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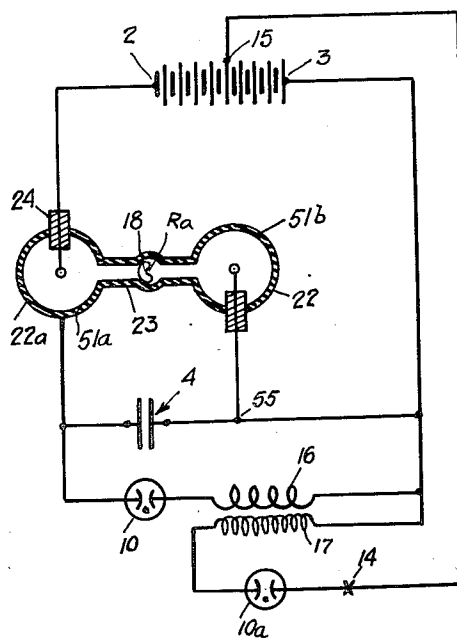
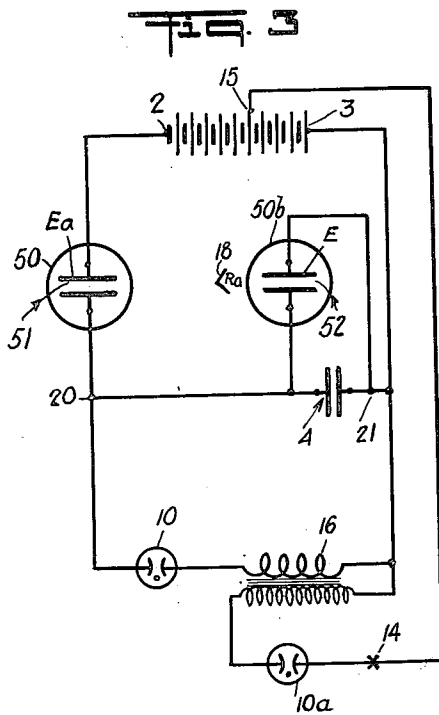
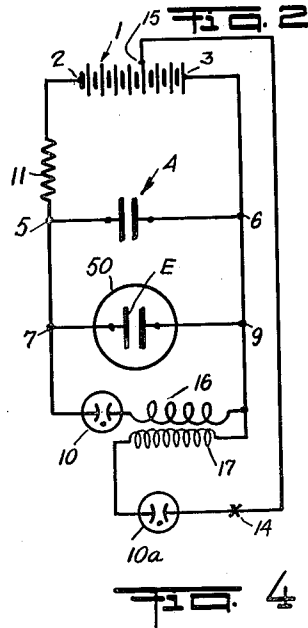
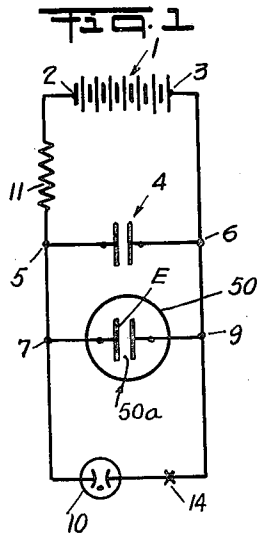
F. PERRIN ET AL

2,375,130

RELAY

Filed Dec. 12, 1942

2 Sheets-Sheet 1



INVENTORS
Francis Perrin & Boris Pregel
BY
Mock & Rhum
ATTORNEYS

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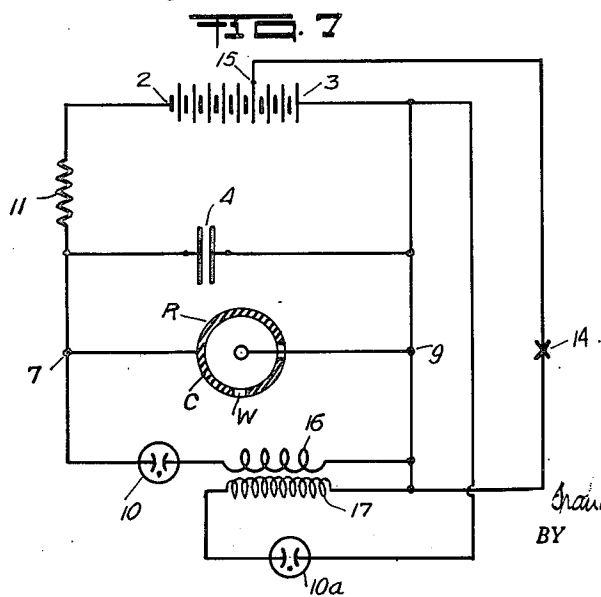
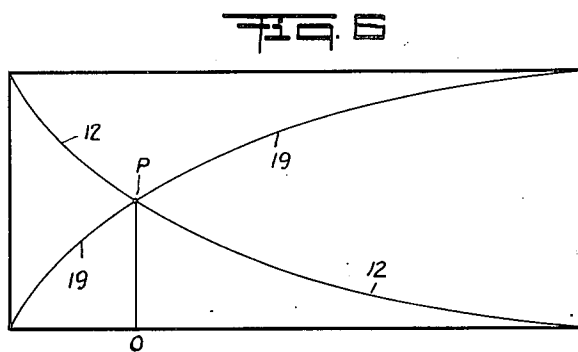
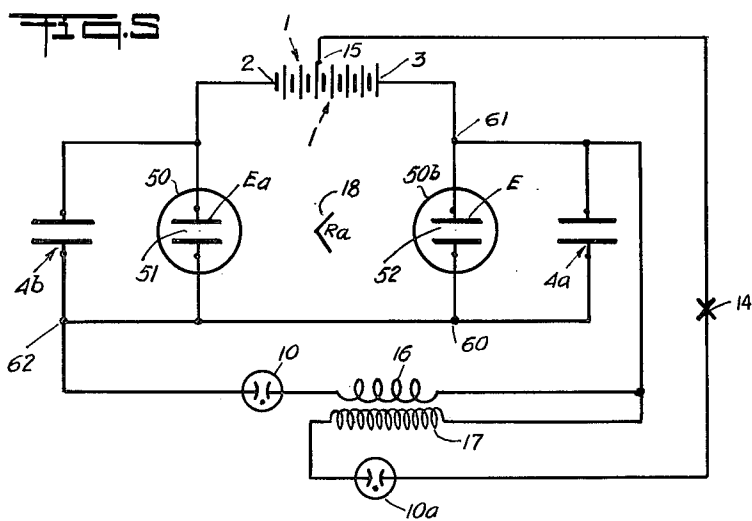
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RELAY

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2 Sheets-Sheet 2



INVENTORS

INVENTORS
Francis Perrin & Boris Pregel
BY

BY

Mock + Rhum

ATTORNEYS

UNITED STATES PATENT OFFICE

2,375,130

RELAY

Francis Perrin and Boris Pregel, New York, N. Y.,
assignors to Canadian Radium & Uranium
Corporation, New York, N. Y., a corporation of
New York

Application December 12, 1942, Serial No. 468,846

7 Claims. (Cl. 250—83.6)

Our invention relates to a new and improved relay.

Said relay may be of the delayed-action type, so that the desired result or relay effect will be produced at the end of a substantial predetermined period after the relay has been primed or set into operation. Said relay may produce said desired result quickly after it has been set into operation.

The relay includes one or more control elements or control units. These units have a variable conductivity regulated independently of heat, and without the use of mechanical devices. Such unit may conduct current, either by ionization or by electronic emission. The ionization can be produced by radio-active material. Electronic emission can be secured by a photo-electric cell which operates without a heated cathode. For example, such photo-electric cell can have an unheated caesium cathode, which will emit electrons at normal temperature of about 20° C. under the action of light.

The relay can be used for various military and industrial purposes, such as to produce delayed explosions of bombs, including aerial bombs.

The principal objects of the invention are to produce a simple and durable relay, which can be made at relatively low cost, and to magnify the minute ionization current or electronic current which is produced in the control unit or units, without the use of electronic tube amplifiers.

Numerous additional objects of the invention are set forth in the annexed description and drawings, which illustrate various embodiments.

The drawings are wholly diagrammatic.

Fig. 1 illustrates one embodiment of our invention in its simplest form. This utilizes a single resistance unit which has a falling characteristic, and a single control unit.

Fig. 2 illustrates a second embodiment, which utilizes two such resistance units and a single control unit. This delivers more energy than the embodiment of Fig. 1.

Fig. 3 illustrates a third embodiment which has two said resistance units and two said control units.

Fig. 4 illustrates a fourth embodiment, which utilizes two ionization chambers which have conductive metal walls.

Fig. 5 illustrates another embodiment which utilizes a pair of capacitances, a pair of said resistance units, and a pair of said control units.

Fig. 6 shows the curves which illustrate the

relation between lapse of time and ionization, in using gaps in which a gas or mixture of gases is ionized. In Fig. 6 the ordinate is the ionization, and the abscissa is the lapse of time. Fig. 6 refers to ionization by means of the radiations from radio-active material. Curve 12 represents the falling ionization which is produced by a decaying radio-active substance, such as radon which is separated from radium. Curve 19 represents the progressive accumulation of a short-life decaying radio-active substance which is produced by a long-life radio-active substance, such as radon which is produced by radium.

Fig. 7 shows another embodiment, in which a photo-electric cell is used.

The invention will first be described with reference to the use of relay units which utilize the rate of spontaneous disintegration of radio-active material, with particular reference to the control of delayed explosions, as for example, in producing the delayed explosions of aerial bombs or other bombs.

One of the most easily available radio-active substances is radon, which is a gaseous emanation of radium. The half-life period of radon is approximately four days, the exact length of said half-life period being more accurately designated as about 3.8 days.

By using different radio-active substances which have different respective half-life periods, we can produce delays in the action of the relay between a few days and a few weeks. The period of delay depends upon the choice of the radio-active substance, since respective radio-active substances have respective different half-life periods.

We can also secure different periods of delay, while using a single radio-active substance which may be radon or many other radio-active substances. In such case, we use different applied voltages and different resistances in the circuit, so that the period of delay can be varied from about 50% to 400% of the half-life period of the respective radio-active substance. By using different radio-active substances, the period delay can be controlled from a few hours to several months. Amongst other radio-active substances, we include, radon, radium A & B & C which is an active deposit of radon, polonium or radium F.

If it is desired to produce a delayed effect, the main problem is efficiently to utilize the small amount of radio-active substance that may commercially be used in a relay, in order to lower its expense.

The easiest way to observe the decrease in ac-

tivity of a radio-active substance is to measure the decrease of an ionization current which is produced in a gas which is located in an electric field and which is subjected to the radiation of the radio-active substance. However, such ionization currents are very small. For example, if a fraction of a milligram of radium is used, the ionization current is only a small fraction of a microampere. The use of much larger quantities of radium or the like would be prohibitively expensive.

We have therefore devised a simple and efficient relay, by means of which a continuous current of 10-50 milliamperes is established in order to produce the desired effect, when a very small initial ionization current, which is a small fraction of a microampere, and which is produced by a radio-active substance, has decreased to a predetermined fraction of its initial value. The invention is not limited to using the decrease in such ionization current.

Fig. 1 shows a source of electric current 1 which may be of any type. It may consist of a number of dry cells which are connected in series, in order to provide a voltage of 100 volts at the terminals 2 and 3 of said source 1. It is to be understood that any details which are stated herein, in order to give one or more working examples, are merely illustrative and that the invention is not limited to the same. The terminal 2 is connected through a resistor 11 to one terminal 5 of a condenser or capacitance 4. The terminal 3 of the source 1 is connected to the other terminal 6 of said capacitance 4. In the example stated herein, the resistance of the resistor 11 is about 1,000 megohms. The capacity of the series-connected dry cells of the source 1 can be very small. The capacity of the condenser 4 is about 0.1 microfarad. The dielectric of the condenser 4 should have maximum resistivity, in order to minimize any leakage current through said condenser. It is therefore preferable to provide a mica dielectric for said condenser 4.

The terminals 5 and 6 of the condenser 4 are respectively connected to the terminals 7 and 9 of an ionization chamber 50 which has spaced electrodes E, which are separated by gap 50a. The electrodes E are connected to the circuit at the points 7 and 9. Said ionization chamber 50 may contain air at normal atmospheric pressure of 760 millimeters of mercury. The invention is not limited to the use of any particular gas or gases between the electrodes E, or to the pressure of the gaseous medium which is located between the electrodes E. This pressure may be lower or higher than atmospheric pressure. The ionization chamber may contain a vapor or vapors, mixtures of vapors and gases, etc. In this specific example, the distance between the electrodes E is about 1 cm.

The terminals 5 and 6 of the condenser 4 and the terminals 7 and 9 of the ionization chamber 50 are connected to the electrodes of a neon lamp 10. This lamp 10 may contain neon or other gas under suitable low pressure, so that the striking voltage of said lamp 10 is about 80 volts. After the lamp 10 has been struck, current can be sent through said lamp at a voltage which is less than the striking voltage. The lamp 10 is therefore an example of a resistance which has a falling characteristic. This type of resistance is sometimes designated as a negative resistance.

When the voltage at the terminals 5, 6, which is the same as the voltage between points 7 and

9, exceeds 80 volts, the condenser 4 will discharge through said lamp 10.

The ionization chamber 50 is provided with a suitable quantity of radio-active substance, so that the initial maximum ionization current between the electrodes E is, for example, 0.8 microampere.

The lamp 10 is connected in parallel with the gap 50a, between the points 7 and 9, so that the potential difference which is applied to lamp 10, is the potential difference between the points 7 and 9.

This potential difference between points 7 and 9 depends upon the ratio of the resistance of gap 50a, to the sum of the resistance of said gap 50a and the resistance of resistor 11. Hence, when the resistance of gap 50a is the initial minimum resistance, the potential difference between points 7 and 9 will be only about 20 volts, so that the initial voltage drop in resistor 11 will be 80 volts. As the ionization current diminishes, as indicated by curve 12 of Fig. 6, and the resistance of gap 50a therefore increases, the difference of potential between points 7 and 9 will increase to the striking voltage, after a predetermined period of time which is regulated by the resistance of the resistor 11, and the rate of decay of the radio-active substance, with the resultant increase of space resistance of gap 50a. For example, if radon is used as the radio-active material, the voltage which is applied to lamp 10 may be equal to the striking voltage, at the expiration of a delay period of eight days. The circuit of lamp 10 includes an electric fuse 14, which may be replaced by any device which is to be operated or energized by the electric current which is passed through lamp 10.

In using the embodiment of Fig. 1, the source 1 is connected to lamp 10, only after the gap 50a has been sufficiently ionized to prevent the immediate striking of said lamp 10.

The discharge energy in this embodiment of Fig. 1 is small, unless a large condenser 4 is used, so that for many purposes it would be necessary to use a condenser of much larger capacity than as above stated.

The circuit of Fig. 2 makes it possible to secure much greater discharge energy through the fuse 14 or other device. This circuit contains a second neon lamp 10a which is similar to the lamp 10. In the embodiment of Fig. 2, the voltage between the terminals 2 and 3 of the series-connected dry cells 1 is about 100 volts, if the striking voltage of lamp 10 is 80 volts. One terminal of the auxiliary lamp 10a is connected through the fuse or other device 14, to a point 15 of the series-connected dry cells, so that the voltage between the points 15 and 3 is a suitable fraction of the total terminal voltage between the terminals 2 and 3. The voltage between the points 15 and 3 is sufficient to maintain a current through lamp 10a, after said lamp 10a has been struck. Said voltage between points 15 and 3 is less than said striking voltage.

The circuit of the lamp 10 includes a primary transformer coil or inductance 16, which is inductively coupled to a secondary transformer coil or inductance 17. The transformer 16-17 is a step-up transformer. The number of turns in the coil 16 is about 2½% of the number of turns in the coil 17, and the inductive coupling between said coils 16 and 17 is very close. Hence, when the condenser 4 discharges through said lamp 10 and inductance 16, sufficient voltage will be induced in coil 17 to strike lamp 10a. The

discharge of condenser 4 through lamp 10 and inductance 16 may be oscillatory or non-oscillatory.

According to the principle of operation previously stated, the condenser 4 will discharge through the lamp 10, only after a predetermined period of time has elapsed. Lamp 10a will be struck by said discharge, by means of the transformer. Current from source 1 is then passed through the lamp 10a, until the explosion or other desired effect takes place. The current which can thus be sent through the fuse or other device 14, which is in the circuit of lamp 10a, can be from 10-20 milliamperes if an ordinary small sized neon lamp 10a is used. By using a well-known special type of neon lamp, said current which is sent through the lamp 10a from source 1 can be as large as 50 milliamperes. The power which is thus made available by the relay can be approximately a watt, which is sufficiently great to produce the explosion or other desired result.

In the examples above given, we have described the use of a radio-active substance which begins to decay as soon as it is introduced into the ionization chamber, so that the period of delay of the action of the relay, begins from the time when such substance is introduced into said ionization chamber.

However, we can also use any radio-active substance which will continuously emanate radon.

Radium has a very long half-life period of about 2000 years and a given quantity of radium will produce a continuous supply of radon. Said radon is a gas which will accumulate in a closed ionization chamber up to a maximum equilibrium limit, because one half of the radon disintegrates during a period of approximately four days. Hence, when this limit is reached, the rate of supply of radon will be equal to its rate of decay.

We can therefore introduce radium or a radium alloy or compound into the respective ionization chambers 50 of the embodiments of Figs. 1 and 2, thus producing a constant ionization current which will not diminish. The relay can be primed by removing the radium or the like from said ionization chamber, thus starting the period of decay of the radon and the increase in resistance of gap 50a.

The radium can be removed either manually or automatically in the case of an aerial bomb, when the bomb is dropped. We have not illustrated simple conventional mechanisms for removing a plug which contains the radium from said ionization chamber when the bomb is dropped, because such conventional devices form no part of our invention per se.

We can also subject the gap 50a to ionization from any source, so that the ionization will stop immediately when the action of such source is discontinued. Such source may be Roentgen rays, ultra-violet light or the like. For example, if the circuit of the Roentgen ray machine is opened, the resistance of gap 50a will rise rapidly, thus causing a very rapid operation of the relay. Hence the invention is not limited to the use of any particular ionizing means, or to the location of the same in the ionization chamber 50.

Fig. 3 diagrammatically shows a carrier 18, one face of which is provided with a layer Ra of radium or radium alloy or radium compound. Fig. 3 also shows the use of a pair of ionization chambers 50 and 50b, which may be identical.

These ionization chambers have respective pairs of electrodes Ea and E, which have respective gaps 51 and 52. The preferred physical construction of the embodiment of Fig. 3 is shown in Fig. 4, which shows that the ionization chambers are connected by an intermediate tube, and that the carrier 18 is a turnable valve, which closes said intermediate tube, so as to prevent the passage of gas between said ionization chambers. Hence, if the solid layer Ra is radium or a radium compound or radium alloy, which yields radon, the supply of said radon can be limited only to one of said ionization chambers. If the layer Ra is of the aforesaid type, radon will be supplied only to the ionization chamber 50b, when the carrier 18 is in the non-priming position which is shown in Fig. 4, and said radon will be accumulated in chamber 50b, up to a maximum limit at which the rate of decay will equal the rate of supply. While carrier 18 is in said non-priming position, the circuit of lamp 10 will be open, because of the very high resistance of gap 51.

In order to prime the device, carrier 18 is turned through an angle of 180° from the position shown in Fig. 4, in order to supply radon to chamber 50 and to discontinue the supply of radon to chamber 50b.

The resistance of gap 51 will therefore diminish at a rate which corresponds to the increase of ionization which is designated by curve 19. The resistance of gap 52 will simultaneously increase at a rate which corresponds to the decrease of ionization current which is designated by curve 12. At the point P, the resistances of said gaps 51 and 52 will be equal, and the respective voltage drops through said respective gaps will be equal.

The ordinate OP represents said equal ionization currents.

After the device of Fig. 3 and Fig. 4 has been thus primed, the voltage which is applied to the lamp 10 is the difference of potential between points 20 and 21. The resistance between points 20 and 21 will progressively increase, while the resistance of gap 51 will simultaneously progressively decrease. Hence the voltage between points 20 and 21 will increase to the striking voltage, after a predetermined period of time. The condenser 4, which will then be charged to the striking voltage, will then discharge through lamp 10 and primary coil 16. This will strike lamp 10a, by means of the transformer, and lamp 10a will then receive a steady current from the source 1, until the electric fuse 14 or other device has been operated.

The embodiment of Fig. 3 eliminates the use of the high resistance 11, which is desirable, because such high resistances vary with variations in temperature. The embodiment of Fig. 3 also diminishes the effect of variations in the voltage of the dry cells, which may result from changes in temperature or the lapse of time.

The potential difference between the points 15 and 3 is sufficient to maintain the current through the lamp 10a, after said lamp has been struck, as in Fig. 2.

In the embodiment of Figs. 1-3, the walls or envelopes of the chambers 50, 50b are made of glass or other non-conductive material.

In the embodiment of Fig. 4, we use a pair of chambers 22 and 22a which have conductive metal walls which are fixed to the connecting tube 23, whose wall is also made of conductive metal. Hence the walls of chambers 22 and 22a and the

wall of tube 23 are electrically connected to each other. The carrier 18 is shaped like a valve, so that it always separates the respective gaseous fillings of the chambers 22 and 22a, in all positions of said carrier 18. Said carrier 18 is preferably made of glass or other non-conductive material, but we are not limited to any particular material. The position of the carrier 18 which is shown in Fig. 4, is the non-priming position. In such non-priming position, the layer Ra of radioactive material supplies radon, only to the chamber 22. Each said chamber 22 and 22a has a single internal electrode, which is separated from the respective metal wall by insulation 24.

In the non-priming position of Fig. 4, radon is supplied only to chamber 22, and the filling of chamber 22a remains non-ionized. Hence the circuit of source 1 remains open, because the internal electrode of chamber 22a is insulated from the metal wall of said chamber. While carrier 18 is held in said non-priming position, radon is accumulated in chamber 22, either up to or less than the maximum possible accumulation of said radon.

When the carrier 18 is turned to the priming position, the supply of radon to chamber 22a is commenced, and the supply of radon to chamber 22 is stopped. The internal space resistance of chamber 22a will progressively decrease, while the internal space resistance of chamber 22 is simultaneously increased.

Each said chamber 22 and 22a has its internal electrode located centrally with respect to its metal wall, which is of closed spherical shape save for the opening of tube 23.

When current initially flows from the internal electrode of chamber 22a through the space of said chamber 22a to its metal wall, a part of said current will flow through the metal wall of tube 23 to the metal wall of chamber 22, through the ionized filling of chamber 22 to its respective internal electrode, and to point 55 of the circuit. Hence the voltage which is applied to lamp or tube 10 will be less than the striking voltage of said lamp or tube 10, until the internal resistance of chamber 22 will increase to a predetermined limit. At the end of a predetermined delay period, the condenser 4 will be charged to the striking voltage, and said condenser 4 will discharge through lamp 10 and primary coil 16, thus striking lamp 10a. The carrier 18 can be held in its non-priming position during a relatively short period, so that the filling of the chamber 22 will be ionized less than the maximum, before the carrier 18 is turned to the priming position. In each of the embodiments, the circuit can be provided with a conventional manually operated switch. The valve chamber in which carrier 18 is located, can have an opening, so that when carrier 18 is turned counterclockwise through an angle of 90° from the non-priming position of Fig. 4, no radon will be supplied either to chamber 22 or chamber 22a, so that their respective internal resistances will be a maximum. The radon will then escape to the outer atmosphere, through said opening.

The carrier 18 can then be turned to the position shown in Fig. 4, and said carrier 18 can be held in said position for a short period, so that the ionization of the filling of chamber 22 will be less than the maximum, and the supply of radon to chamber 22 will be less than the maximum. When carrier 18 is then turned to the priming position, the initial voltage which is applied to lamp 10 will be less than the striking

voltage of said lamp 10, but the said lamp 10 can then be struck at the end of a period which is less than the maximum period of delay. Said period of delay can be very short.

This striking can be secured when the fillings of the tubes 22 and 22a are equally ionized, as illustrated by the point of intersection of the curves 12 and 13 in Fig. 6.

The embodiment of Fig. 5 is the same in construction and operation as the embodiments of Figs. 3 and 4, save that the embodiment of Fig. 5 has two identical condensers 4b and 4a.

When carrier 18 is in the non-priming position of Fig. 5, the circuit of the source 1 is open, since gap 51 is non-conductive, save that a transient charging current will leak through condenser 4b, and there may be a slight leakage current. The terminals of condenser 4a are connected to the circuit at points 60 and 61, and point 62 has the same potential as point 60. Hence, while some current flows through condenser 4b and gap 52, while carrier 18 is in said non-priming position, the lamp 10 will not be struck because the voltage drop between points 62 and 61 will be less than the striking voltage. While the carrier 18 is in said non-priming position, the condenser 4a is shunted by the conductive gap 52. As previously mentioned, the circuit can be provided with any conventional switch, which need not be closed until gap 52 has become sufficiently conductive.

When the carrier 18 is turned to priming position, and the resistance of gap 51 has been sufficiently lowered and the resistance of gap 52 has been sufficiently increased, the lamp 10 will be struck and the condenser 4a will discharge through lamp 10 and inductance 16, in an oscillatory or non-oscillatory discharge, thus striking lamp 10a. While condenser 4a is thus discharged, the charge of condenser 4b will increase.

The fuse or other device 14 can be omitted, so that the lamp 10 or 10a will be the only element which is operated.

In each embodiment, we utilize a source of current whose circuit includes a discharge element which has a falling characteristic and which has a predetermined striking voltage. The voltage of said source exceeds said striking voltage. Said circuit has a shunt which is connected to said circuit across the terminals of said discharge element. Said shunt has a pair of spaced electrodes whose gap has an ionizable gas, or ionizable vapor as an equivalent. Hence the voltage which is applied to said discharge element is the voltage which is applied across said shunt. Said gas is ionized by radon or other radio-active material, so that when said ionization exceeds a predetermined minimum, the voltage across said shunt is less than said striking voltage. In addition, and as an optional element, a capacitance is connected to said circuit in parallel to said discharge element, so that the voltage which is applied to said capacitance exceeds said striking voltage, only when the voltage across said shunt exceeds said striking voltage. This capacitance, if used, is connected to the terminals of said discharge element independently of said gap, so that the discharge current of said capacitance does not pass through said gap.

The use of a capacitance is desirable in order to produce a short and strong current pulse by the discharge of said capacitance when the striking voltage is reached. In addition, if the main circuit includes an inductance, the discharge of the condenser is preferably oscillatory. An inductance, like the coil 16, can be included in the

main circuit in which said capacitance is located, even if said main circuit is not coupled to an auxiliary circuit which has an auxiliary discharge element. The main circuit can be coupled to said auxiliary circuit in any manner, instead of using the inductive coupling which is disclosed herein, as one type of such coupling.

The ionizing means which are mentioned in the claims may be radon, other radio-active material or other source of ionizing energy.

Fig. 7 shows the substitution of a photoelectric cell R for the ionization chamber 50 of Fig. 2. Said cell R has a cathode C of caesium or the like, which is connected to point 7 of the circuit and to the negative terminal 2 of the source of current 1. The anode of said cell R is connected to point 9 and to the positive terminal 3. Said cell R has the usual window W. When light is excluded from window W, said cell R has high resistance, so that lamp 10 is subjected to the striking voltage. While the cathode of said cell R is energized by light so as to emit electrons, the resistance of cell R is sufficiently low so that lamp 10 is not struck. Hence the relay device of Fig. 7 is operated only when light is excluded from said cell R. We can use any type of photo-electric cell, which operates at ordinary temperature. Photo-electric cells can be substituted in the other embodiments. For example, in the embodiment of Fig. 3, the ionization chamber 50 can be replaced by a photo-electric cell which normally receives no light and ionization chamber 50b can be replaced by a photo-electric cell which normally receives light. This relay may be operated by operating respective shutters or by changes in light intensity so as to subject the cathode of the photo-electric cell which replaces chamber 50 to light or to variations in intensity of light, and excluding light from the cathode of the photo-electric cell which replaces chamber 50b, or changing the intensity of the light on the respective cathode. Such a relay may operate rapidly.

Strictly speaking, the space current of a highly evacuated photo-electric cell is an electronic current instead of an ionization current. Such a photo-electric cell may have sufficient residual gas, so that its space current is increased by ionization. The use of a photo-electric cell or cells of the "cold" type is within the scope of the invention. However, we greatly prefer the use of radio-active material, as distinguished from all other means for securing a space current.

In the embodiment of Fig. 4, each ionization chamber 22 and 22a has a pair of spaced electrodes, since the metal wall of each said chamber constitutes an electrode.

The ionizable material in the gaps between the electrodes of the ionization chambers, and the cathode of the photo-electric tube, are generally designated as radiation-responsive means, since they are responsive either to the radiations of radio-active material, light radiations, etc. Such radiation-responsive means are responsive at ordinary temperature.

The resistor 11 may be omitted, if the internal resistance of the source of electric current is sufficiently great.

The device 14 is generically designated as an ultimate current-consuming device. In each embodiment, we eliminate the necessity of including a mechanically-controlled switch, for controlling the supply of current to the ultimate current-consuming device. In circuits such as Fig. 2, we use the source of current 1 for the dis-

charge element 10a, as a matter of convenience. In the embodiment illustrated in Fig. 2, for example, the part of battery 1 between 15 and 3 could be replaced by another source of current, whose voltage is below the striking voltage of the discharge element 10a. In each embodiment, the ultimate current-consuming device 14 is directly connected to a respective source of current through a discharge element 10 or 10a which has a falling characteristic, so that the respective discharge element 10 or 10a is connected in series with device 14, and the respective discharge element 10 or 10a directly blocks the supply of current to the ultimate current-consuming device 14 until said discharge element is struck. Figs. 2, 3, 4, 5, and 7, each show a single effective circuit, which has one or more branches. Each said circuit has a control shunt which controls the application of the striking voltage across the respective discharge element 10 or 10a. Each said control shunt includes a radiation-responsive element and additional independent resistance.

We claim:

1. In combination, a source of current, a circuit whose terminals are connected to said source of current, an ultimate current-consuming device located permanently in said circuit, a discharge element connected in said circuit in series with said ultimate current-consuming device, said discharge element having a falling characteristic and requiring a striking voltage which exceeds its operating voltage after it has been struck, said discharge element directly blocking the passage of current through said ultimate current-consuming device until said discharge element has been struck and permitting the passage of current through said ultimate current-consuming device after said discharge element has been struck, said circuit having a control-shunt which controls the application of striking voltage across said discharge element, said circuit having resistance additional to the resistance of said shunt, said control shunt having electrodes which are separated by a gap in which an ionizable gas is located so that the resistance of said shunt is decreased by increased ionization of said gas, said additional resistance being sufficiently high so that said control shunt blocks the application of striking voltage to said discharge element as long as the resistance of said ionizable gas in said gap is below a predetermined limit, and a source of radiation for ionizing the gas in said gap.

2. In combination, a source of current, a circuit connected to the terminals of said source, a discharge element located in said circuit, said discharge element having a falling characteristic and a striking voltage and an operating voltage which is less than said striking voltage after said discharge element has been struck, the voltage of said source exceeding said striking voltage, a primary coil of a transformer connected in series with said discharge element, a control shunt connected in said circuit across said discharge element and said primary coil so that the voltage which is applied across said discharge element and said primary coil is the voltage which is applied across said control shunt, said control shunt including spaced electrodes which are separated by a gap in which ionizable gas is located so that the resistance of said shunt is decreased by increased ionization of said gas, a source of radiation for ionizing the gas in said gap, the voltage across said control shunt being less than the striking voltage when said gas is ionized above a predetermined limit, a capacitance connected

to said circuit in parallel relative to said discharge element and said primary coil, said capacitance being connected to said discharge element and said primary coil independently of said gap, the voltage of said capacitance exceeding said striking voltage only when the voltage across said shunt exceeds said striking voltage, said circuit including a branch which has a secondary coil which is inductively coupled to said primary coil, said branch including an auxiliary discharge element of the aforesaid type which is connected in series with said secondary coil, said branch being connected to a source of current whose voltage is less than the striking voltage of said auxiliary discharge element and which exceeds the operating voltage of said auxiliary discharge element.

3. In combination, a source of current, a circuit connected to the terminals of said source, a discharge element located in said circuit, said discharge element having a falling characteristic and a striking voltage and an operating voltage which is less than said striking voltage after said discharge element has been struck, the voltage of said source exceeding striking voltage, a primary coil of a transformer connected in series with said discharge element, a control shunt connected in said circuit across said discharge element and said primary coil so that the voltage which is applied across said discharge element and said primary coil is the voltage which is applied across said control shunt, said control shunt including spaced electrodes which are separated by a gap in which ionizable gas is located, so that the resistance of said control shunt is decreased by increased ionization of said gas, a source of ionization for ionizing the gas in said gap, the voltage across said shunt being less than the striking voltage when said gas is ionized above a predetermined limit, a capacitance connected to said circuit in parallel relative to said discharge element and said primary coil, said capacitance being connected to said discharge element and said primary coil independently of said gap, the voltage of said capacitance exceeding said striking voltage only when the voltage across said shunt exceeds said striking voltage, said circuit including a branch which has a secondary coil which is inductively coupled to said primary coil, said branch including an auxiliary discharge element of the aforesaid type which is connected in series with said secondary coil, said branch being connected to a source of current whose voltage is less than the striking voltage of said auxiliary discharge element and which exceeds the operating voltage of said auxiliary discharge element, said gap having radon associated therewith in order to ionize said gas.

4. In combination, a source of current, a circuit whose terminals are connected to said source of current, an ultimate current-consuming device located in said circuit, a discharge element connected in said circuit in series with said ultimate current-consuming device, said discharge element having a falling characteristic and requiring a predetermined striking voltage which exceeds its operating voltage after striking, said discharge element directly blocking the passage of current through said ultimate current-consuming device until said discharge element is struck and permitting the passage of current through said ultimate current-consuming device after said discharge element is struck, said circuit having a control-shunt which controls the

application of striking voltage across said discharge element in accordance with the voltage drop across said shunt, said control shunt having electrodes which are separated by a gap in which an ionizable gas is located, so that the resistance of said control shunt is decreased by increased ionization of said gas, said control shunt blocking the application of striking voltage to said discharge element as long as the resistance of said ionizable gas in said gap is below a predetermined limit, a second shunt which includes a capacitance whose terminals are connected to the terminals of said control-shunt so that the voltage of said capacitance is equal to the voltage applied across said shunt, and means for ionizing the gas in said gap.

5. In combination, a source of current, a circuit whose terminals are connected to said source of current, an ultimate current-consuming device located permanently in said circuit, a discharge element connected in said circuit in series with said ultimate current-consuming device, said discharge element having a falling characteristic and requiring a striking voltage which exceeds its operating voltage after striking, said discharge element directly blocking the passage of current through said ultimate current-consuming device until said discharge element has been struck and permitting the passage of current through said current-consuming device after said discharge element has been struck, said circuit having a control shunt which controls the application of striking voltage across said discharge element, in accordance with the voltage drop across said shunt, said control shunt having a gap through which space current can be sent, said gap including radiation-responsive means so that the resistance of said shunt is proportional to the intensity of the radiation which is received by said radiation-responsive means, a source of radiation for said radiation-responsive means, said circuit having resistance independent of said shunt so that the applied voltage across said shunt is proportional to the ratio of the resistance of said shunt to the sum of the resistance of said shunt and of said additional resistance, said control shunt blocking the application of said striking voltage as long as its resistance is below a predetermined limit.

6. In combination, a source of current, a circuit whose terminals are connected to said source of current, an ultimate current-consuming device located in said circuit, a discharge element connected in said circuit in series with said ultimate current-consuming device, said discharge element having a falling characteristic and requiring a striking voltage which exceeds its operating voltage after it has been struck, said discharge element directly blocking the passage of current through said ultimate current-consuming device until said discharge element has been struck and permitting the passage of current through said current consuming device after said discharge element has been struck, said circuit having a control shunt which controls the application of striking voltage across said discharge element according to the voltage drop across said control shunt, said shunt having a first radiation-responsive resistor therein, said circuit having a second radiation-responsive resistor between one end of said source and one end of said control shunt, the resistance of each radiation-responsive resistor being in proportion to the radiation received thereby, radiation-supplying means adapted to control the respective resistances of said respec-

tive radiation-responsive resistors, said control shunt blocking the application of striking voltage across said discharge element as long as the resistance of its radiation-responsive resistor is below a predetermined proportion of the resistance of the second radiation-responsive resistor.

7. A combination according to claim 6, in which the primary coil of a transformer is connected in series with said discharge element, said ultimate-current consuming device being located in a branch of said circuit, said branch including the

secondary coil of said transformer and a second discharge element of the aforesaid type which is connected in series with said ultimate current-consuming device, said branch having a source of current whose voltage is less than the striking voltage of said second discharge element and equal to the operating voltage of said discharge element.

FRANCIS PERRIN.
BORIS PREGEL.