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ARC EXTINGUISHING SYSTEM

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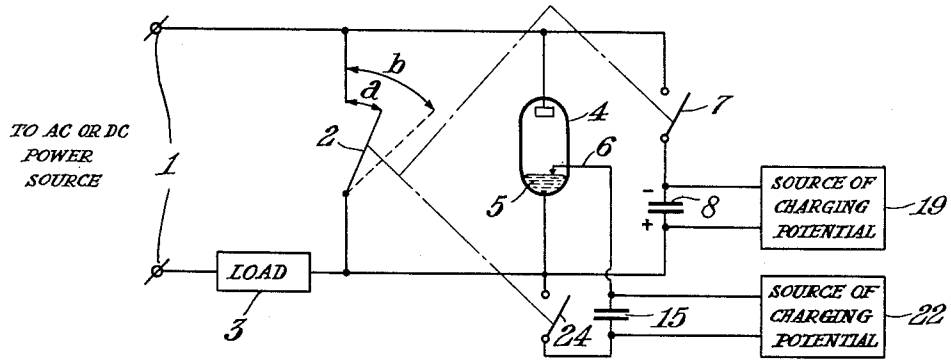

Fig. 1.

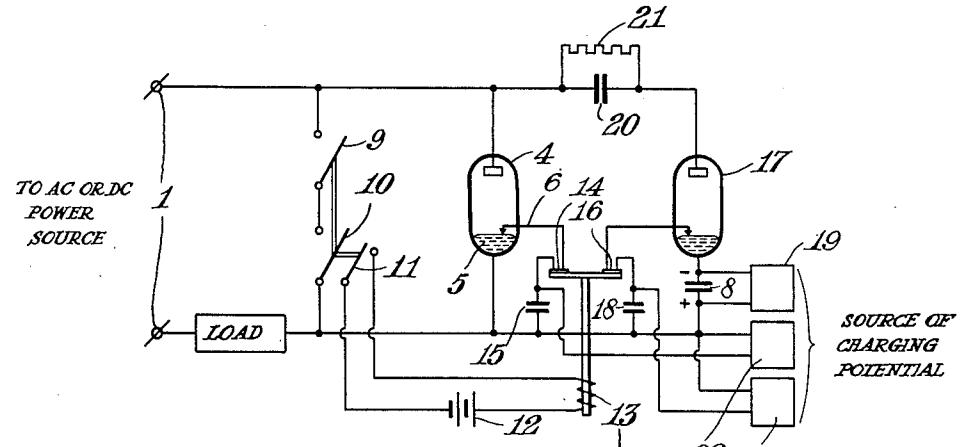

Fig. 2.

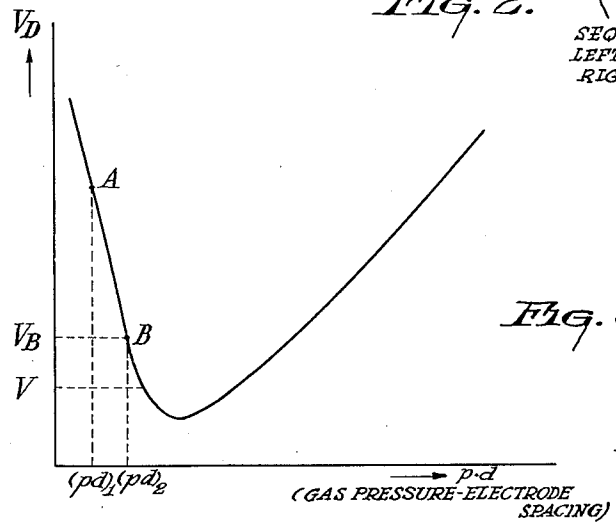

Fig. 3.

INVENTOR.
ADRIANUS CORNELIS VAN DORSTEN
BY Fred M Vogel
AGENT.

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ARC EXTINGUISHING SYSTEM

Adrianus Cornelis van Dorsten, Eindhoven, Netherlands, assignor, by mesne assignments, to Hartford National Bank and Trust Company, Hartford, Conn., as trustee

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4 Claims. (Cl. 175—294)

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The invention relates to a device for switching off direct or alternating current, which consists of a mechanical switch which has connected in parallel with it a mercury cathode gas- or vapour-discharge tube which, after the switch has been opened, is automatically ignited and is then forcedly extinguished.

Although such a device is fundamentally known it has never been found possible in practice, more particularly for switching direct current of large power of, say, some tens of kilovolts and of some hundreds of amperes, to realize such a device.

The invention is based on the recognition that this is really possible if a series of exactly determined requirements is satisfied.

According to the invention, the device has the following features:

(*a*) The tube is ignited within a limited period of time t_1 from the moment at which the switch is opened, in such manner that in the meanwhile sparking or arcing to a degree detrimental to the contacts is avoided.

(*b*) The tube is extinguished within a period of time t_2 which is so chosen that within the time t_1+t_2 the contacts have been sufficiently spaced apart and the space between the contacts has been sufficiently deionized to prevent renewed sparking or arcing at the contacts due to the returning voltage.

(*c*) Re-ignition of the tube due to the returning voltage is avoided, on the one hand, by the use of a tube of such small dimensions and, on the other hand, by the choice of a thus limited time period t_2—and hence of a limited increase of pressure due to the tube being heated by the passage of current during the time interval t_2—that the product of gas pressure p and electrode spacing d at the end of the period t_2 is located below a determined critical value.

By "a determined critical value" should be meant hereinafter a value of the product pd which is located in the region in which the breakdown voltage increases with the decrease of the value of pd (Paschen's curve) and the magnitude of which depends upon the value of the returning voltage.

It may be pointed out here that at high voltages the desired effect cannot be obtained with a tube of excessively large dimensions so that in this case in the first instance a tube of the smallest possible dimensions is to be preferred. Since with a decrease of the dimensions also the thermal capacity of the tube decreases, this implies that with a smaller tube also the

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period t_2 must again be shorter in order to satisfy the condition of a sufficiently low vapour pressure.

However, this cannot be continued unlimitedly since in the connection mentioned under (*b*) the time period t_2 plays a certain part, for according to (*b*) the total of the time periods t_1 and t_2 should be so chosen that there exists the possibility of de-ionizing the space between the contacts to a sufficient extent. In this case there exist different possibilities with respect to the determination of t_1 and t_2. For a clear apprehension it should, however, be mentioned beforehand that the desired high re-ignition voltage may be obtained in any known manner, for example by opening the contacts to a sufficient extent, by utilizing an air current, by providing the contacts in another medium such as oil, etc. and by any combination of these steps.

If now in connection with the production of sparks at the contacts for t_1 the highest allowable value is taken, only the period of time t_2 is available for the de-ionization with the above-mentioned means, which period must therefore have in this case a certain minimum value. Dependently upon the switched voltage and current the time period t_2 may, however, be reduced still further, to wit by reducing the period t_1. At a comparatively low voltage and with a high current intensity a decrease of t_1 affords, comparatively to the case of a high voltage with a high current intensity, less ionization in the arc between the contacts due to this reduction of time. In this case the space between the contacts can be de-ionized more easily and the period t_2 can be taken accordingly shorter than the above-mentioned minimum value, which is also desirable in view of the high current intensity taken over by the tube. The returning voltage is comparatively low so that even a comparatively small distance between the contacts may prevent the production of a new arc after the time t_1+t_2. In this case it is indeed advisable already in itself, in connection with the high current intensity, to take the period t_1 not at its maximum.

If, on the other hand, the voltage is comparatively high and the current intensity is low, t_1 may be taken slightly longer than in the preceding case since due to the high voltage a larger distance between the contacts is desirable and the low current intensity brings about less ionization, which is, however, increased again due to the longer duration of t_1. The period t_2 may be larger in this case since firstly also the current taken over by the tube is of low intensity so that

unadmissible heating and, attended therewith, an unadmissible vapour pressure occur less rapidly and secondly the ionization brought about due to the longer duration of t_1 requires a longer de-ionization period.

It follows from the above that the choice of the lowest and highest allowable values of t_1 and t_2 as well as that of the total of these periods is based on a compromise which depends in any particular case upon the voltage and the current intensity which are to be switched and on the choice of the dimensions of the tube. In general it may be said that t_2 and t_1 are of the order of magnitude of 10^{-3} seconds.

It should furthermore be mentioned that the practical possibility of switching off a high current intensity at a low voltage according to the invention, which possibility appeared from experiments, also demonstrates the possibility of switching off short-circuit powers in electric high-voltage networks, for in the switching off operation the high voltage is not applied to the switch but to the load so that in the first instance only the high current intensity has to be taken into account, the switching off thereof being now possible in virtue of the above. In this connection only the high voltage which returns after the switch has been opened and the parallel tube has been extinguished is important, which consequently implies that steps must be taken against the renewed production of an arc between the contacts and, as the case may be, within the tube. Such steps are known, however, so that it may be expected that they will not give rise to particular drawbacks.

According to a further feature of the invention, the mechanical switch is constituted in the manner known per se by two or more than two mechanical switches which are located in series and which are to be opened simultaneously and which, for example, may be coupled with one another, owing to which, more particularly in switching high current intensities at a high voltage, the certainty that upon the return of the switching voltage arcing between the switch contacts is avoided is obtained even in the case of comparatively small distances between the contacts. In connection with the switching-off rapidity of mechanical switches, which rapidity is tied down to determined maximum limits, this is particularly important in carrying out the invention, when very short time periods have to be combined in the correct manner to a predetermined program. Owing to the fact that the total voltage if two arcs located in series is accordingly higher than the voltage of a single arc of the same length as that of the two arcs together we obtain the advantage that the anode voltage of the parallel tube, which voltage is determined by the total of the arc voltage, is higher so that the tube can be ignited more easily at the correct instant. The certainty of correct ignition increases practically to 100% even with the use of two switches.

According to one suitable embodiment of the invention the tube is ignited with the aid of means controlled by the position of the switch which has already been opened. We thus obtain a simple circuit-arrangement which is beneficial to the reliability of service.

According to the invention, as means of extinguishing the tube there enters into account more particularly a circuit-arrangement wherein the tube has connected in parallel with it the series-connection of an extinguishing condenser, an auxiliary condenser and a switch, preferably an auxiliary discharge tube, whilst the ratio between the capacities is so chosen that the returning switching voltage is substantially taken up by the auxiliary condenser. This will be explained more in detail in the following description of the drawing.

The invention will be explained more fully with reference to the accompanying drawing which diagrammatically represents, by way of example, one embodiment thereof.

Referring to Fig. 1 a source of direct-current voltage 1 is connected through the intermediary of a mechanical switch 2 to a load 3. In parallel with the switch 2 is connected a gas- or vapour-discharge tube 4 which comprises a mercury cathode 5 and a controlling member 6 in the form of an immersed ignition electrode of high resistance or a capacitative ignition electrode. Finally, in parallel with the tube 4 are connected furthermore in the known manner a switch 7 and a condenser 8 which, for example, has been charged beforehand by a source of charging potential 19 with the polarity indicated.

Upon assuming that the load 3 is supplied via the switch 2 which is closed at first, the diagram shown functions as follows:

The switch 2 is opened with the result that between the contacts the beginning of an arc is struck. Then the tube 4 is ignited with the aid of the ignition electrode 6 so that the arc at the switch 2 is taken over by the tube. This is accomplished by means of a charged condenser 15, the charge being obtained from a source of charging potential 22. Subsequently the tube is extinguished by closing the switch 7, owing to which the anode voltage of the tube is sufficiently reduced by the charged condenser 8 and, if required, the anode even acquires for a short time a sufficiently negative potential to extinguish the tube.

According to the invention, the tube is ignited within a limited period of time t_1 so that sparking or arcing to a degree detrimental to the contacts does not occur. In the figure, the largest length of the arc between the contacts which is allowable in this connection is denoted by a. The maximum time t_1 is determined therefore by the quotient between the distance a and the rapidity of opening of the contacts, which rapidity should have, as the case may be, a certain minimum value on account of the requirements to be satisfied but, on the other hand, is tied down from the point of view of construction to a certain maximum. The ignition of the tube 4 within the period t_1 set therefore may occur, for example, dependently upon the position of the movable switch arm 2 by means of an additional contact switch 24 or in the case of electromagnetic switching off with the aid of a properly chosen time in any known manner as will be explained more fully with reference to Fig. 2. According to the invention, use is made furthermore of a tube 4 of so small dimensions and after being ignited, this tube is extinguished after a period t_2 of so short duration that re-ignition of the tube by the returning switching voltage 1 is prevented.

The behaviour of the switching tube may be explained with reference to Fig. 3 which shows qualitatively the course of Paschen's breakdown curve for a rarefied gas, and wherein the breakdown voltage V_D has been plotted as a function of the product pd of gas pressure and electrode spacing. Detailed information relative Paschen's curve may be found in "Applied Electronics," a publication of The Technology Press, Massachu-

setts Institute of Technology. During the switching operation the tube is in a state which is characterized by that portion of the curve which is located to the left of the minimum. At the end of the period t_1 the tube is in a state indicated by a point A. When the arc burns during the period of time t_2 the pressure increases so that at the end of this period at a point B the valve $(pd)_2$ is reached. This point corresponds to the voltage V_B. Re-ignition does not occur as long as care is taken to ensure that V_B exceeds the returning voltage V.

As may be seen from the figure, at a given voltage V this condition may always be fulfilled if the product pd on the branch AB remains below a determined critical value $(pd)_2$. In the above mention is made of the steps with the aid of which this may be effected in accordance with the invention.

The tube is extinguished by closing the switch 7, which may also be effected dependently upon the switch 2 or, as the case may be, dependently upon the ignition impulse at the electrode 6.

Finally, the periods t_1 and t_2 must be so chosen that, in connection with the opening rapidity of the switch 2 and with the additional de-ionization means which, as the case may be, may be employed, within the total of the period t_1+t_2 the space between the contacts denoted in Fig. 1 by b is, as has been set out in detail hereinbefore, in a state so as to prevent the renewed production of an arc between the contacts after the tube has been extinguished. In the case illustrated the distance $b—a$ constitutes therefore a measure for the time period t_2, if only the opening rapidity of the switch is taken into account.

Although Fig. 1 refers to the switching off of direct-current voltage, which has hitherto still been considered in practice as most difficultly realizable alternating voltage may also be switched off in a forced manner in accordance with the invention at any point within the cycle, for example within one tenth of a half-cycle.

Fig. 2 represents a device according to the invention wherein the switch 2 of Fig. 1 consists of two mechanical switches 9 and 10 located in series and coupled with one another. The switch 10 comprises an additional auxiliary switch 11, owing to which the correct moment of ignition of the tube 4 is fixed by means of a battery 12, a relay 13, contacts 14 and a charged condenser 15, condenser 15 being charged by a source of charging potential 22. The construction of the contacts 14 and 16 is such that a short and, as the case may be, regulable moment (t_2) after the closure of the first-mentioned contacts the last-mentioned contacts are closed, owing to which the tube 17 is ignited with the aid of a charged condenser 18, charged by a source 23, with the result that the condenser 8 charged by the device 19 (see also Fig. 1) is discharged via an auxiliary condenser 20 through the tube 4, the tube being extinguished by this impulse. Relatively to the condenser 8 the auxiliary condenser 20 is so dimensioned that it substantially takes up the switching voltage which returns after the tube 4 has been extinguished. This is particularly advantageous in switching high voltages because the comparatively large extinguishing condenser need not be insulated with respect to the returning high voltage since the discharge in the tube 17 breaks off timely after the condenser 20 has been charged. In the case of a periodically operating device it is advisable to shunt the condenser 20 by a leakage resistance 21, owing to which a sufficient discharge of the condenser within the period of time available therefore can be obtained.

It will be evident that known means other than the relay shown may also be utilized to ensure that the tube is ignited and extinguished at the correct moments.

With a circuit-arrangement utilized experimentally voltages of about 20 kilovolts and, on the other hand, currents up to 200 amperes were switched with the aid of a mechanical switch and a gas discharge tube wherein the distance between the electrodes amounted to a few centimetres and which had a volume of approximately 100 cube cms.

What I claim is:

1. Apparatus for disconnecting a load from a power source, said apparatus comprising a mechanically operated switch interposed between said load and said source and having a pair of contacts separable after opening at a prescribed rate, a gaseous discharge device having a cathode connected to one of said contacts, an anode connected to the other contact and an ignition electrode, a first normally open switching element, a first charged capacitor for providing a firing pulse and connected between said electrode and said cathode through said first element, means responsive to the operation of said switch to close said first element subsequent to the moment at which said switch is opened thereby igniting said device for a first predetermined period, a second normally open switching element, a second charged capacitor for providing an extinguishing pulse and connected between said cathode and said anode through said second element, and means responsive to the operation of said switch to close said second element at the termination of said first period thereby to extinguish said device for a second predetermined period immediately succeeding said first period, said contacts during said first period being so spaced whereby an arc thereacross is not detrimental to said contacts, said contacts during said second period having a sufficiently wide spacing and the space between the contacts being sufficiently de-ionized to prevent arcing between the contacts, said device having a Paschen's curve characteristic wherein the product of electrode spacing and gas pressure existing at the end of said second period has a value effecting a magnitude of breakdown voltage for said device greater than is supplied by said power source whereby re-ignition of said device subsequent to said second period is prevented.

2. Apparatus for disconnecting a load from a power source, said apparatus comprising a mechanically operated switch interposed between said load and said source and having a pair of contacts separable at a predetermined rate after opening, a gaseous discharge device having a cathode connected to one of said contacts, an anode connected to the other of said contacts and an ignition electrode, a first normally open switching element, a first charged capacitor for providing a firing pulse and connected between said cathode and said electrode through said first element, a second normally open switching element, a second charged capacitor for providing an extinguishing pulse and connected between said anode and said cathode through said second element, an electromagnetic relay for actuating said first and second elements, means responsive to the operation of said switch for actuating said relay, said relay being arranged to close said first element subsequent to the moment at which said switch is opened thereby

igniting said device for a first predetermined period, said relay being further arranged to close said second switch at the termination of said first period thereby extinguishing said device for a second predetermined period immediately succeeding said first period, said contacts during said first period being so spaced whereby an arc thereacross is not detrimental to said contacts, said contacts during said second period having a spacing sufficiently wide and the space between the contacts being sufficiently de-ionized to prevent arcing between the contacts, said device having a Paschen's curve characteristic wherein the product of electrode spacing and gas pressure existing at the end of said second period has a value effecting a magnitude of breakdown voltage greater than is supplied by said power source, whereby re-ignition of said device subsequent to said second period is obviated.

3. Apparatus for disconnecting a load from a power source, said apparatus comprising a mechanically operated switch interposed between said load and said source and having a pair of contacts separable at a predetermined rate after opening, first and second gaseous discharge devices each having a cathode, an anode and an ignition electrode, the cathode and anode of said first device being connected to said pair of contacts, first and second normally open switching elements, first and second charged capacitors for producing firing pulses, said first capacitor being connected between the cathode and ignition electrode of said first device through said first element, said second capacitor being connected between the cathode and ignition electrode of said second device through said second element, a third charged capacitor for providing an extinguishing pulse and connected between the cathodes of said first and second devices, means intercoupling the anodes of said first and second devices, an electromagnetic relay for actuating said first and second elements, means responsive to the operation of said switch for actuating said relay, said relay being arranged to close said first element subsequent to the moment at which said switch is opened thereby igniting said first device for a first predetermined period, said relay being further arranged to close said second switch at the termination of said first period thereby igniting said second device and extinguishing said first device for a second predetermined period immediately succeeding said first period, said contacts during said first period being so spaced whereby an arc thereacross is not detrimental to said contacts, said contacts during said second period having a spacing sufficiently wide and the space between the contacts being sufficiently de-ionized to prevent arcing between the contacts, said first device having a Paschen's curve characteristic wherein the product of electrode spacing and gas pressure existing at the end of said second period has a value effecting a magnitude of breakdown voltage greater than is supplied by said power source whereby re-ignition of said first device subsequent to said second period is obviated.

4. Apparatus as set forth in claim 3, wherein said means for intercoupling the anodes of said first and second devices comprises a condenser connected in parallel with a resistor.

ADRIANUS CORNELIS VAN DORSTEN.

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