

Oct. 4, 1955

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2,719,966

ELECTRONIC ANNUNCIATOR

Filed Nov. 1, 1951

3 Sheets-Sheet 1

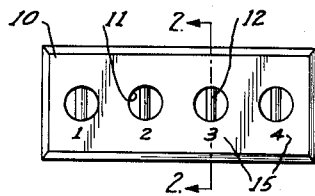


Fig. 1.

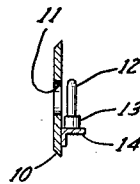


Fig. 2.

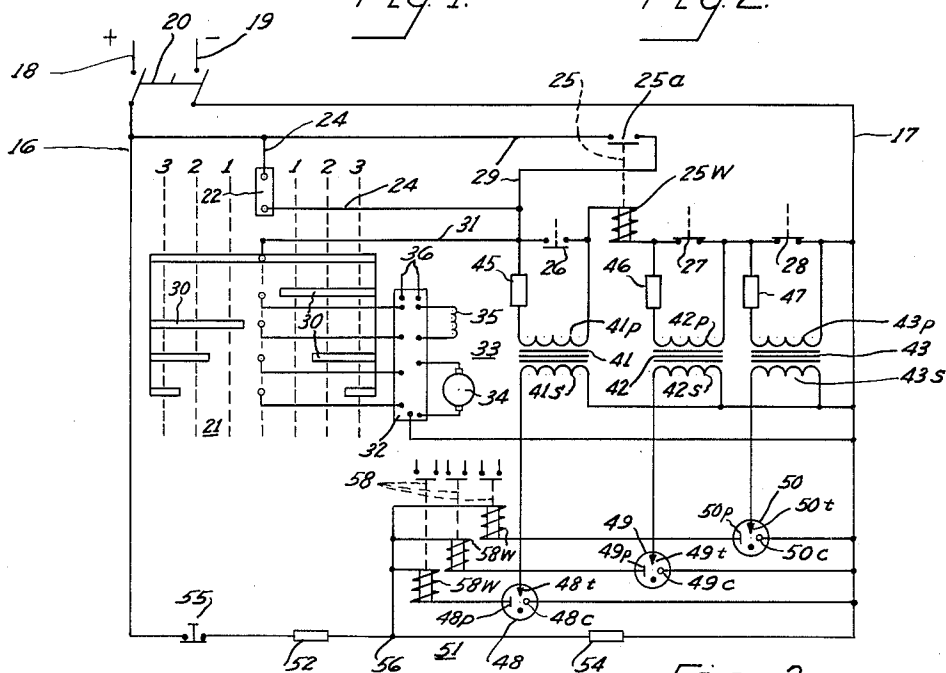


Fig. 3.

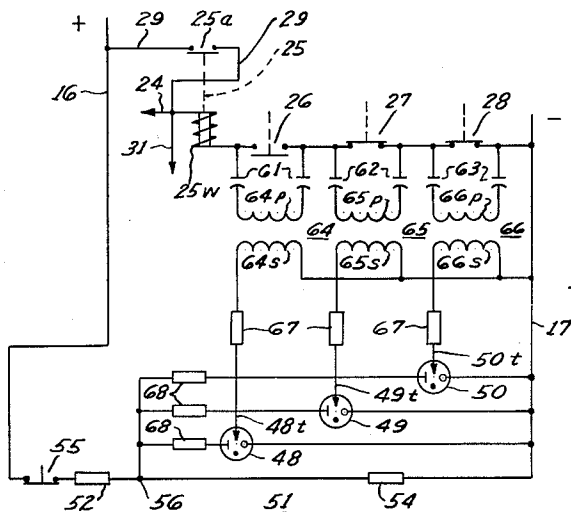


Fig. 4.

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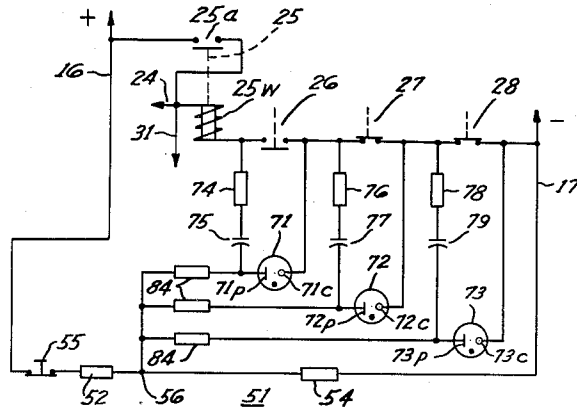


Fig. 5.

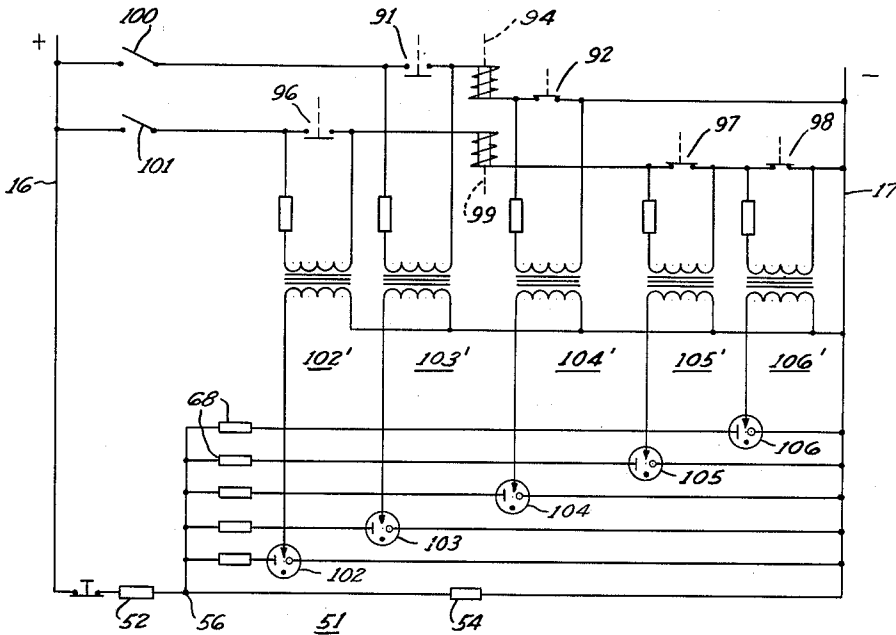


Fig. 6.

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3 Sheets-Sheet 3

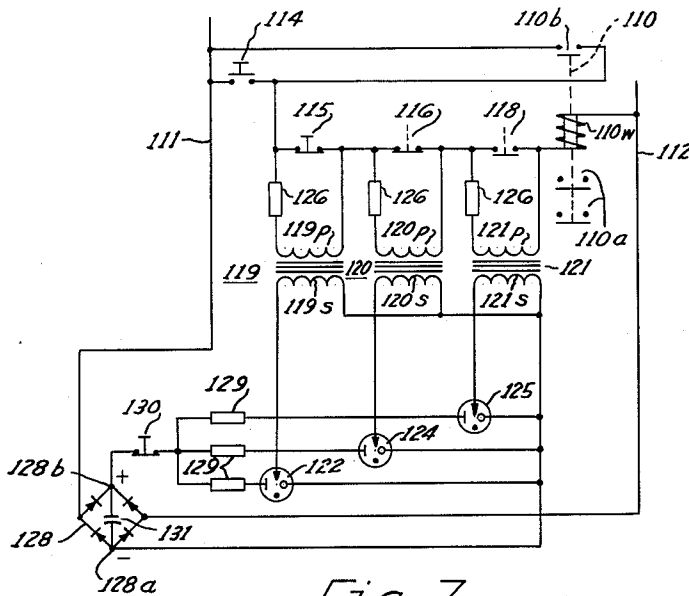


Fig. 7.

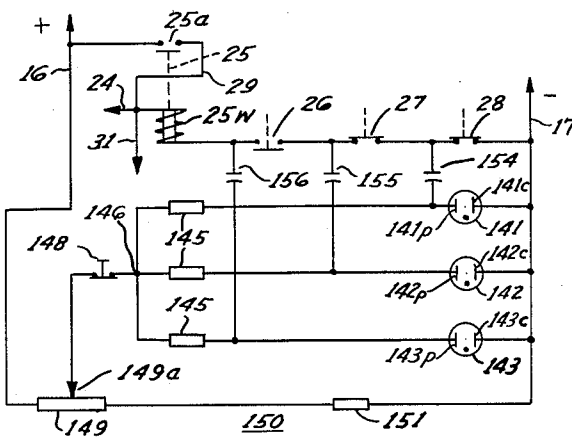


Fig. 8.

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2,719,966

ELECTRONIC ANNUNCIATOR

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Application November 1, 1951, Serial No. 254,321

18 Claims. (Cl. 340—253)

This invention relates to an electronic annunciator and more particularly to an electronic annunciator having many different uses but eminently suitable for indicating which, if any, of a plurality of protective contacts in an undervoltage protection circuit for a motor opened to stop the motor.

Heretofore, electromagnetic annunciators having movable indicating flags or vanes have been used with industrial motor controllers to indicate which specific one, or ones, of several protective contacts in series with an undervoltage relay opened to cause the relay to shut down the machine driven by the motor. The time required to locate the cause of the shutdown is thereby greatly reduced, particularly when some of the contacts which could have caused the shutdown are located in widely separated locations or some are of the type that immediately reclose after opening so that no indication that they had opened is otherwise available. In fact, some system of contact opening indication has become almost an economic necessity for many complex electrically driven industrial machines because of the large number of widely separated protective contacts required and the high cost of any extended shutdown. Although the prior electromagnetic annunciators can be made to perform satisfactorily, their relatively high cost and large size makes it desirable to provide a less expensive and more compact annunciator.

An electronic annunciator in accordance with the present invention uses only inexpensive and conventional electrical components of very small size and therefore is more compact and less expensive than prior electromagnetic annunciators. Furthermore, the present annunciator is capable of giving a positive indication of the opening of one or more protective contacts in undervoltage protection circuits of relatively low inductance, is operative irrespective of whether the protective contacts are on the negative or positive side of the undervoltage relay and whether or not the contacts are in the same or different circuits, and retains its initial indication until manually reset even though other of the protective contacts had been subsequently opened or the opened contact had reclosed.

It is an object of this invention to provide an annunciator having the foregoing advantages.

Another object is to provide an annunciator which is electronically operated.

Another object is to provide an electronic annunciator in which a voltage surge upon opening of a contact causes the ignition of a gaseous discharge tube.

Another object is to provide an electronic annunciator in which the glow of an ignited gaseous discharge tube may be used as the indicating medium.

Among other objects is the provision of electronic annunciators in which a three-element, gaseous discharge

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tube has its control electrode connected so as to become operative to initiate ignition of the tube upon occurrence of a voltage surge across a contact; or in which a three element, cold cathode, gaseous discharge tube has its starter or trigger electrode connected so as to become operative to cause ignition of the tube upon opening of a contact; or in which a plurality of two-element, gaseous discharge tubes are fired selectively by changes in the potential of capacitors respective to the tubes; or in which the starter or trigger electrode of a three-element, cold cathode, gaseous discharge tube is coupled to a contact through a transformer and responds when the contact opens to cause ignition of the tube, or in which the pairs of electrodes of a plurality of two-element, cold cathode, gaseous discharge devices are connected in respective loop circuits each including a contact and a capacitor.

Additional objects are to provide an electronic annunciator capable of indicating which of a plurality of contacts opened whether the contacts are in the same or separate circuits and to provide an electronic annunciator capable of being supplied from either an alternating or a direct current source.

In one illustrated embodiment of this invention, a plurality of identical, cold cathode, three-element, gaseous discharge devices or tubes are connected in parallel across a portion of a voltage divider so that a voltage is impressed between their respective plates and cathodes. This voltage is less than that required to initiate an arc discharge between the plates and cathodes of the tubes but is sufficient to maintain such a discharge after it has been initiated. A plurality of transformers have their primary windings connected in respective loop circuits each of which includes one of a plurality of protective contacts that are interposed in an undervoltage protection circuit in series with each other and with an operating winding of an electromagnetic undervoltage relay. The secondary windings of the transformers are connected between the trigger electrodes and cathodes of the tubes, respectively. Upon opening of any of the protective contacts, a current flows momentarily through the primary of its associated transformer. The resulting voltage surge in the secondary of that transformer is applied to its associated trigger electrode causing it to become sufficiently positive with respect to its associated cathode to initiate an arc discharge that continues between the cathode and plate of the corresponding one of the tubes. This arc discharge is readily visible and provides an indication as to which one of the several contacts opened. The cathode-plate circuits of the tubes may be opened manually at any time to extinguish those of the tubes which have been ignited.

In another illustrated embodiment of this invention, two element, cold cathode, gaseous discharge devices or tubes are used instead of three-element tubes and are connected in respective loop circuits with the protective contacts, suitable capacitors being inserted in the loop circuits, respectively. Upon opening of any one of the contacts, the side of the opened contact nearest the positive supply conductor suddenly changes from the potential of the negative supply conductor to the potential of the positive supply conductor. Since the voltage across a capacitor cannot change instantaneously, there is a sudden increase in the potential across the electrodes of the tube associated with the one of the contacts that has opened, and that tube accordingly breaks down and emits a visible glow. When the contact that opened recloses, the ignited tube is not extinguished because the resulting voltage surge is substantially absorbed by a suitable resistor and the now lower re-

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sistance of the conducting tube. The ignited tube may be extinguished by opening of a reset switch. Thus the annunciators operate by employing the characteristics of gaseous discharge tubes by which a visible discharge is initiated by a surge in voltage resulting from opening of an inductive circuit and continues thereafter at voltage below the surge value.

Further objects and advantages of this invention will become apparent from the following description wherein reference is made to the drawings, in which:

Fig. 1 is a front elevation of the indicating portion of an electronic annunciator in accordance with this invention,

Fig. 2 is a section taken along the line 2—2 of Fig. 1,

Fig. 3 is a wiring diagram of an electronic annunciator in accordance with this invention which may have its indicating tubes arranged as shown in Figs. 1 and 2,

Figs. 4 and 5 illustrate modifications of the annunciator of Fig. 3,

Fig. 6 is a wiring diagram showing how the annunciators of Figs. 3 and 4 may be used to indicate the operation of contacts in separate circuits,

Fig. 7 shows how an annunciator in accordance with this invention may be used with an alternating current source, and

Fig. 8 illustrates a further modified annunciator.

Referring to Figs. 1 and 2, a suitable panel 10 has a plurality of horizontally aligned circular openings 11 behind which a plurality of gaseous discharge devices or tubes 12, each having a transparent envelope, are respectively mounted. Thus, when any one of the tubes 12 becomes ignited, its glow is visible from the front of the panel 10 through its associated one of the openings 11. Preferably, the tubes 12 are mounted in respective sockets 13 carried by a bracket 14 attached to the rear of the panel 10. Suitable indicia 15 may be placed on the front of the panel beneath the openings to identify each of the tubes 12 in relation to a specific one of a plurality of protective contacts with which the tubes 12 are operatively associated in a manner to be described. The indicia 15 may be a simple numbering system as shown or the name of each of the contacts and its physical location may be inscribed on the panel.

Referring now to Fig. 3, conductors 16 and 17 are arranged to be connected respectively to a positive supply conductor 18 and a negative supply conductor 19 of a source of direct current (not shown) by means of a suitable switch such as a knife switch 20. A conventional three-speed point, reversing master switch 21, illustrated in developed form, has an off-point segment 22 which, only when the master switch 21 is in the off position, completes an undervoltage protection circuit from the conductor 16 to the conductor 17 through a conductor 24, an operating winding 25w of an electromagnetic undervoltage relay 25 having a normally open contact 25a, and through a plurality of protective contacts 26, 27, and 28 connected in series with each other and with the winding 25w. As shown, the winding 25w is interposed on the negative side of the contact 26 and on the positive side of the contacts 27 and 28, but the winding 25w and the contacts 26, 27, and 28 may be arranged in any other order if desired.

The relay 25 is operatively energized and its contact 25a is closed if the master switch 21 is in the off-position, the knife switch 20 and all of contacts 26, 27, and 28 are closed, and an adequate voltage exists between the conductors 18 and 19. The relay 25 when operatively energized completes its own holding circuit through its contact 25a and a conductor 29 from the conductor 16 to the contact 26. The holding circuit bypasses the conductor 24 and the segment 22 and serves to maintain the relay 25 in its operated position when the master switch 21 is moved in either direction from the off-position.

Additional segments 30 of the master switch 21 are con-

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nected to the conductor 16 through a conductor 31, the conductor 24, and the segment 22 when the master switch is in the off-position, and are connected to the conductor 16 through the conductors 31 and 29 when the master switch 21 is in any of its operating positions and the contact 25a is closed. The segments 30 may be arranged to control the operation of suitable electromagnetic switches (not shown) of a controller 32 for an electric translating device such as a motor 33 having an armature winding 34 and a field winding 35 and arranged to be supplied with power through conductors 36 which may be connected to the same source as the conductors 18 and 19. It will be understood that the undervoltage relay 25 and one or more of the contacts 26, 27, and 28 may be included in the controller 32.

The particular undervoltage protection circuit and master switch arrangement illustrated in Fig. 3 is indicative of conventional practice for providing undervoltage protection in a motor controller. For example, should the voltage at the conductors 18 and 19 decreases below the drop-out value of the relay 25 or any one or more of the contacts 26, 27, or 28 open momentarily, the contact 25a opens. If the master switch 21 is in any of its operating positions, opening of the contact 25a disconnects the segments 30 from the conductor 16 and the controller 32 operates to deenergize the motor 33. It is then necessary to return the master switch 21 to the off-position before the segments 30 can be connected again to the conductor 16 to permit the motor 33 to be restarted.

The contacts 27 and 28 are shown as normally closed and the contact 26 is shown as normally open, but when conditions are proper for operation of the motor 33, all of the contacts 26, 27, and 28 are closed. Although only three protective contacts 26, 27, and 28 are illustrated, it is to be understood that any number of normally open or normally closed contacts may be provided, as many as twenty or more not being uncommon. Exemplary functions for contacts such as the contacts 26, 27, and 28 are to provide protection against overloading of the motor 33, overtravel or overspeed of a machine driven by the motor, low oil pressure, stopping of a related machine, and the like.

So long as all of the contacts 26, 27, and 28 are closed, operation is normal and may proceed, but if any one or more of these contacts open, abnormal conditions have occurred and the motor 33 is deenergized automatically and brought to a stop. In order to restart the motor, after a stoppage for this reason, it is necessary to return the master switch 21 from an operating position to the off-position in order to reset the undervoltage relay 25. Many protective contacts such as the contacts 26, 27, and 28 are often of the type that immediately reclose after they have opened, and hence give no indication of their operation, and some may be located at remote points. Hence, it often requires considerable time merely to discover which of the several protective contacts opened to cause the motor to stop. Since it is undesirable to restart the motor 32 until the cause of its automatic stoppage is ascertained and corrected if necessary, considerable time often elapses before an attempt should be made to restart the motor 33 even though the cause of the shutdown when once determined can be quickly corrected. The annunciator now to be described is combined with the undervoltage protection circuit to provide a readily visible indication at a single location as to which of the protective contacts 26, 27, and 28 opened to stop the motor 33 thereby permitting more rapid discovery of the cause of stoppage.

The annunciator, as illustrated in Fig. 3, comprises a plurality of voltage transferring means in the form of transformers 41, 42, and 43, preferably of the iron core type, having their respective primary windings 41p, 42p, and 43p connected in loop circuits with the contacts 26, 27, and 28, respectively, by respective coupling means which include resistors 45, 46, and 47, respectively. The resistance of each of the resistors 45, 46, and 47 is so se-

lected with respect to the resistance of its associated primary winding 41p, 42p, or 43p that, when its associated one of the contacts 26, 27, or 28 opens and the next highest expected voltage is at the conductors 18 and 19, the relay 25 opens its contact 25a. In fact, it is possible and preferable to make the resistance of the resistors 45, 46, and 47 so high that the current that flows to the winding 25w when any one of them is operatively in the circuit is insignificantly small as compared to the drop-out current of the relay 25.

A plurality of gaseous discharge tubes 48, 49, and 50 are arranged to be responsive to the voltage across the contacts 26, 27, and 28, respectively. Preferably, the tubes 48, 49, and 50 are cold cathode, three-element, gaseous discharge tubes containing respective plates or anodes 48p, 49p, and 50p, cathodes 48c, 49c, and 50c, and starter or trigger electrodes 48t, 49t, and 50t. The gas filling is usually neon, argon, or krypton, each of these gases giving a characteristically colored glow upon ignition of the tube. The envelopes of the tubes are transparent so that the glow is visible and can serve as an indication of the ignition or non-ignition of the tube. In the operation of tubes of this type, a relatively small amount of electrical energy supplied to the starter electrode initiates an arc discharge between the cathode and starter electrode which in turn initiates a much greater discharge between the cathode and main anode. In tubes of this type which are at present commercially available, known as the OA4G and 5823, a starting potential of at least about 85 to 100 volts preferably applied through a resistance of not more than one-half megohm is required. As mentioned, the tubes 48, 49, and 50 have transparent envelopes so that their internal glow is visible, and preferably are mounted in a single location in the manner of the tubes 12 of Figs. 1 and 2.

The transformers 41, 42, and 43 have secondary windings 41s, 42s, and 43s, one terminal of each of which is connected to the conductor 17 and the other terminals of which are connected respectively to the trigger electrodes 48t, 49t, and 50t.

A voltage divider 51 comprising a pair of series connected resistors 52 and 54 is arranged to be connected across the conductors 16 and 17 through a normally-closed push button 55 interposed between the resistor 52 and the conductor 16. Either one or both of the resistors 52 and 54 may be made adjustable if desired. A junction point 56 intermediate of the resistors 52 and 54 is connected to a common terminal of parallel circuits including operating windings 58w of respective relays 58 and the plates 48p, 49p, and 50p, respectively. The cathodes 48c, 49c, and 50c are each connected directly to the conductor 17. Preferably the resistors 52 and 54 are selected so that when none of the tubes 48, 49, and 50 is ignited, the voltage across the resistor 54 and thus between the respective cathode and plates of the tubes is approximately midway between the potential required to initiate an arc discharge between the cathodes and plates and the extinction potential of such discharge.

The operation of the circuit of Fig. 3 may be explained by assuming that the relay 25 is in its operated position with its contact 25a closed and the master switch 21 is in one of its operating positions. Should any one or more of the contacts 26, 27, and 28 open momentarily at this time and then either stay open or reclose, the relay 25 drops out to open the contact 25a which removes power from segments 30 of the master switch 21 which in turn causes the controller 32 to effect deenergization of the motor 33. The motor 33 accordingly slows down and stops and cannot be reenergized unless the master switch 21 is first returned to the off-position. The relay 25 operates to close its contact 25a when the master switch 21 reaches the off-position, provided all of the protective contacts which opened have reclosed, but the master switch 21 should not be moved again to an operative position

until the cause of the shutdown is ascertained and corrected if necessary.

The annunciator portion of the circuit of Fig. 3 provides a readily visible indication as to which one or which ones of the contacts 26, 27, or 28 opened. This is because, upon opening of any of the contacts 26, 27, and 28, current starts to flow through the one or more of the primary windings 41p, 42p, and 43p which are associated with the opened contact or contacts. Because of the inductance of the winding 25w, this current is for an instant relatively large, but, because one or more of the resistors 45, 46, and 47 are now effectively in series with the winding 25w, soon decreases to a value insufficient to maintain the relay 25 in its operated position or to pick up the relay 25 when the master switch 21 is returned to the off-position. However, the current surge around the opened one of the contacts 26, 27, and 28 is sufficient to induce a voltage in the secondary of its associated transformer which causes ignition of the appropriate one of the tubes 48, 49, and 50, the other tubes remaining unignited.

For example, assuming that the contact 27 opened, the current surge in the primary winding 42p is sufficient to induce a voltage in the secondary winding 42s which causes the trigger electrode 49t to become sufficiently more positive than the cathode 49c to cause ignition of the tube 49. Once ignited, the tube 49 remains ignited and produces a visible glow due to current flowing (electron sense) from the negative conductor 17, through the cathode 49c, this plate 49p, one of the windings 58w, the resistor 52, and the push button 55 to the positive conductor 16. The tube 49 by its characteristic glow thus indicates that, of the several contacts 26, 27, and 28, the contact 27 in this instance opened and caused opening of the contact 25a and consequent shutdown of the machine driven by the motor 33. The one of the relays 58 in series with the tube 49 is picked up by the plate current of the tube and any suitable device operated by this relay 58 may also be used to indicate that, of the several contacts, it was the contact 27 that opened. Upon drop out of the relay 25, the master switch 21 should be returned to its off-position.

After checking the cause of opening of the contact 27, correcting any fault, if necessary, and reclosing of the contact 27, if necessary, the master switch 21 may be moved again to an operative position so as to restart the motor 33. At any time prior to or after resumption of operation, the push button 55 may be opened momentarily to extinguish the tube 49 and to de-energize the energized one of the relays 58.

Had the contacts 26 or 28 opened instead of the contact 27, the tubes 48 or 50 would have become ignited instead of the tube 49. If more than one of the contacts 26, 27, and 28 opened instead of but one, the appropriate tubes in each instance would have become ignited. Since the tubes 48, 49, and 50 may be grouped at a single location and provided with suitable indicia, for example, in the manner illustrated in Figs. 1 and 2, the glow produced by any one of the tubes immediately shows which of the several contacts 26, 27, and 28 opened to stop the machine driven by the motor 33. Devices operated by the several relays 58, respectively, also may be grouped at a single location to provide such indication if desired.

Fig. 4 illustrates modifications which may be made in the complete circuit of Fig. 3. Elements in Fig. 4 which are the same as those of Fig. 3 are referred to by the same reference numerals. Referring to Fig. 4, the resistors 45, 46, and 47 of Fig. 3 are replaced by pairs of capacitors 61, 62, and 63 and the transformers 41, 42, and 43 of Fig. 3 are replaced by transformers 64, 65, and 66 which may be of the air core type, and which have primary windings 64p, 65p, and 66p, respectively, and secondary windings 64s, 65s, and 66s, respectively. The individual capacitors of the pair of capacitors 61 are arranged in series, one on each side of the primary winding 64p, and the capacitors 62 and 63 are similarly arranged in the loop circuits in-

cluding the primary windings 65_p and 66_p and the contacts 27 and 28, respectively. Suitable resistors 67 may be interposed respectively between the secondary windings 64_s, 65_s, and 66_s and their associated trigger electrodes 48_t, 49_t, and 50_t.

As mentioned, the resistors 45, 46, and 47 of Fig. 3 must be of such value that when any one of the contacts 26, 27, or 28 opens, the current flowing in the resistor associated with the open contact must become less than the drop-out value of the relay 25 when the voltage at the supply conductors 18 and 19 is at its highest value. In Fig. 4, on the other hand, when one of the contacts 26, 27, or 28 opens, a momentary charging current flows through the associated pair of the capacitors 61, 62, and 63. This charging current is sufficient to cause a voltage surge in the secondary winding 64_s, 65_s, or 66_s capable of causing ignition of the appropriate one of the tubes 48, 49, or 50. The charging current momentarily is also sufficient to hold the relay 25 in its operated position, but after the lapse of a few micro-seconds, it decreases below the drop-out value of the relay 25 and thereafter reaches zero. Accordingly, the relay 25 in Fig. 4 drops out after a very slight time delay and thereafter its winding 25_w is completely de-energized. If desired, only one capacitor may be interposed in each of the loop circuits, but two are preferable to provide protection against accidental short circuiting of one. It will also be understood that additional protection against failure of the capacitors could be provided by using, in addition, current limiting resistors such as the resistors 45, 46, and 47 of Fig. 3.

In the circuit as shown in Fig. 4, the relay 58 of Fig. 3 have been replaced by resistors 68, the glow of the tubes 48, 49, and 50 only being used in this instance to indicate which of the contacts 26, 27, and 28 operated. Also, in Fig. 4 the relay winding 25_w is illustrated on the positive side of all of the contacts 26, 27, and 28. It will be understood that either or both of these last two changes may be made in Fig. 3 if desired.

Fig. 5 also illustrates a modified annunciator which also may be used with the undervoltage protection circuit of Fig. 3.

Referring to Fig. 5, a plurality of two-element, cold cathode, gaseous discharge tubes 71, 72, and 73 having transparent envelopes are connected in respective loop circuits including the protective contacts 26, 27, and 28, respectively. The loop circuit including the contact 26 and the tube 71 also includes, in series, a coupling means in the form of a resistor 74 and a voltage transferring means in the form of a capacitor 75. Similarly, the loop circuit including the contact 27 includes a series-connected resistor 76 and a capacitor 77, and the loop circuit including the contact 28 and the tube 73 includes a series-connected resistor 78 and a capacitor 79. The tubes 71, 72, and 73 have plates 71_p, 72_p, and 73_p which are connected to the positive side of their associated contacts 26, 27, and 28 through the capacitors 75, 77, and 79, respectively, and the resistors 74, 76, and 78, respectively, and have cathodes 71_c, 72_c, and 73_c, respectively, which are connected to the negative side of their associated contacts 26, 27, and 28. Each of the tubes 71, 72, and 73 should have a relatively large differential between its ignition and extinction potential. If desired, the tubes 71, 72, and 73 may be the same as the tubes 48, 49, and 50 but arranged to operate as two-element tubes with the trigger electrodes 48_t, 49_t, and 50_t connected directly to their respective cathodes 48_c, 49_c, and 50_c.

The voltage divider 51 including the series connected resistors 52 and 54 is connected between the conductors 16 and 17 with the reset switch 55 interposed between the resistor 52 and the conductor 16. The plate circuits of the respective tubes 71, 72, and 73 are completed between the conductor 17 and the junction point 56 between the resistors 52 and 54 in series with respective resistors 84.

With all of the tubes 71, 72, and 73 extinguished, the voltage across the resistor 54 is preferably intermediate

between the extinction and ignition potential of tubes, and, if all of the contacts 26, 27, and 28 are closed, the capacitors 75, 77, and 79 become charged to the value of this voltage. Upon opening of one of the contacts 26, 27, or 28, for example, the contact 27, the side of the contact 27 nearest to the relay winding 25_w suddenly changes from the potential of the negative supply conductor 17 to that of the positive supply conductor 16. Since the voltage across a capacitor cannot change instantaneously, there is a sudden increase in voltage at the plate 72_p of the tube 72. The cathode 72_c of the tube 72, however, remains at the potential of the negative conductor 17. This voltage difference is sufficient to cause the tube 72 to break down and emit a visible glow, and it remains ignited by the current flowing through its plate circuit and the associated one of the resistors 84. When the contact 27 again recloses, the tube 72 does not become extinguished because the resulting negative or reverse surge is absorbed by the resistor 76 and the now lower resistance of the conducting tube 72. The tube 72 may be extinguished by momentarily opening the reset switch 55. Similarly, the tubes 71 and 73 become ignited upon opening of their associated contacts 26 and 28.

In the circuits of Figs. 3, 4, and 5, the simultaneous opening of any two or more of the contacts 26, 27, and 28 results in the ignition of the appropriate ones of the tubes 48, 49, and 50 or 71, 72, and 73. In the circuits of Figs. 3 and 4, should one of the contacts open after one has already opened, the tube ignited by the opening of the first contact remains ignited. In other words, the annunciator "remembers" which contact opened first. In the circuit of Fig. 5, however, this memory ability is not present, since the opening of any one of the contacts on the negative side of the contact which first opened causes the ignited tube to be extinguished.

Fig. 6 illustrates an annunciator similar to that of Fig. 3 but arranged to indicate which of several contacts such as 91 and 92 in series with an operating winding of an electro-magnetic relay 94 might have opened to deenergize the relay 94, and which of several contacts such as 96, 97, and 98 in series with an operating winding of an electro-magnetic relay 99 might have opened to deenergize the relay 99. The relays 94 and 99 may also be controlled by respective switches 100 and 101.

The annunciator of Fig. 6 comprises a plurality of three-element, cold cathode, gaseous discharge tubes 102 through 106 having their respective trigger electrodes connected in triggering circuits 102' through 106'. The triggering circuits 102' through 106' are identical with each other and with the triggering circuits of Fig. 3 and are associated with the contacts 96, 91, 92, 97, and 98, respectively. The cathode-plate circuits of the tubes 102 through 106 are completed in parallel from the negative conductor 17 through the respective cathodes and plates and respective resistors 68 to the junction point 56 between the resistors 52 and 54.

In operation of the circuit of Fig. 6, opening of either or both of the contacts 91 and 92 or any of the contacts 95, 96, and 98 causes ignition of its associated one of the tubes 102 through 106 which by its glow indicates which of the contacts opened.

Fig. 7 is a fragmentary wiring diagram which illustrates how the other annunciators described herein may be modified to be used with an alternating current source.

Referring to Fig. 7, an electromagnetic contactor 110 which might serve to control an alternating current motor (not shown) by means of its normally open main contacts 110_a has its operating winding 110_w connected between suitable alternating current supply conductors 111 and 112 through a normally open start push button 114, a normally closed stop push button 115, a normally closed protective contact 116, and a normally open protective contact 118. A normally-open auxiliary contact 110_b is arranged to by-pass the push button 114 to provide a holding circuit for the contactor 110.

A plurality of transformers 119, 120, and 121 have their primary windings 119p, 120p, and 121p, connected in loop circuits with the push button 115 and the contacts 116 and 118, respectively, and have one terminal of each of their secondary windings 119s, 120s, and 121s connected to a negative terminal 128a of a full wave rectifier 128 and the other terminals of their secondary windings connected, respectively, to trigger electrodes of respective three-element, cold cathode, gaseous discharge tubes 122, 124, and 125 which may be the same as the tubes 48, 49, and 50 of Figs. 3 and 4. A plurality of resistors 126 interposed in the respective loop circuits have their ohmic values so selected with respect to the impedance of the winding 119w, the impedance of their associated primary windings 119p, 120p, or 121p, and the highest voltage expected between the conductors 111 and 112 that, upon opening of the push button 115 or either of the contacts 116 and 118, the contactor 110 drops out.

The cathode-plate circuits of the respective tubes 122, 124, and 125 are connected in parallel with each other across direct current output terminals 128a and 128b of the rectifier 128 which has its alternating current terminals connected between the conductors 111 and 112. Resistors 129 are interposed in the plate circuits, respectively, which are controlled by a push button 130. A capacitor 131 serves to filter the D.C. output of the rectifier 128.

Operation of the system of Fig. 7 is similar to that of Fig. 3, the voltage that appears in the secondary windings 119s, 120s, and 121s upon opening of its associated push button 115 or contacts 116 and 118 causing the appropriate one of the trigger electrodes to ignite its associated tube 122, 124, and 125.

In the electronic annunciator of Fig. 8, a plurality of two-element, cold cathode, gaseous discharge tubes 141, 142, and 143 which may be similar to the tubes 71, 72, and 73 of Fig. 5 have their respective cathodes 141c, 142c, and 143c connected to the negative conductor 17 and their respective plates 141p, 142p, and 143p connected through respective resistors 145 to a junction point 146. The junction point 146 is connected through a normally closed push button or reset switch 148 to an adjustable intermediate point 149a on a resistor 149 which forms part of a voltage divider 150 also including a resistor 151 and connected between the conductors 16 and 17 with the resistors 149 and 151 in series. Thus the tubes 141, 142, and 143 are connected in parallel with each other across the resistor 151 and the right hand portion of the resistor 149 and preferably are subjected to a potential midway between their ignition and extinction potentials.

The plate 141p is connected through a capacitor 154 to the positive side of the contact 28, the plate 142p is connected through a capacitor 155 to the positive side of the contact 27, and the plate 143p is connected through a capacitor 156 to the positive side of the contact 26. The positive side of the contact 26 is arranged to be connected to the positive conductor 16 through the winding 25w of the undervoltage relay 25 and, in parallel, through the conductor 29 including the contact 25a and the conductor 24 which includes the off-point segment 22 as shown in Fig. 3.

When conditions are normal and all of the contacts 26, 27, and 28 are closed, the capacitors 154, 155, and 156 are charged to the voltage appearing across the resistor 151 and the right hand portion of the resistor 149 and none of the tubes 141, 142, and 143 is ignited. Upon opening of the contact 26, the relay 25 becomes de-energized and the side of the contact 26 nearest to the relay winding 25w suddenly changes from the potential of the negative conductor 17 to that of the positive conductor 16. Since the voltage across a capacitor cannot change instantaneously, there is a sudden increase in potential at the plate 143p. The cathode 143c, however, remains at the potential of the negative

conductor 17. This voltage difference is sufficient to cause the tube 143 to break down and emit a visible glow, and it remains ignited by the current flowing through its plate circuit and the associated one of the resistors 145.

If the contact 27 opens instead of the contact 26, the relay 25 becomes deenergized and the side of the contact 26 nearest the relay winding 25w as well as the side of the contact 27 nearest the contact 26 suddenly change from the potential of the negative conductor 17 to the potential of the positive conductor 16. In this instance the tubes 142 and 143 both become ignited. If the contact 28 opens instead of the contacts 26 or 27, all three of the tubes 141, 142, and 143 become ignited.

The tubes 141, 142, and 143 are preferably arranged in a row as are the tubes 12 of Fig. 1 so that when but one of the tubes, for example, the tube 143, at one end of the row becomes ignited, it will be known that the contact 26 nearest the positive conductor 16 opened. If both of the tubes 142 and 143 become ignited, it will be known that the contact 27 opened, and if all three of the tubes 141, 142, and 143 become ignited, it will be known that the contact 28 opened.

The ignited ones of the tubes 141, 142, and 143 may be extinguished at any time by opening the push button 148.

Although a preferred and several modified arrangements of apparatus and circuits are disclosed herein, it is to be understood that such are merely illustrative of the principles of the invention.

Having thus described my invention, I claim:

1. An electronic annunciator system comprising an electroresponsive device, control circuit means connecting said device across a source of power and including a plurality of contacts in series with each other and in series with said device, a plurality of gaseous discharge tubes each having a pair of electrodes across which a gaseous discharge when once initiated is maintained so long as a potential in excess of a predetermined minimum potential is impressed therebetween, plate circuit means connecting each of said pairs of electrodes to a source of power independently of said control circuit means and operative independently of the electrical condition of said control circuit means to impress between the electrodes of each tube a predetermined intermediate potential which is in excess of said minimum potential but less than a higher potential required to initiate a discharge between the electrodes of each tube, voltage transferring means connected to said tubes, respectively, and operative when subjected to a voltage above a predetermined value to initiate a discharge between the pair of electrodes of its associated tube irrespective of the electrical condition of any of the other ones of said tubes, and coupling means electrically associated with said contacts, respectively, and with said voltage transferring means, respectively, so that said tubes are electrically associated with said contacts, respectively, said coupling means being operative upon opening of any of said contacts while said circuit means is connected to said source of power and carrying current to subject the voltage transferring means associated with the opened contact to a voltage above said predetermined value thereby to initiate a discharge which is capable of being maintained by said plate circuit means between the electrodes of each one of said tubes associated with an opened contact.

2. The electronic annunciator system of claim 1 characterized in that said tubes constitute visible signals and have transparent envelopes and are so mounted that at least a portion of each of said envelopes is exposed to view.

3. The electronic annunciator of claim 2 characterized in that said tubes are provided with indicia

which relates each tube with the contact with which it is electrically associated.

4. The electronic annunciator system of claim 1 characterized in that said tubes are of the cold cathode type.

5. The electronic annunciator system of claim 1 characterized in that said tubes are each of the three-element, cold cathode type having a trigger electrode and each of said voltage transferring means is connected to said trigger electrode and one of said other electrodes of its associated tube in a circuit operatively isolated from all of the other voltage transferring means.

6. The electronic annunciator system of claim 5 characterized in that said electroresponsive device includes an inductive winding, said contacts are connected in series with each other and in series with said winding and are all closed at the same time to energize said winding while said control circuit means is connected to its source of power, and said coupling means includes coupling circuits respective to said contacts and operative upon opening of its associated contact to subject the voltage transferring means associated with the opened contact to a voltage above said predetermined value.

7. The electronic annunciator system of claim 6 characterized in that said electroresponsive device is an undervoltage relay.

8. The electronic annunciator system of claim 6 characterized in that each of said voltage transferring means comprises a transformer having its primary winding connected by its associated coupling circuit in parallel with its associated contact.

9. The electronic annunciator system of claim 8 characterized in that each of said coupling circuits includes a resistor connected in series with its associated primary winding in a loop circuit with the contact associated with its associated primary winding.

10. The electronic annunciator system of claim 8 characterized in that each of said coupling circuits includes a capacitor connected in series with its associated primary winding in a loop circuit with the contact associated with its associated primary winding.

11. The electronic annunciator system of claim 1 characterized in that said tubes are of the two-element, cold cathode types, each of said voltage transferring means comprises a capacitor, and the associated one of said coupling means connects its capacitor in a loop circuit including its associated contact and tube.

12. An undervoltage protection system comprising an electromagnetic undervoltage relay having an operating winding, an undervoltage relay circuit including said winding and adapted to be connected across a source of power for energizing said winding from the source, a plurality of contacts connected in series with each other in said undervoltage relay circuit and in series with said winding, means maintaining all of said contacts in closed position for effecting energization of said winding upon connection of said undervoltage relay circuit across the source of power, means for opening said contacts selectively to effect deenergization of said winding, a plurality of gaseous discharge tubes each having a pair of principal electrodes and a transparent envelope and capable of emitting a visible glow when current is flowing across said electrodes, plate circuit means connecting each of said pair of electrodes to a source of power independently of said undervoltage relay circuit and operative independently of the electrical condition of said undervoltage relay circuit to impress a voltage across each pair of said electrodes, firing means for said tubes, respectively, and each operative to initiate conduction of its associated tube irrespective of the electrical condition of any other tube, and means operatively associating said firing means with said contacts, respectively, in a manner such that the conduc-

tivity or non-conductivity of said tubes depends upon whether its associated contact is open or closed.

13. An undervoltage protection system comprising an electromagnetic undervoltage relay having an operating winding, a circuit means including said winding and adapted to be connected across a source of power for energizing said winding from the source, a plurality of contacts connected in series with each other in said circuit means in series with said winding, means maintaining all of said contacts in closed position for effecting energization of said winding upon connection of said circuit means across the source of power, means for opening said contacts selectively to effect deenergization of said winding, a plurality of transformers each having a primary and a secondary winding, coupling means connecting said primary winding across said contacts, respectively, a plurality of three-element, cold cathode, gaseous discharge tubes each having an anode, a cathode, and a trigger electrode, plate circuit means independent of said circuit means and respective to said tubes and operatively isolated each from the other in a manner such that conduction and non-conduction of a tube has no effect on any other tube, each of said plate circuit means connecting the anode and cathode of its associated tube to a source of power independently of said circuit means and operative independently of the electrical condition of said control circuit means to impress across the anode and cathode of its associated tube a potential which is less than the potential required to initiate a discharge between the anode and cathode thereof but sufficient to maintain said discharge, means connecting one terminal of each of said secondary windings to said trigger electrodes, respectively, and means connecting the other terminals of said secondary windings to each other and to said cathodes.

14. The undervoltage protection system of claim 13 characterized in that resistors are interposed in said coupling means respectively, the resistance of said resistors being so related to the voltage of the source and the resistance of said primary windings and said relay winding that opening of any of said contacts while said circuit means is connected to said source causes said relay to drop out.

15. The undervoltage protection system of claim 14 characterized in that said relay is an alternating current relay, said circuit means is adapted to be connected across a source of alternating current, and a rectifier arranged to be connected to said source has its direct current terminals connected to said anodes and said cathodes, respectively.

16. The undervoltage protection system of claim 13 characterized in that said coupling means includes capacitors, respectively.

17. An undervoltage protection system comprising an electromagnetic undervoltage relay having an operating winding, a circuit including said winding and having positive and negative terminals adapted to be connected across a source of direct current power for energizing said winding from the source, a plurality of contacts connected in series with each other in said circuit means in series with said winding between said winding and said negative terminal, means maintaining all of said contacts in closed position for effecting energization of said winding upon connection of said circuit means across the source of power, means for opening said contacts selectively to effect deenergization of said winding, a plurality of cold cathode, gaseous discharge tubes each having an anode and a cathode, a plurality of capacitors, means connecting said anodes through said capacitors, respectively, to the sides, respectively, of said contacts nearest said positive terminal, and plate circuit means including means connecting said cathodes to said negative terminal and connected to said anodes and cathodes independently of said circuit, said plate circuit means being operative when energized to im-

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press a potential across the anode and cathode of each tube which is less than the potential required to initiate a discharge between the anode and cathode thereof but sufficient to maintain said discharge.

18. The undervoltage protection system of claim 17 5 characterized in that said means connecting said cathodes to said negative terminal connects each of said cathodes to the side of its associated contact that is nearest said negative terminal.

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