In this example it will be supposed that the magnitudes of the resistances are arranged so that the working condition is one of instability.

The electrical stimulus from outside which it is desired to detect is applied in the grid circuit S in the first tube so as to make the grid G1 transiently more positive (for example) in potential relative to the filament. This causes an increase of current in the anode circuit of the first tube and consequently an increase of the potential difference between the terminals of the anode circuit resistance R1. This increased potential difference is transferred to the grid of the second tube in such a manner that the grid becomes more negative than before relative to its filament. Consequently the anode current of the second tube decreases and the potential difference between the terminals of its anode circuit resistance R2 decreases also. This decrease of potential difference is now transferred to the grid circuit of the first tube in such a manner that it tends to make the grid more positive relative to the filament. The result of these processes is that a positive stimulus from outside given to the grid of the first tube initiates a chain of changes which, if the conditions for instability are supposed to have been arranged, will result finally in the anode current of the first tube attaining the highest value possible under the E.M.F. of its battery and the anode current of the second tube falling to its lowest possible value. This condition persists after the disappearance of the initial stimulus in the example here being discussed. In the initial condition with the two tube arrangement just described the anode current of the first tube is made very small and that of the second tube large; after the reception of the outside stimulus on the grid of the first tube the final condition is a large anode current in the first tube and a small anode current in the second tube. Either the decreases or the increases of anode current can be used for indicating, or, if desired, the difference of potential arising between points of the circuits. In order to restore the initial conditions it is necessary in this example to interrupt for an instant the linkage between the tubes or to stop the operation of one or both of the tubes, as for instance by dimming its filament. If on the other hand the conditions are those for stable working the electrical changes persist only while the outside stimulus is steadily applied.

In the above described arrangements two tubes have been shown, but any even number of tubes may be used in cascade the anode circuit of the last being linked with the grid circuit of the first; an even number of tubes is required so that the electrical action passed back from the last tube to the first shall be of the same sign as the original stimulus applied to the first grid. We may also use any even number of tubes by grouping them in pairs, arranging each pair independently in accordance with this invention and combining the pairs in any suitable manner, as for example by including transformers in addition to resistances in the circuits. In speaking of pairs or even numbers of tubes in this paragraph and throughout this specification we wish it to be understood that two or more tubes connected in parallel for the sake of passing a larger current than is appropriate for one tube to pass must be counted as one tube. Thus, as an example, when large currents are expected and only small tubes are available, we may clearly use say three tubes connected with grids joined in parallel and with anodes joined in parallel as our so called first tube and say four tubes connected with grids joined in parallel and with anodes joined in parallel as our so called second tube, for these grouped tubes are used instead of single large tubes. We may on the other hand in the typical two tube arrangement place the two anodes with their respective grids and with one filament in one evacuated vessel without departing from the spirit of our invention, these two sets of electrodes would therefore be regarded as two valves or tubes although situated in one bulb.

We do not wish to be limited to the specific circuit arrangements shown in Figure 1 which is only an example. Various other circuit arrangements may be employed without departing from the spirit of the invention. As another example the circuit of Figure 2 may be given. Here a stimulus applied to the grid G1 of the first tube gives rise to a change of current in the anode circuit resistance R1, and the consequent change of potential along this resistance is communicated to the grid G2 of the second tube, this change of potential being of opposite sign from that initially imposed upon the grid G1 of the first tube. The

change now produced in the anode current and in the potential drop along the resistance R2 in the anode circuit of the second tube is communicated to the grid G1 of the first tube, its sign being the same as that of the stimulus applied initially to the first grid. In both these modes of connection shown in the figures the batteries e^1, e^2, in the grid circuits are introduced for the purpose of adjusting the voltages of the grids to suitable values according to the well known methods of using three-electrode tubes. Further in each of the circuits shown in the figures and in other circuits it is, for example, possible to replace the anode batteries E1, E2 shown in the figures by batteries with resistances in series or in parallel with them, or to place either anode battery or a portion of it in any other part of the anode circuit. Also the input arrangements may, instead of the transformer shown, take a variety of well known forms of apparatus for transferring voltage and may be altered in position in the circuits; and the indicating instruments I shown in the figures may be replaced by known apparatus for indicating or transferring changes in current or voltage either at the positions shown or at other positions in the circuits. Further the conductive electrical connection shown in the figures as passing direct from the resistance in the anode circuit of the one tube to the grid of the other tube may be replaced by any conductive chain of apparatus known in the art provided that the electrical action so communicated from the anode circuit of the one tube to the grid circuit of the other tube is substantially the same in sign or phase as the action that would actually be communicated by a direct conductive connection.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is :—

1. A method of relaying or enhancing an electrical action or stimulus communicated to the control electrode of an ionic tube or valve by connecting together electrically a pair or an even number of ionic valves or three-electrode tubes with intervening resistances and with return conductive connection from the last to the first to obtain by retroaction or by a chain of electrical reactions a strengthening of the initial stimulus.

2. A relay for enhancing magnifying or indicating an electrical action or stimulus impressed upon a three-electrode valve or tube or other ionic tube, more particularly upon the grid or control circuit of the valve or tube, comprising a pair or pairs of valves or tubes, with resistances in their plate or anode and grid or control circuits, and connected electrically in sequence and with a return conductive connection from the last to the first to give a return effect or retroaction of the same sign as the original stimulus and obtain magnification or indication.

3. A method of relaying or magnifying in electrical circuits for use in telegraphy and telephony by the use of two three-electrode tubes or valves arranged so that the potential difference along a resistance in the anode circuit of the first tube or valve is communicated to the control electrode or grid of the second tube or valve and the potential difference along a resistance in the anode circuit of the second tube or valve is communicated conductively to the control electrode or grid of the first tube or valve in order to enhance any electrical action or stimulus communicated to the control electrode of the first tube or valve.

4. The use of a pair or pairs or an even number of three-electrode valves or tubes connected in sequence by resistances and so that the potential difference along a resistance in the anode circuit of the last valve or tube is communicated conductively to the control electrode of the first valve or tube.

5. A relay or amplifying apparatus comprising a pair of three-electrode valves so arranged that an increase in potential occurs on the grid of the first valve relative to its filament, and by reason of a potential difference derived from a resistance in the anode circuit of the first valve the grid of the second valve becomes more negative relative to its filament so that the anode current of the second valve decreases, and a decrease of potential difference from a resistance in the anode circuit of the second valve is transferred conductively to the grid circuit of the first valve in order to get a high or maximum value for the anode current of the first valve and a low or minimum value for the anode current of the second valve.

6. A relay or amplifying apparatus comprising a pair of three-electrode valves so arranged that a decrease in potential occurs on the grid of the first valve relative to its filament and by reason of a potential difference derived from a resistance in the anode circuit of

the first valve the grid of the second valve becomes more positive relative to its filament so that the anode current of the second valve increases and an increase of potential difference from a resistance in the anode circuit of the second valve is transferred conductively to the grid circuit of the first valve in order to get a low or minimum value for the anode current of the first valve and a high or maximum value for the anode current of the second valve.

7. The method of relaying or enhancing an electrical action or stimulus by a pair or even number of three-electrode tubes substantially as described.

8. A relay or magnifying apparatus for telegraphic work comprising a pair or even number of three-electrode tubes substantially as described.

Dated this 16th day of February, 1920.

H. G. LAW,
Agent for the Applicants.

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(2nd Edition)

FIG. 1.

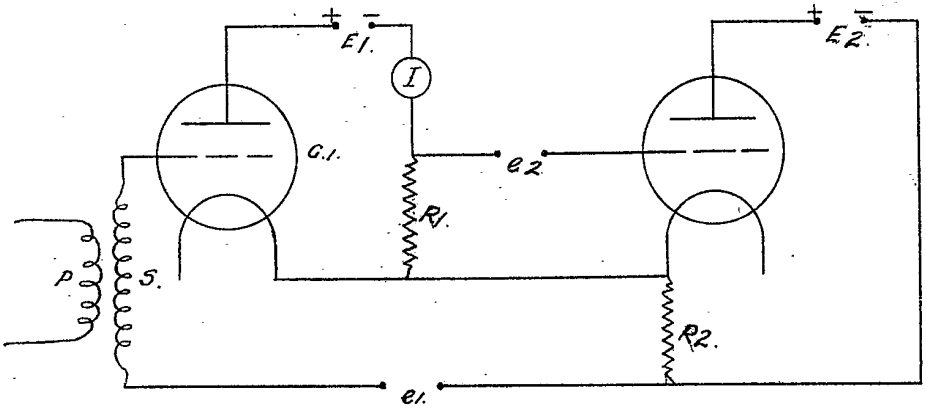
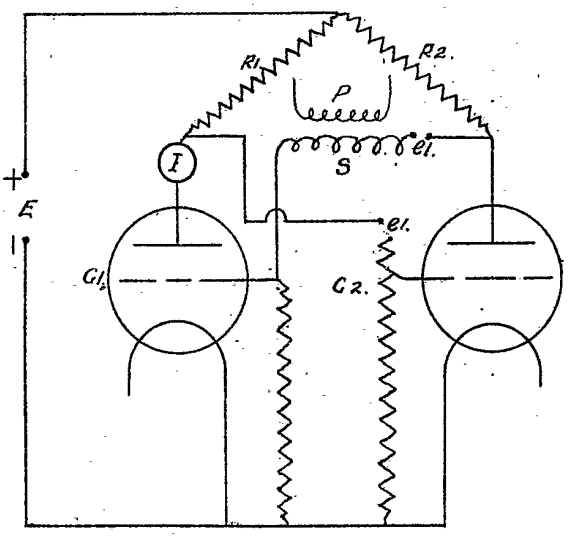


FIG. 2.



[This Drawing is a reproduction of the Original on a reduced scale.]

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