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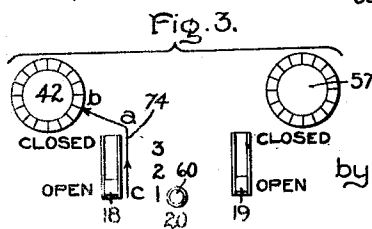
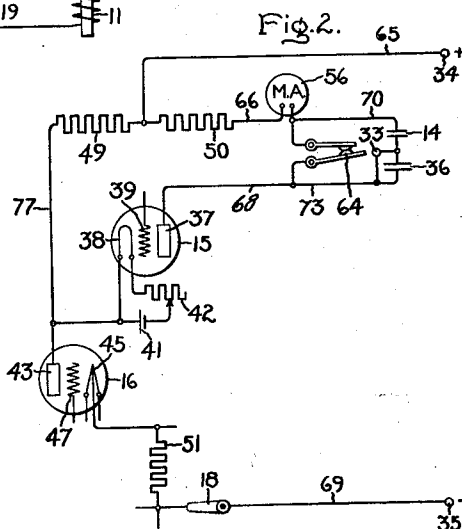
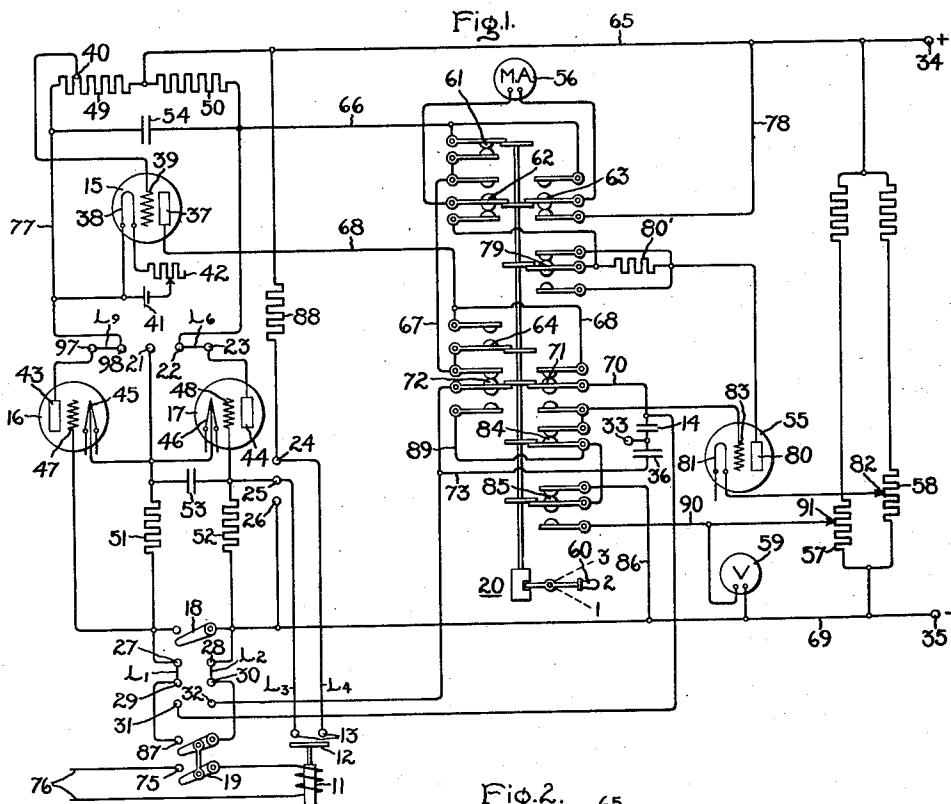
M. E. BIVENS

2,021,766

ELECTRONIC TIMER

Filed June 28, 1934

5 Sheets-Sheet 1



Inventor:
Maurice E. Bivens.
by *Harry E. Dunham*
His Attorney

Nov. 19, 1935.

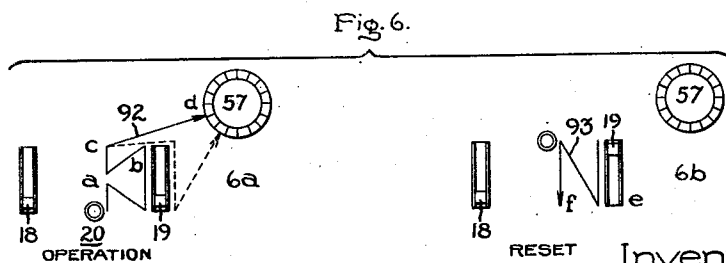
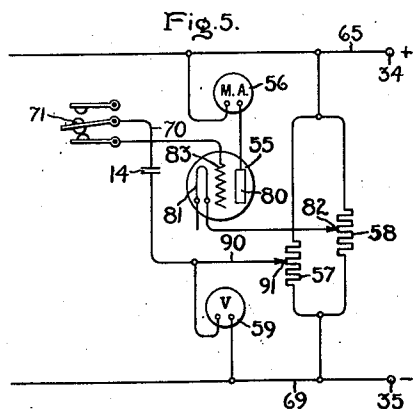
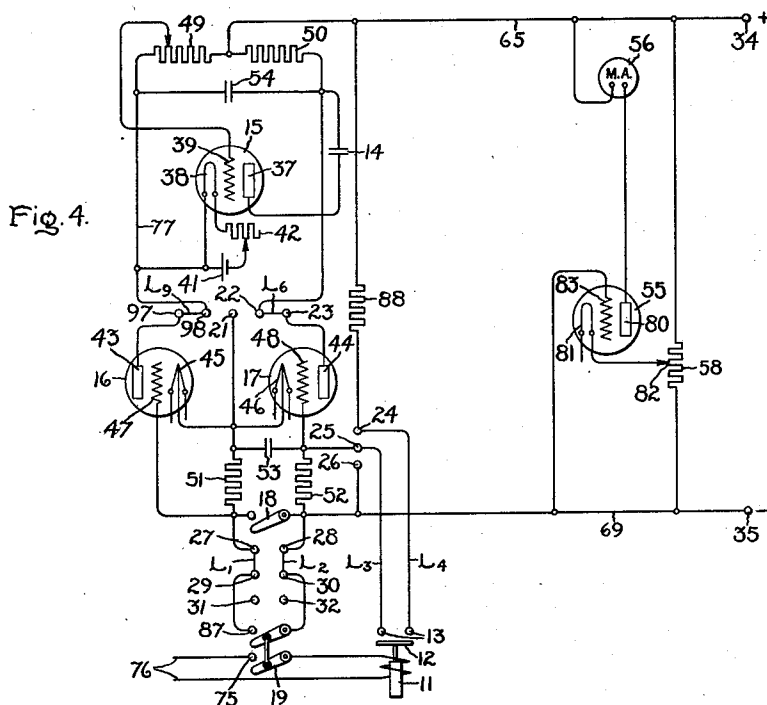
M. E. BIVENS

2,021,766

ELECTRONIC TIMER

Filed June 28, 1934

5 Sheets-Sheet 2



RESET

Inventor:

Maurice E. Bivens,

Harry E. Dunham

His Attorney.

Nov. 19, 1935.

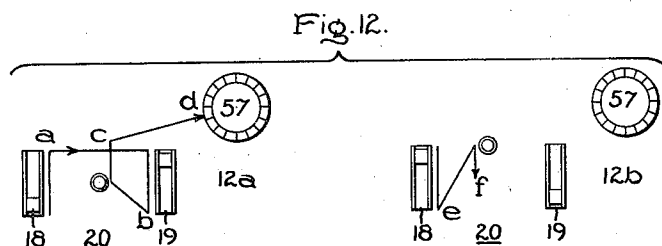
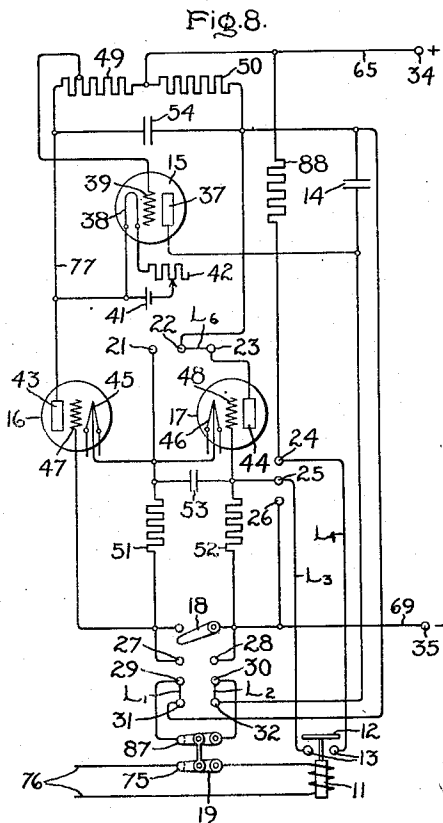
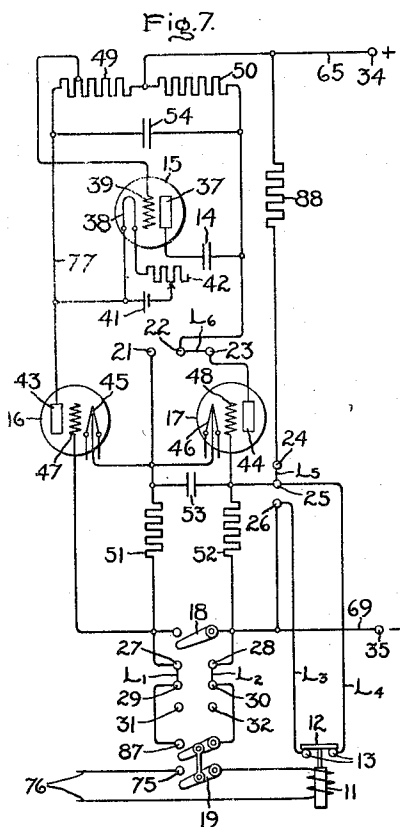
M. E. BIVENS

2,021,766

ELECTRONIC TIMER

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5 Sheets-Sheet 3



Inventor:
Maurice E. Bivens,
by *Harry E. Dunham*
His Attorney.

Nov. 19, 1935.

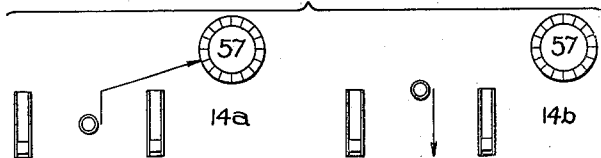
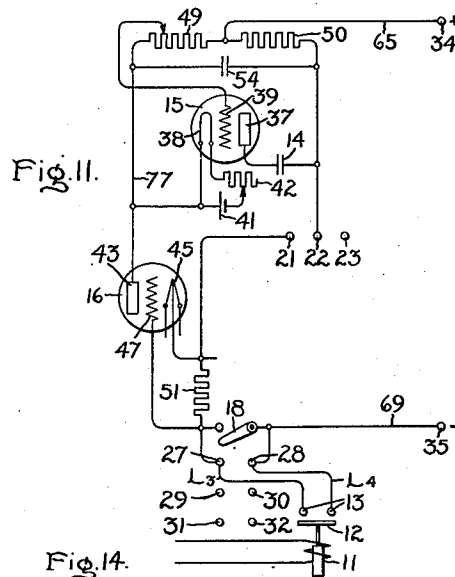
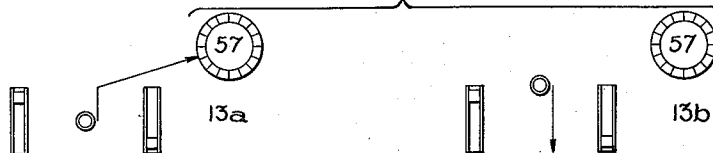
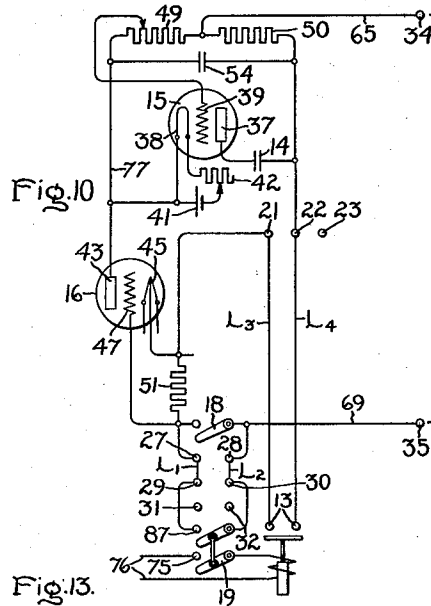
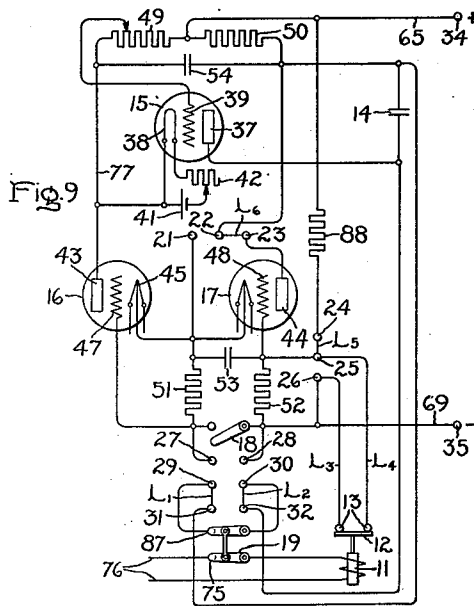
M. E. BIVENS

2,021,766

ELECTRONIC TIMER

Filed June 28, 1934

5 Sheets-Sheet 4



Inventor:
Maurice E. Bivens,
by *Harry E. Dunham*
His Attorney.

Nov. 19, 1935.

M. E. BIVENS

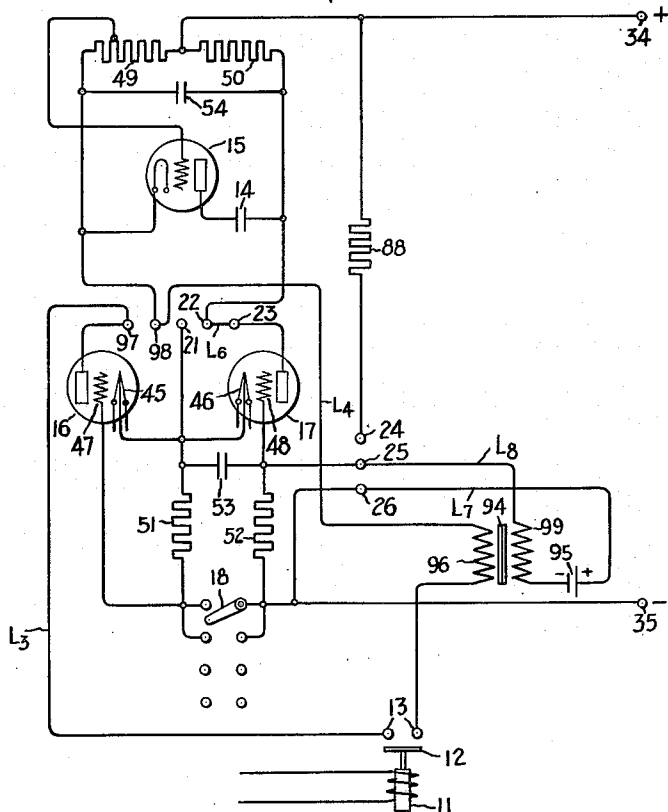
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Fig. 15.



Inventor
Maurice E. Bivens,
by *Harry E. Dunham*
His Attorney

UNITED STATES PATENT OFFICE

2,021,766

ELECTRONIC TIMER

Maurice E. Bivens, Media, Pa., assignor to General Electric Company, a corporation of New York

Application June 28, 1934, Serial No. 732,827

16 Claims. (Cl. 175-183)

My invention relates to timing devices and concerns particularly electronic timers for checking relay operations.

It is an object of my invention to provide an inertialess device for measuring extremely short, as well as longer, intervals of time with accuracy.

It is a further object of my invention to provide a device which may be set for measuring not merely the time interval between the opening and closing of an electrical contact or vice versa but also the time interval between the opening or closing of one electrical contact and the opening or closing of another electrical contact.

The objects of my invention include providing a relay timer for measuring both total time, open or closed, as well as the operating time of either normally-open or normally-closed relays either when energized or when deenergized.

Other and further objects and advantages will become apparent as the description proceeds.

In accordance with my invention in its preferred form, I determine the time required for the consummation of an operation by determining the amount of charge supplied to a timing condenser through a constant-current circuit during the operation. Preferably, I supply inertialess means, such as grid-controlled discharge tubes, for controlling the starting and stopping of the charging current at the beginning and the end of an operation to be measured. The discharge tubes are connected in parallel circuits with resistors in their anode leads or source of current. Current is initiated in one tube at the beginning of a time interval to be measured and shifted to the other at the end of the interval by controlling potential of the control grids in response to operations to be timed. In consequence, a potential difference is built up and then reversed between the tube anodes. A timing condenser in series with a constant-current rectifier is connected between the anodes of the discharge tubes and receives charging current only during the time interval. The voltage acquired by the timing condenser is compared with a measurable voltage to determine the length of the time interval. Changeable connections are provided to permit connecting a relay to be tested in the apparatus in different ways with respect to the control grids of the tubes for the purpose of checking different types of relay operations.

The features of my invention which I believe to be novel and patentable will be pointed out in the claims appended hereto. A better understanding of my invention, itself, however, may be obtained by referring to the following description

taken in connection with the accompanying drawings.

Fig. 1 of the drawings is a circuit diagram of an embodiment of my invention; Fig. 2 is a simplified diagram of a portion of the apparatus of Fig. 1 showing the circuit made when the apparatus is set for adjusting the charging current of the timing condenser; Fig. 3 is a symbolic operation diagram showing the manner in which the apparatus is manipulated to obtain the circuit of Fig. 2 and to adjust the condenser-charging current; Fig. 4 is a simplified circuit diagram of the apparatus set for testing the closing of the contacts of a relay when the relay is energized; Fig. 5 is the circuit diagram of the setting for measuring the charge collected by the timing condenser to determine the operating time of the relay; Fig. 6 is a symbolic operating diagram of the manipulation of the apparatus for timing the operation of a relay when energized. Simplified circuit diagrams of the apparatus set for timing some other types of relay operations are shown in the following figures: Fig. 7, relay with circuit-opening contacts when energized; Fig. 8, relay with circuit-closing contacts when deenergized; Fig. 9, relay with circuit-opening contacts when deenergized; Fig. 10, operating time of relay with circuit-closing contacts when energized including summation of opening time intervals of bouncing contacts, or duration of one or more intervals with contacts open; and Fig. 11, duration of one or more intervals with contacts closed. Figs. 12, 13 and 14 are symbolic operating diagrams representing the manipulation of the apparatus respectively for testing the operation of a relay when deenergized, for measuring the duration of one or more intervals with contacts open, and for measuring the duration of one or more intervals with contacts closed. Fig. 15 is a simplified circuit diagram of the apparatus set for timing the first only of a series of contact closures.

Referring now more in detail to the drawings in which like reference characters are used to designate like parts throughout, in Fig. 1, a relay to be tested is shown at 11 with a movable contact 12 and stationary contacts 13. The timing apparatus includes a timing condenser 14, a constant-current tube 15 connectible in series with condenser 14, and a pair of grid-controlled discharge tubes 16 and 17 for controlling the charging of condenser 14. Switches 18 and 19 are provided for operating the apparatus to test a relay, and a switch 20 is provided for changing the circuits of the apparatus for adjusting, relay testing, or reading in a manner which will be

explained hereinafter. A plurality of connection posts or terminals 21 to 33, 97 and 98, adapted to be joined by connecting links or leads are provided for reconnecting the apparatus to make

- 5 different types of time measurements or for testing different types of relay operations also in a manner to be explained. Current is supplied to the apparatus from a suitable source through terminals 34 and 35.
- 10 If desired, the range of the apparatus may be extended by connecting a second condenser 36, preferably of different capacity, in series with condenser 14 and either connecting a jumper from terminal 33 to one of the terminals 31 or
- 15 32 to short out one of the condensers or leaving the condensers in series to obtain different values of capacity.

- The constant-current tube 15 may be of any desired type, such as a three-element vacuum tube having an anode 37, a filamentary cathode 38, and a grid 39 which may be tied to the cathode 38 or to a point 40 slightly more positive. The cathode 38 is heated by a current source 41, and its emission is controlled by a rheostat 42.
- 20 The tube 15 is operated in the saturated portion of its characteristic curve so that the entire filament emission is attracted by the anode and the current remains substantially constant regardless of variations in anode voltage within the operating range.

- The discharge tubes 16 and 17 may, if desired, be of the gas or vapor-filled discharge type and are provided with anodes 43 and 44, cathodes 45 and 46, and control grids 47 and 48. The anodes 43 and 44 are connected through resistors 49 and 50 to terminal 34 of source 34—35, and the cathodes 45 and 46 are joined and connected through a resistor 51 to one terminal of switch 18, which is interposed between resistor 51 and terminal 35 of source 34—35. The grid 47 is connected to the common terminal of resistor 51 and switch 18, and the grid 48 is connected through a resistor 52 to the live terminal of switch 18 or terminal 35 of source 34—35. Preferably, a condenser 53 is connected between cathode 46 and grid 48 to hold grid 48 negative for an instant and prevent tube 17 from firing when switch 18 or 19 is closed. A condenser 54 is connected across the ends of resistors 49 and 50 to depress the anode potential of either tube 16 or 17 when the other is made conducting and to facilitate shifting current from tube 16 to tube 17 and vice versa, as will be explained.

- A thermionic voltmeter for measuring the charges accumulated by condenser 14 is also provided, including a three-element discharge tube 55, a plate milliammeter 56, potentiometers 57 and 58, and a comparison voltmeter 59, which may, of course, be calibrated directly in milliseconds.

- The switch 20 has three positions indicated by the positions 1, 2 and 3 of the handle 60 by means of which the movable contacts may be moved upward for position 1 or downward for position 3, as is apparent from the drawings. In order to adjust the charging current of condenser 14, the switch 20 is moved to position 1 or the adjusting position; before timing a relay, switch 20 is moved to position 2 or the testing position; and for reading the length of the time interval measured in the testing position, the switch 20 is moved to position 3 or the checking position.

- When switch 20 is moved to the adjusting position 1, its movable contact 61 is lifted, breaking
- 75 the charging circuit from terminal 34 and resistor

50 to timing condenser 14, and contacts 62, 63 and 64 are lifted against corresponding stationary contacts to form a circuit from terminal 34 of current source 34—35 through conductor 65, resistor 50, conductor 66, contact 63, milliammeter 56, contact 62, conductor 67, contact 64, conductor 68, constant-current tube 15 (through electrodes 37 and 38), discharge tube 16 (through electrodes 43 and 45), resistor 51, switch 18, conductor 69, to terminal 35 of source 34—35. For convenience this circuit has been redrawn as Fig. 2, showing only the portion of the apparatus included in the circuit. It will be observed that the lifting of contact 64 also shorts out the timing condenser 14 (or 36) by closing a connection across the condensers through a conductor 70, contacts 71, 64, 72 and conductor 73. The desired charging-current adjustment is obtained by adjusting the emission of tube 15 by means of rheostat 42 until the tube passes the desired current as indicated by the milliammeter 56.

The manner of manipulating the apparatus to adjust the value of charging current is shown symbolically in Fig. 3, in which the switches 18, 19 and 20, the rheostat 42, and potentiometer 57 are represented schematically by means of their operating handles or control dials. The switches 18 and 19 are open when the handles of switches 18 and 19 are down, and closed when their handles are up. Likewise, the positions marked 1, 2, and 3 are the positions of handle 60 of switch 20 for the current-adjusting, testing and reading positions, respectively. As indicated in Fig. 3, before the charging current adjustment is made, switches 18 and 19 are in their open positions, and switch 20 is in position 1. The letters *a*, *b*, *c* along the bent arrow 74 which rises along the slot for the handle of switch 18 and then points toward the control dial of rheostat 42, indicate that in adjusting charging current, first switch 18 is moved from the open to the closed position (operation *a*), then the rheostat 42 is adjusted (operation *b*), and finally the switch 18 is returned to the open position (operation *c*). Since change of position or adjustment of switches 18 and 19 and potentiometer 57 is not required during the adjustment of charging current, no arrows are shown in Fig. 3 along the symbols for these elements of the apparatus.

To time a relay with circuit-closing contacts, when energized, the relay 11 is connected as shown in Figs. 1 and 4 with the lower blade and stationary contact 75 of double-pole switch 19 interposed in the circuit to the exciting winding of relay 11 from a source of current 76. The switch 20 is moved to position 2 and the circuit of Fig. 4 results, as will now be explained.

Referring to Fig. 1, condenser 14 and constant-current tube 15 are connected in series across the ends of resistors 49 and 50 in a circuit comprising conductor 66, contacts 61, conductor 67, contacts 72, conductor 73, timing condenser 14 (assuming that the alternative timing condenser 36 is shorted out by means of a jumper across its terminals 32 and 33), conductor 70, contacts 71, conductor 68, anode 37 of tube 15, its cathode 38, and conductor 77. A plate circuit for thermionic voltmeter tube 55 is formed from terminal 34 of source 34—35, through conductor 78, contacts 63, milliammeter 56, contacts 62 and 79, anode 80 of tube 55, cathode 81, to tap 82 of potentiometer 58. A grid circuit is also formed from grid 83 of tube 55, through contacts 84 and 85, and conductors 86 and 69 to terminal 35 of source 34—35.

In timing the relay, after switch 20 has been moved to position 2 to give the circuit of Fig. 4, switch 19 is closed. This simultaneously energizes relay 11 by closing contacts 76, and energizes discharge tube 16 by closing contacts 87 of switch 19. In the specific embodiment of my invention illustrated in the drawings, the arrangement is such that I prefer to employ at both 16 and 17 tubes having negative grid-control characteristics, i. e., they are conductive when the grid voltage is less negative than a given value. When switch 19 is closed, the negative charge on condenser 53 holds the potential of grid 48 below the critical value for a sufficient length of time to prevent tube 17 from becoming conducting and permitting tube 16 to become conducting. Accordingly, current flows from terminal 34, through conductor 65, resistor 49, conductor 77, link L_a, anode 43 of tube 16, cathode 45, resistor 51, link L₁, contact 87 of switch 19, link L₂, and conductor 69 to terminal 35 of source 34—35. Both grids 47 and 48 are driven negative by the drop in resistor 51 so that current cannot start in tube 17. However, current having started in tube 16 continues regardless of the grid voltage in accordance with the known characteristic of gas or vapor-filled discharge tubes.

The tube 16 has a high conductivity compared with tube 15 and when tube 16 becomes conducting there is a relatively large voltage drop in resistor 49. This voltage drop is impressed on timing condenser 14 through resistor 50 and tube 15, and condenser 14 is charged at a substantially constant rate controlled by constant-current tube 15 from the instant when switch 19 is closed.

When the relay 11 operates to close its contacts 13, however, the grid 48 of tube 17 is driven positive being connected to the positive side of the line through lead L₃, contacts 13, lead L₄, and a resistor 88. In consequence, tube 17 becomes conducting, current flows from terminal 34 through conductor 65, resistor 50, tube 17, resistor 51, switch 19, and conductor 69 to terminal 35 of source 34—35. A voltage drop takes place in resistor 50 and the anode potential of tube 16 is momentarily depressed so far as to extinguish the current in tube 16 by reason of the voltage drop in resistor 51 and the negative charge which had been built up in condenser 54. Although the charge then quickly leaks off condenser 54, tube 16 cannot regain conductivity since its grid 47 is held negative by the voltage drop in resistor 51, now maintained by the plate current of tube 17.

As a result of the shift of current from tube 16 to tube 17, and from resistor 49 to resistor 50, reversing the polarity of the IR drop in circuit 49, 50, 14, 15, 77, the cathode of tube 15 becomes positive with respect to its anode 37 and current cannot flow therein, thereby stopping the charging of timing condenser 14 and isolating it from the circuit. The reading of milliammeter 56, indicating the plate current of voltmeter tube 55, is observed. The plate current may be set at a suitable value if desired by adjusting the ratio between plate voltage and grid bias of tube 55 by means of sliding tap 82 of potentiometer 58.

The magnitude of the charge collected by condenser 14 is now measured to determine the operating time of the relay 11, the time during which condenser 14 was being charged. For this purpose, switch 20 (Fig. 1) is moved to its reading position 3.

In order to prevent shorting the timing condenser 14, the arrangement is such that the con-

tact 84 opens before the movable contacts 71 and 72 close on the corresponding lower stationary contacts.

It will be observed that during the opening of contact 85, the grid 83 of the tube 55 is momentarily free. During this transition period, the negative grid bias (from 82 to 35) is removed and the plate current of tube 15 would increase appreciably, possibly causing the milliammeter 56 to swing off scale materially if it were not for the simultaneous operation of contacts 79 and 85.

A resistor 80' provided in series with anode 80 of tube 55 and the movable contact 79 is of such magnitude that when the resistor 80' is inserted in the anode circuit by the momentary opening of contact 79, the plate current is limited to approximately normal value, that is, the value of plate current with no plate resistance and with the grid bias opposed by the drop from 82 to 35. When the switch 20 (Fig. 1) is moved to position 3, the reading position, the circuit shown in the simplified diagram of Fig. 5 results as will now be explained.

In Fig. 1 lowering movable contacts 79, 71, 72 and 85 of switch 20 against the corresponding lower stationary contacts closes a circuit from terminal 34 of source 34—35 through conductors 78, contacts 63, milliammeter 56, contacts 62, contacts 79, anode 80 of tube 55, its cathode 81, to tap 82 of potentiometer 58 just as in the testing position 2 of switch 20, represented by Fig. 4. The grid circuit, however, is changed. It may be traced from grid 83 through contact 71, conductor 70, condenser 14 (assuming again that condenser 36 has been shorted out by a jumper between posts 32 and 33), conductor 73, lower contacts 72, conductor 89, lower contacts 85, conductor 90 to tap 91 of potentiometer 57. The voltmeter 59 is permanently connected between tap 91 and the lower ends 35 of potentiometers 57 and 58.

It will be observed that instead of being connected directly to terminal 35, grid 83 is now connected to tap 91 of potentiometer 57 through the timing condenser 14 (Figs. 4 and 5). The condenser 14 is so connected that the voltage of the condenser 14 opposes the positive bias provided by tap 91. If necessary, the tap 91 is adjusted along potentiometer 57 until milliammeter 56 gives the same reading of plate current as before, indicating that the voltage of condenser 14 equals that between tap 91 and terminal 35. This voltage may be read by voltmeter 59. Since condenser 14 is in the grid circuit, no current is drawn from it and its voltage is accurately determined.

The time interval to be measured or the operating time of the relay 11 is readily deduced from the voltage just measured of condenser 14. If E represents the voltage developed in condenser 14 during a time interval to be measured, I represents the charging current in milliamperes, C the capacity in microfarads, and T the time in milliseconds, then

$$T = \frac{E \cdot C}{I}$$

If the charging current in milliamperes I is adjusted to be numerically equal to the microfarads C of the timing condenser, the voltage reading of voltmeter 59 will represent the time in milliseconds. For other adjustments of the charging current or capacity to extend the operating range of the timer, a multiplication factor (C/I) is used. For example, if condenser 36 is made to have ten times the capacity of condenser 14, the

range of the time may be increased ten times by short-circuiting condenser 14 by a jumper between posts 31 and 33 and allowing condenser 36 to be charged instead.

5 The operations to be performed in timing a relay when energized and reading the length of the time interval are represented symbolically in Fig. 6, in which the parts of the apparatus to be operated are illustrated schematically as explained in connection with Fig. 3. Part 6a of the figure represents the operation and part 6b the resetting of the apparatus. Referring to the Figure 6a, and following the broken line 92 towards its arrow head, switch 20 is moved from position 1 to testing position 2 (operation a), switch 19 is moved from open position to closed position (operation b), switch 20 is moved to its reading position 3 (operation c), and the potentiometer 57 is adjusted to restore the plate current reading of milliammeter 56 to its original value (operation d). Alternatively, if desired, after operation c, following the dotted line, switch 19 may first be opened, and then potentiometer 57 may be adjusted.

25 Referring to Figure 6b, following broken line 93, the apparatus is reset by opening switch 19 again (operation e) and moving switch 20 back to its current-adjusting position 1 (operation f). The charging current must be adjusted when the timer is first placed in service, but thereafter needs only to be checked occasionally except for readjustment to provide a different time range. However, the switch 20 must be momentarily placed in position 1 before making a time measurement in order to dissipate the charge existing from the preceding measurement, which would otherwise add directly to the measurement to be made.

Other types of time interval measurement are made and the timing of other types of relay operations is performed in an analogous manner, having modified the connections of the apparatus with removable links or leads and in some cases rearranging the order of the operations performed.

45 To measure the time required for a normally-closed relay to open its contacts instead of for a normally-open relay to close its contacts, a connecting link L₅ is placed between connection posts 24 and 25, and leads L₃ and L₄ are attached to posts 25 and 26 as in Fig. 7 instead of between posts 24 and 25 as in Figs. 1 and 4. The charging current of condenser 14 may be adjusted in the manner already explained. The sequence of operation in actually timing the relay and obtaining the reading is also the same as that described in connection with Figs. 4, 5 and 6, since this case also involves measuring the time required for a relay to operate after it has been energized. When switch 19 is closed, the relay 11 becomes energized as before and tube 16 becomes conducting as before, causing a voltage drop in resistor 49 which is impressed on condenser 14 which commences being charged. Tube 17 now has its grid 48 continually connected to the positive side of the line through the resistor 88, but it is now initially connected directly to the negative side of the line through leads L₃ and L₄ and relay contacts 12 and 13, which short out resistor 52.

70 When the relay 11 opens its contacts, however, and removes the short across resistor 52, the potential of grid 48 rises to a value at which the tube 17 becomes conducting, the ratio of resistances of resistors 88 and 52 being such that the

required division of voltage is obtained. As before, when tube 17 becomes conducting, tube 16 is extinguished, the voltage applied to the constant-current tube reverses and condenser 14 ceases being charged. The voltage of condenser 14, due to its accumulated charge, is measured in the same manner as already explained in connection with Fig. 5.

10 In measuring the time required for a normally-open relay to close its contacts when deenergized, a different sequence of operations is employed while actually testing the relay but the methods of adjusting charging current and of reading the voltage of the timing condenser 14, in this case as in all the subsequent cases to be described, may be the same as has already been described. Before making the test, links L₁ and L₂ are removed from between connection posts 27 and 29 and between 28 and 30 and placed between posts 29 and 31 and between 30 and 32. Leads L₃ and L₄ are connected to posts 24 and 25, respectively, and link L₅ is removed from between posts 24 and 25.

The test is begun with switch 20 in position 2 and switch 19 closed (Figs. 8 and 12a). First, switch 18 is closed (operation a, Fig. 12a), and then switch 19 is opened (operation b). Referring to Fig. 8, when switch 18 is closed, tube 16 becomes conducting and charging current commences to flow through tube 15. Condenser 14 cannot begin charging, however, until the short across it through switch blade 87 is removed by opening switch 19, at which time relay 11 is deenergized by the separation of contacts 75 and commences to operate. Upon the completion of the relay operation and the closing of its contacts 13, grid 48 is driven positive, causing current to be shifted from tube 16 to tube 17 and stopping the charging of condenser 14. The reading is then taken (operations c and d, Fig. 12a), and the apparatus is reset for another test (operations e and f, Fig. 12b).

45 For observing the time required for a normally-open relay to open its contacts when deenergized, the removable links and leads are placed as shown in Fig. 9; L₁ between connection posts 29 and 31; L₂ between 30 and 32; L₅ between 24 and 25; leads L₃ and L₄ connected to 25 and 26. The sequence of operations is as described just above and shown in Fig. 12. The operation of the circuit will be apparent from the explanation of partially analogous circuits, Figs. 7 and 8. When switch 18 is closed, tube 16 starts conducting; when switch 19 is opened, relay 11 is deenergized and condenser 14 starts charging; and when contacts 13 open, grid 48 is driven positive, communicating the tubes 16 and 17 and condenser 14 stops charging.

60 It is apparent that in the cases previously described bouncing of the contacts after the original closing or opening is without effect on the operation of the apparatus. Once the contacts 13 have operated to make grid 48 positive and tube 17 conducting, grid control of tube 17 is lost and it continues to conduct in the known manner of grid-controlled gas or vapor discharge tubes. Resumption of charging of condenser 14 is prevented and the relay operating time for only the original closing or opening operation is measured. However, if it is desired to take into account the effect of bouncing, i. e., the momentary reopening or reclosing of the contacts after they have opened or closed, this may also be done.

75 For a relay closing when energized, the effect of bouncing contacts is taken into account by modi-

5 flying the circuit shown in Fig. 4 to produce that shown in Fig. 10; that is, link L_6 is removed from between posts 22 and 23 and leads L_3 and L_4 are connected to posts 21 and 22. The sequence of operations in manipulating the apparatus is as shown in Fig. 6. Comparing Fig. 10 with Fig. 4, it will be apparent that the distinction in operation of the apparatus is that in Fig. 10 whenever contacts 13 reopen, the circuit through resistor 50 to conductor 69 is broken and current is re-established in tube 16 instead of continuing to flow through tube 17 as in Fig. 4. Consequently, charging current flows in condenser 14 during the time that contacts 13 are open and the measurement obtained is the summation of closing time and open time intervals. Obviously, the circuit of Fig. 10 may be used generally for measuring the duration of one or more intervals that a pair of contacts 13 are open. The initial positions of the switches and the sequence of operations would be as indicated in Fig. 13.

For measuring the operating time of a relay closing when deenergized including the summation of opening time intervals for bouncing contacts, the connection of Fig. 8 is modified as indicated in connection with Fig. 10, that is, link L_6 is removed from between posts 22 and 23 and leads L_3 and L_4 are connected to posts 21 and 22. The sequence of operations in manipulating the apparatus is as shown in Fig. 12 and as explained in connection with that figure. For the reasons stated in the previous paragraph, the measurement includes the summation of open time intervals.

Fig. 11 represents the arrangement of the apparatus used when it is desired to measure the duration of one or more intervals that a pair of contacts, such as 13, remains closed. Links L_1 , L_2 and L_6 have been removed from between connection posts 29 and 31, 30 and 32, 22 and 23, respectively, and leads L_3 and L_4 have been connected to posts 27 and 28, respectively. Manifestly, condenser 14 is charged only during the periods that a circuit is closed through contacts 13 and tube 16 conducts current. Fig. 14 represents the sequence of operating during the manipulation of the apparatus.

Another type of measurement which the extreme flexibility of my apparatus permits is the measurement of the time duration of the first only of a series of contact closures. To make a measurement of this type, the apparatus illustrated in Fig. 1 is connected to include a transformer 94 and a voltage source 95, forming the circuit illustrated in Fig. 15. The link L_6 is removed from between posts 97 and 98 and the contacts 13 of the relay 11 are connected in series with the primary winding 96 of the transformer 94 to the connection posts 97 and 98 by means of the leads L_3 and L_4 . The secondary winding 99 of the transformer 94 is connected in series with the voltage source 95 to connection posts 25 and 26 by means of leads L_7 and L_8 . The connections are such that the negative side of the voltage source 95 is connected to the grid 48 of tube 17, and the terminals of transformer windings 96 and 99 connected to posts 98 and 25 have the same polarity.

In measuring the time duration of the first of the series of closures of contacts 13, the switch 20 is first moved to position 1 to insure the removal of any charges from the timing condenser 14, and then returned to position 2. The switch 18 is then closed but neither discharge tube 16 nor 17 becomes conducting since the anode circuit of tube 16 is open through contacts 13 and the voltage source 95 maintains a negative potential on the grid 48 of discharge tube 17. Upon a closure of the contacts 12 and 13, the anode circuit of tube 16 is closed and tube 16 begins to conduct.

As explained in connection with the previous measurements, the charging current begins to flow into the timing condenser 14 upon the initiation of a discharge in tube 16. The current impulse through the primary winding 96 of transformer 94 caused by the closure of contacts 13 produces an induced voltage in secondary winding 99 but the polarity is such that the grid 48 of tube 17 is merely driven further negative by this induced voltage and the induced voltage has no effect on the discharge tube 17 which is maintained non-conducting by the current flowing in resistor 51 from discharge tube 16, which produces a negative bias on grid 48 of tube 17.

Upon the opening of the contacts 12 and 13, the current through primary winding 96 of transformer 94 is interrupted and a voltage of opposite polarity is induced in transformer secondary 99, causing the grid 48 of tube 17 to become positive with respect to its cathode 46 and making the tube 17 conducting. The circuit to tube 16 having been interrupted, the polarity of the voltage acting in the circuit of the timing condenser 14 is reversed, as in the previous examples, and the charging of the condenser 14 ceases. Should the contacts 12 and 13 be reclosed subsequently, tube 16 will remain non-conducting owing to the fact that the current flowing through tube 17 and resistor 51 biases the grid 47 of tube 16 negatively and prevents the reestablishment of a discharge in tube 16. The charge accumulated in timing condenser 14 is measured, as explained in connection with the previous examples, by moving switch 20 to position 3, adjusting the potentiometer 57, and taking the reading of milliammeter 56 and voltmeter 59.

It will be seen, therefore, that the connection of Fig. 15 permits measuring the duration of the first of a series of contact closures irrespective of the number of reclosures which may occur.

In accordance with the provisions of the patent statutes, I have described apparatus which I now consider to represent the best embodiment of my invention and certain methods of operation embraced therein for the purpose of explaining its principle and showing some of its applications but it will be obvious to those skilled in the art that many modifications and variations are possible and I aim, therefore, to cover all such modifications and variations as fall within the scope of my invention which is defined in the appended claims.

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

1. An electric device for timing relay operations comprising a condenser, means adapted to charging said condenser at a substantially uniform rate, means for starting and stopping the charging of said condenser simultaneously with the beginning and end, respectively, of a relay operation to be timed, and means responsive to the charge accumulated by said condenser.

2. A device for timing relay operations comprising a condenser, means adapted to charging said condenser at a substantially uniform rate, means for modifying the connections of said device to permit measurement of both closing and opening times of normally-open and normally-closed relays, means for starting and stopping the

charging of said condenser simultaneously with the beginning and end, respectively, of a relay operation to be timed, and means responsive to the charge accumulated by said condenser.

3. Apparatus for timing the operation of an electrical relay having an energizing winding and a pair of relatively movable contacts adapted to open and close an electrical circuit, which timing apparatus comprises a condenser, means adapted to charging said condenser at a substantially uniform rate, means for starting and stopping the charging of said condenser, adjustable means for connecting the contacts of the relay being timed to said charge-starting and stopping means, said connecting means being adapted to setting the apparatus for measuring opening and closing times of normally-open and normally-closed relays, and means for determining the charge collected by said condenser.

4. A method of timing the operation of a relay having an energizing winding in a relay-operating circuit and having a pair of relatively movable contacts, which comprises simultaneously initiating an operation of said relay through control of said operating circuit and causing a condenser to start charging through a constant-current unidirectional circuit, causing the polarity of the supply to said last mentioned circuit to be reversed simultaneously with the operation of said contacts, and determining the voltage of said condenser.

5. The method of timing the operation of an electrically operated contact controlling relay which consists in simultaneously initiating the operation of said relay and starting to charge a condenser at a constant rate, stopping the charging of said condenser simultaneously with the operation of said relay and measuring the charge on said condenser.

6. The method of timing relay operations which consists in charging a condenser at a uniform rate only during the interval between the initiation of such relay operation and the completion of the relay operating movement and then measuring the charge on said condenser.

7. A device for timing relay operations which comprises a unidirectional constant-current circuit including a condenser, a direct current source of charging current supplying said circuit, means for connecting said condenser circuit to said source in a direction normally to cause current to flow in said circuit at the beginning of a relay operation, means for reversing the polarity of said source upon the completion of said operation, and means for determining the quantity of charge collected by said condenser.

8. A timer comprising in combination, a condenser, a constant-current rectifier in series therewith, a direct current voltage source connected to said condenser and said rectifier in a direction normally to cause current to flow in said rectifier, means for energizing said voltage source at the beginning of an operation to be timed, means for reversing the polarity of said voltage at the conclusion of the operation, and means for determining the amount of electric charge accumulated by said condenser during said operation.

9. A timer comprising in combination, a condenser, a thermionic tube having an anode and a cathode and operated in the saturated portion of its characteristic curve in which the entire emission of said cathode is attracted by said anode, whereby said tube passes a constant current substantially independent of variations in voltage ap-

plied to the electrodes of said tube, a direct current source of voltage to which said condenser and said tube are connected in series, the connections being such as normally to tend to cause current to flow in said tube, means for energizing said voltage source at the beginning of a time interval to be measured, means for reversing the polarity of said voltage at the end of the time interval, and means responsive to the amount of electric charge accumulated by said condenser during said time interval.

10. A timer comprising in combination, a source of current, a pair of discharge tubes, each having an anode, a cathode, and a control grid, and being connectible in parallel to said source of current, separate resistors connected in series with the anodes of said tubes, a timing condenser and a constant-current rectifier connected in series between the anodes of said tubes, a second condenser connected between the anodes of said tubes, means for closing a circuit from said current source to said tubes at the beginning of a time interval to be measured, thereby initiating a discharge current in one of said tubes, giving rise to a potential difference in one of said series resistors and in the circuit of said constant-current rectifier and said timing condenser and giving rise to a charging current in said condenser, means for momentarily at least maintaining the control grid of the other of said tubes at too low a potential to permit the tube to become conducting at the beginning of the time interval, means for raising the potential of the control grid of said latter tube at the conclusion of the time interval, thereby making the tube conducting and shifting current from the former of said tubes to the latter and from one of said series resistors to the other, whereby the potential difference between said anodes and in the circuit of said rectifier and said timing condenser is reversed, terminating the charging of said condenser.

11. A timer comprising in combination, a source of current, a pair of discharge tubes, each having an anode, a cathode, and a control grid, a resistor connected between the anode of one of said tubes and one side of said current source, a second resistor connected between the anode of the other of said tubes and the same side of said current source, a constant-current rectifier and a timing condenser connected in a cross-circuit in series between the anodes of said tubes, a second condenser connected between said anodes, a switch between the other side of said current source and the cathodes of said tubes arranged to be closed at the beginning of a time interval to be measured, thereby initiating a discharge in the first of said tubes, a second switch adapted to connect the control grid of the second of said discharge tubes to the anode side of said current source and arranged to be closed at the end of a time interval to be measured, thereby making the latter discharge tube conducting, shifting current therefrom from the first of said tubes and reversing the potential difference in said cross-circuit, whereby said timing condenser receives charging current only during a time interval to be measured.

12. A timer comprising in combination, a pair of capacitatively-coupled parallel circuits including grid-controlled discharge tubes and having a cross-connection including a rectifier and a timing condenser, means for energizing one of said tube circuits at the beginning of a time interval to be measured, thereby giving rise to a voltage in said cross-circuit causing said condenser to start receiving a charge, means for raising the grid po-

tential of the tube in the second of said parallel circuits at the end of a time interval to be measured, thereby making said second tube conducting, depressing through said capacitive coupling the voltage acting on the tube in the first of said parallel circuits until said tube is deenergized, shifting the current between said parallel circuits to reverse the voltage in said cross-circuit and terminate the charging of said condenser.

13. A device for timing the opening of the contacts of a relay when the relay is energized which comprises a pair of parallel circuits including grid-controlled discharge tubes and having a cross-connection including a rectifier and a timing condenser, means for simultaneously energizing said relay and one of said tube circuits, thereby giving rise to a voltage in said cross-circuit causing said condenser to start receiving a charge, a voltage divider having a tap determining the grid potential of the tube in the second tube circuit, one side of said voltage divider being initially short-circuited by the contacts of the relay, whereby the grid potential of said second tube is initially held below the point at which said tube becomes conducting, and the opening of the contact serves to raise the grid potential of said tube, causing it to become conducting, to shift the current between said parallel tube circuits, to reverse the voltage in said cross-circuit, and to terminate the charging of said condenser.

14. A device for timing the operation of a relay when deenergized comprising a pair of parallel circuits having a cross-connection including a rectifier and a timing condenser in series, one of said parallel circuits initially carrying current and producing a potential difference in said cross-circuit tending to cause a charging of said condenser, means initially maintaining said relay energized and short-circuiting said condenser to prevent it from receiving charging current, said means being adapted simultaneously to deenergize said relay and to remove the short from said condenser, permitting charging thereof, means for shifting the current from the initially conducting circuit to the other parallel circuit upon the operation of said relay, thereby reversing the potential difference in said cross-circuit and terminating the charging of said condenser.

15. A device for measuring the summation of the original operating time of a circuit-closing relay having bouncing contacts and the time during which the contacts may be open again, which comprises, in combination with a source of current, a tube circuit supplied thereby comprising a resistor and a discharge tube in series, a second circuit in parallel with said tube circuit including a second resistor in series with the contacts of the relay being tested, a cross-circuit between

said first mentioned circuits including a timing condenser and a rectifier in series, capacitive coupling between said first mentioned circuits, and means for simultaneously starting the operation of the relay and closing said tube circuit, thereby energizing said circuit and giving rise to a voltage in said cross-circuit causing said condenser to start receiving a charge, whereby said condenser continues receiving a charge until the relay contacts close causing current to flow in said second circuit, depressing through said capacitive coupling the voltage applied to said tube below that at which current can continue to flow in said tube circuit, reversing the voltage in said cross-circuit to stop the charging of said condenser while the relay contacts are closed, but permitting current to flow again in said tube circuit and in said condenser-charging cross-circuit during such time as the relay contacts may again be open.

16. A device for timing the first of several repeated closures of a pair of contacts which comprises a pair of parallel circuits including grid-controlled discharge tubes and having a cross-connection including a rectifier and a timing condenser, said discharge tubes each having an anode, a cathode, and a grid, a transformer having primary and secondary windings, a source of biasing potential, and means for reversing the polarity of voltage acting in said cross-circuit when current shifts from one parallel circuit to the other, the primary winding of said transformer and said contacts being connected in series with one of said discharge tube circuits and the secondary winding of said transformer and said source of biasing potential being connected between the cathode and control grid of the discharge tube in the other of said parallel tube circuits whereby the initial closing of said contacts closes a circuit through the first mentioned of said discharge tubes and causes current to flow in said cross-circuit starting the charging of said timing condenser, and the initial opening of said contacts induces a voltage in the secondary winding of said transformer impressing a positive potential on the control grid of said second mentioned discharge tube causing it to become conducting and to commutate said first mentioned discharge tube, reversing the potential in said cross-circuit and terminating the charging of said timing condenser, said first mentioned discharge tube having its grid connected to be negatively biased by the resistance drop due to current flowing in the circuit of said second mentioned discharge tube, preventing the first tube from again becoming conducting in response to subsequent contact closures.

MAURICE E. BIVENS.

CERTIFICATE OF CORRECTION.

Patent No. 2,021,766.

November 19, 1935.

MAURICE E. BIVENS.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, second column, line 56, for the syllable "communicat-" read commutat-; page 7, first column, line 53, claim 15, for "conacts" read contacts; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of January, A. D. 1936.

Leslie Frazer

Acting Commissioner of Patents.

(Seal)

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