June 28, 1932. D. C. PRINCE 1,865,274

CIRCUIT INTERRUPTER

Filed March 23, 1928

Fig. 1.

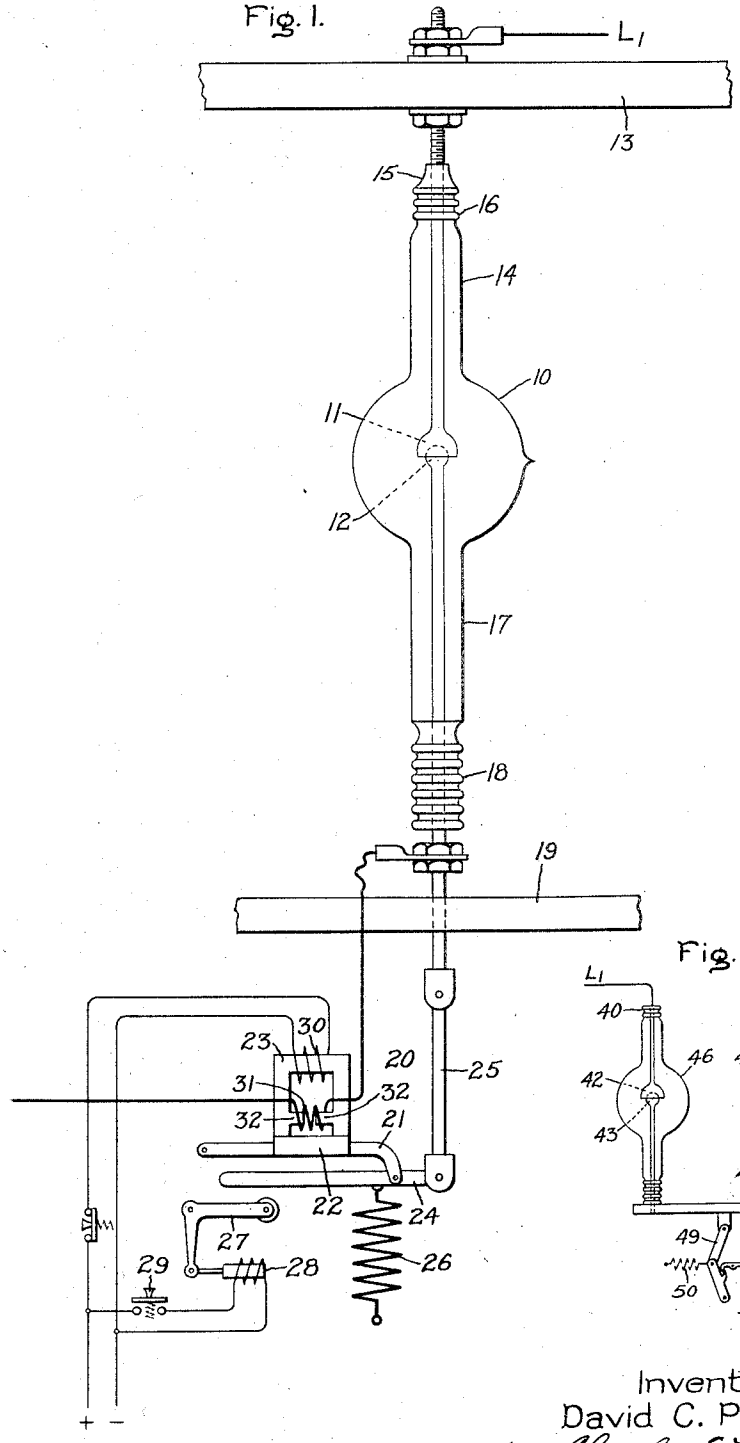
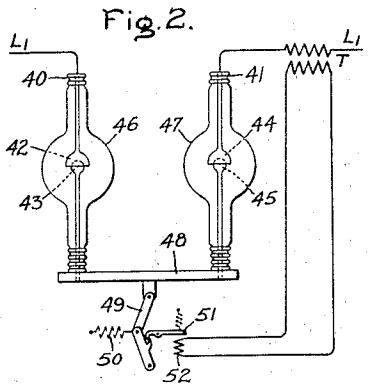


Fig. 2.



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UNITED STATES PATENT OFFICE

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CIRCUIT INTERRUPTER

Application filed March 23, 1928. Serial No. 264,116.

My invention relates to devices for interrupting electric circuits, and more particularly to vacuum switches in which the circuit is interrupted between electrodes separated within a highly evacuated envelope.

One of the principal objects of my invention is to improve the form of the vacuum switch electrodes so as to especially adapt the switch for interrupting either direct or alternating current circuits when the current between the electrodes is in a predetermined direction. More specifically the improved form of vacuum switch electrodes enables the electron flow from a particular one of the electrodes to the seals and other susceptible parts of the envelope to be materially decreased when the circuit is interrupted with the current through the vacuum switch in one direction over that obtaining during the interruption of the circuit with the current in the other direction. In this way destructive electron bombardment of the seals and other susceptible parts of the envelope may be avoided, thereby materially increasing the effective life and reliability of the vacuum switch.

In direct current service, the interruption of the circuit with the current in the required direction through the improved form of vacuum switch may be obtained simply by connecting the switch in the circuit in the proper way. For alternating current service it is a further object of the present invention to provide an electroresponsive operating mechanism for effecting operation of the improved form of vacuum switch only when the alternating current is in the proper direction.

In accordance with the present invention the restriction of the electron flow from the electrodes to the seals and other susceptible parts of the envelope is accomplished by forming the circuit interrupting electrodes with complementary or dissimilar faces, for example, one being concave, or hollow, and the other being convex, or pointed. With the electrodes formed in this manner, the concave, or hollow, electrode has an appreciably greater contact area and substantially envelops the other electrode when the electrodes are initially separated to interrupt the circuit thereby effectively shielding the envelope from the electrons emitted from the pointed, or convex electrode when the circuit is interrupted with the current flowing in the corresponding direction. In addition, the electric fields set up by the potential difference between the electrodes tend to confine the electrons emitted from the convex, or pointed, electrode in the hollow, or concave, portion of the complementary or dissimilar electrode when the circuit is interrupted with the current in the corresponding direction.

As set forth and claimed in my divisional application Serial No. 355,936, filed April 17, 1929, the present invention also contemplates a vacuum switch circuit interrupting system employing a plurality of groups of electrodes having complementary or dissimilar electrode faces of the character described above, and arranged reversely in the circuit so that at least one group of complementary or dissimilar electrodes are effective for interrupting current in one direction, while another group is effective for interrupting current in the opposite direction. With this arrangement when the groups of electrodes are simultaneously operated to interrupt an alternating current circuit or a direct current circuit, which may carry current in either direction, there is always one group of electrodes having the current flow therethrough in the proper direction to effect an interruption of the circuit irrespective of the direction of current in the circuit at the time of operating the electrodes. In the preferred form of the invention, a pair of vacuum switches, each having cooperating electrodes provided with complementary or dissimilar electrode faces are connected in series relation in the circuit with the complementary or dissimilar electrodes disposed in reverse order and are arranged to be operated simultaneously in response to abnormal circuit conditions.

In the accompanying drawing, Fig. 1 illustrates diagrammatically an improved form of vacuum switch embodying the improvements of the present invention, and Fig. 2 shows a circuit interrupting system

in which a plurality of vacuum switches each having circuit interrupting electrodes formed with unsymmetrical or complementary electrode faces are connected in series relation with the complementary electrodes disposed in reverse order.

As shown in Fig. 1, the switch comprises the highly evacuated envelope 10 which may be formed either of glass, as shown, or of metal, to enclose the circuit interrupting electrodes 11 and 12. The electrode 11 is secured to a suitable insulating support 13 and extends through the tubular extension 14 of the envelope 10 into the central bulb portion of the envelope. The end of the tubular extension 14 is sealed to the electrode 11, preferably by means of a yielding sylphon bellows 16, which prevents transmission of jars or shocks to the envelope 10. The electrode 12 is movable into and out of circuit closing engagement with the electrode 11 and extends through the lower tubular extension 17, and is provided with the sylphon bellows seal 18 at the end thereof. The flexibility of the sylphon bellows 18 readily permits the electrode 12 to be moved into and out of circuit closing engagement with the electrode 11. The electrode 12 is maintained in alinement with the electrode 11 by suitable means shown as a guide member 19 through which the lower end of the electrode 12 is adapted to slide.

The envelope 10 of the vacuum switch is exhausted to an extremely low pressure preferably of the order of one hundredth of a micron. In addition the parts of the switch within the vacuum envelope are treated to remove all residual and occluded gases in order to prevent impairment of the vacuum during operation of the switch. This is accomplished preferably by heating the contacts and other parts to a high temperature in a vacuum both before and during the exhaustion of the envelope by high frequency inductive action or by electron bombardment. An auxiliary electron emitting filament not shown in the drawing may be provided in the envelope for this latter purpose. The release of occluded gases may also be accomplished by baking out the entire switch structure in an oven while it is being exhausted.

The engagement and disengagement of the electrode 12 with the electrode 11 is accomplished by means of the electroresponsive operating mechanism 20. This mechanism, as shown diagrammatically in the drawing is of the general type described and claimed in the Tritle Reissue Patent 15,441, dated August 29, 1922, and more particularly described and claimed in Tritle Patent No. 1,560,440, dated November 3, 1925 both being assigned to the assignee of my present invention. As shown, this mechanism comprises a pivoted arm 21 carrying an armature 22 in attractive relation with the controlling electromagnet 23. The arm 21 is pivotally connected with the operating lever 24 which, in turn, is connected to operate the electrode 12 through the connecting link 25. The link 25 preferably is of insulating material so as to isolate the operating mechanism from the high potential which may be impressed upon the electrode 12. A heavy biasing spring 26 is connected to the operating arm 24 so as to strongly bias the electrode 12 out of engagement with the electrode 11. The electrode 12 is operated into engagement with the electrode 11 by means of the pivoted bell crank closing lever 27 connected to the closing electromagnet 28 which is energized by the closing pushbutton 29. The switch is held closed by the magnetic attraction of the armature 22 by the electromagnet 23. The electromagnet 23 is provided with a holding winding 30 which is normally energized from the supply source indicated in the drawing as plus and minus. A tripping winding 31 is associated with the magnetic extensions 32 between the poles of the electromagnet 23. For both direct and alternating current service the tripping winding 31 may be connected directly in series circuit with the electrodes 11 and 12 of the vacuum switch as illustrated in the drawing. It will be understood, however, that for alternating current service the tripping winding 31 may be energized through the agency of a current transformer if desired.

It will be observed that in accordance with the present invention the electrodes 11 and 12 are formed with complementary or dissimilar electrode faces, the enlarged end of the electrode 11 being in the present instance recessed or hollowed out so as to receive the rounded or spherical end of the electrode 12. The concave enlarged end of the electrode 11 is accordingly appreciably greater in area than and substantially envelops the convex end of the electrode 12 when the electrodes are initially separated. As a result, substantially all of the electrons emitted from the electrode 12 during the interruption of the circuit with the current in the proper direction are entrapped by the electrode 11. Consequently the bombardment of the seals and other susceptible parts of the envelope 10 by these electrons is greatly restricted. In this way the enlarged concave end of the electrode 11 effectively shields the seal 15 at the end of the tubular extension 14 from all electron bombardment thereby preventing deterioration and burning through of the sylphon bellows 16. Moreover the hollow electrode 11 also serves to shield the envelope from any hot metal that might be thrown off upon the separation of the electrodes, thereby materially lessening the possibility of cracking or injuring the envelope when made of glass.

With an interruption of current in the direction to produce electron emission from the

upper electrode 11, the electrons would have a free and unrestricted path to the lower sylphon bellows 18 and the seal associated therewith. Hence in order to insure separation of the electrodes 11 and 12 only when the current is in the direction to produce an electron emission from the electrode 12, the control electromagnet 23 is arranged to respond only with the current flowing in the proper direction through the electrodes with both alternating current and direct current. For alternating current service the tripping winding 31 is disposed so as to act cumulatively with the magnetization set up by the holding winding 30 when the current is in the proper direction through the electrodes and to oppose the magnetization of the holding winding 30 when the current is in the other direction. In this way the holding effect of the magnet 23 upon the armature 22 is decreased to permit the biasing spring 26 to separate the electrodes 11 and 12 only with the current in the proper direction through the switch electrodes. Thus for direct current service the electrodes 11 and 12 are connected in the circuit so as always to produce electron emission from the electrode 12 when the circuit is interrupted and the tripping winding 31 is connected to act cumulatively with the holding winding 30 with the current in the corresponding direction, thereby permitting the biasing spring 26 to separate the contacts.

The interruption of the circuit upon separation of the contacts in the vacuum within the envelope 10 is accomplished by the formation of a cathode spot when the contacts 11 and 12 are formed of soft metal such as copper, or the like. This cathode spot phenomenon results from vaporization of the last point of contact occurring upon separation of the soft metal contacts. That is, just before the final separation, the current is concentrated to a very limited area of contact which is thereby brought up to the temperature where the soft metal of the contacts melts and vaporizes. At the same time that the contacts are separating, but are still very close together, the potential drop between the contacts, although quite small in the aggregate, nevertheless provides a voltage gradient of the order of millions of volts per centimeter. This is due to the fact that even a small drop in potential between the contacts divided by the extremely small separation thereof, gives an exceedingly high potential gradient. Since a voltage gradient of the order of millions of volts per centimeter will readily draw electrons from a relatively cold metal, an electron flow is produced from the contact which is of negative potential at the time of separation. The resulting collisions of these electrons with the vaporized metal in the space will ionize some of the metal vapor, thus producing additional electrons as well as positive ions. The positive ions travel towards the negative contact at a very much slower rate than the electrons travel to the positive contact. As a result, the positive ions maintain a very high potential gradient at the negative contact surface, thus continuing to draw out electrons from the negative contact even though the positive contact has meanwhile been separated therefrom to a considerable distance. The bombardment of the negative contact by the positive ions heats the surface thereof to the point where the metal continues to be vaporized, thus maintaining a supply of metal vapor to be ionized in the manner previously pointed out. Thus the process once initiated continues as long as the voltage between the contacts is maintained. Consequently, with the contacts connected in an alternating current circuit, the current continues until the alternating voltage passes through the zero value. When the voltage is thus momentarily withdrawn, the positive ions immediately disappear and the metal vapor diffuses so that when the alternating current voltage is again applied between the electrodes the conditions required for the formation of a cathode spot are no longer present and no current is carried. The circuit is thus interrupted at the zero point of the alternating current wave by the vacuum switch with practically no inductive disturbance or voltage surge in the alternating current circuit. Moreover, the voltage between the contacts required to maintain the current flow is of the order of only 50 or 60 volts. Consequently, only a very small amount of energy is released in the vacuum switch which serves to produce the practically negligible vaporization of the contact material required to maintain the electron flow therein to the zero point of the alternating voltage.

While the vacuum switch with soft metal electrodes is particularly adapted for alternating current service as just pointed out, it is desirable to use a higher melting point metal for the contacts when the vacuum switches are used in direct current service. For example, tungsten metal contacts are particularly adapted for direct current service, since it is extremely difficult to produce sufficient metal vapor therefrom to maintain a cathode spot due to the extremely high melting point thereof. With such high melting point contacts, a thermionic emission is produced by the heating of the last point of contacts. The heat, however, is rapidly dissipated as the contacts are separated and the electron emission quickly ceases, with a resulting interruption of the circuit. With complementary or dissimilar form of electrodes only the electrode from which electrons are emitted need be formed of the high melting point metal.

Due to the dissimilarity of the coacting electrode contacting surfaces wherein the

contact face area of one electrode is appreciably greater than that of another, as a more pointed electrode, the lower potential gradient at the larger electrode surface tends to cause interruption of the circuit with that electrode remaining negative. In other words, the cathode spot once formed on the smaller or pointed electrode surface remains in existence only during that half cycle, the current being interrupted when it passes through the next zero value. The reestablishment of the cathode spot on the larger coacting electrode surface upon reversal of the current, in addition to the factors above mentioned, is precluded by the low potential gradient at that electrode and also by the greater radiating area of the electrode tending to cool it below the point favorable to the establishment of a cathode spot thereon.

From the foregoing description the operation of the circuit interrupter will be obvious. Closure of the switch 29 energizes the closing electromagnet 28 with the resulting operation of the roller bell crank 27 into engagement with the operating arm 24. This operates the arm 24 about its pivotal connection with the lever 21 and moves the armature 22 into abutting engagement with the poles of the holding electromagnet 23. With the holding winding 30 energized, the armature 22 is firmly held in position. However, the electrode 12 is not brought into engagement with the electrode 11 until after the closing electromagnet 28 is deenergized by the opening of the switch 29. Thereupon, the spring 26 rotates the operating lever 24 about its pivotal connection to raise the electrode 12 into engagement with the electrode 11, as brought out in the Tritle patent previously noted. With the electrode 12 thus brought into engagement with the electrode 11 the circuit of the supply line L_1 is closed and the operating lever 24 is free to be released by the controlling electromagnet 23 upon the occurrence of an excessive current in the supply line L_1 in the proper direction through the switch contacts.

Thus it will be seen that the improved form of circuit interrupter of the present invention is particularly adapted to open the circuit with the current flowing in the proper direction with a minimum of burning of the electrodes and deterioration of the seals of the evacuated container due to electron bombardment from the electrodes.

The vacuum switch construction previously described ensures that the circuit is interrupted in a very brief interval of time so that in alternating current service of commercial frequencies the circuit may readily be interrupted within one-half cycle. The small mass of the moving parts required for the vacuum switch together with the quick release thereof by the Tritle type of controlling mechanism, and the high speed of operation obtained thereby combine to ensure that the circuit is interrupted when the alternating voltage reaches the succeeding zero point. Likewise in direct current service a correspondingly rapid interruption of the circuit is obtained.

Referring now to Fig. 2 which shows a combination of vacuum switches each having complementary or dissimilar electrodes of the character described in connection with Fig. 1, it will be seen that the two vacuum switches 40 and 41 are each constructed in substantially the same manner as the vacuum switch 10. The two switches 40 and 41 are connected in the supply line L_1 in reverse order. That is, the complementary or dissimilar electrode faces of switch 40 are arranged oppositely in the circuit to the electrodes of the switch 41. The supply line L_1 may carry either alternating current or direct current where the direction of flow of direct current may be in either direction.

Accordingly, the reversely arranged groups of dissimilar electrode surfaces are effective to cause interruption of the current within a half cycle regardless of its direction, since in order for the current to continue beyond a zero value it is essential that a cathode spot be re-established on one of the larger stationary electrode surfaces. That is, with the current in a given direction, there must be existing concurrently cathode spots in each group of electrodes; one cathode spot being on the small or pointed electrode of one group and the other spot being on the large or concave electrode of the other group. With reversal in current the interruption is effected by that group of electrodes wherein the cathode spot is on the smaller or pointed electrode since the conditions are unfavorable for reestablishment of the cathode spot on the larger coacting electrode surface.

As shown diagrammatically in Fig. 2 the movable electrodes 43 and 45, having the convex electrode faces similar to the electrode 12 of Fig. 1, are connected to be simultaneously operated within the highly evacuated envelopes 46 and 47 in response to excessive current in the supply line L_1. The movable electrodes 43 and 45 are each electrically and mechanically connected to the operating member 48 which preferably is of good current conducting material so as to electrically interconnect the vacuum switches. The cooperating electrodes 42 and 44 which have convex electrode faces corresponding to the electrode 11 of Fig. 1 are connected directly to the supply line L_1. It will be understood that the envelopes 46 and 47 of the vacuum switches 40 and 41 are evacuated to the extremely low pressure and the contacts and other parts of the vacuum switch are treated to remove residual and occluded gases

in the same manner as described in connection with Fig. 1.

The simultaneous operation of the movable contacts 43 and 45 is controlled by the toggle mechanism 49 which is biased by the spring 50 to lower the operating member 48 to which both of the electrodes 43 and 45 are connected. The member 48 is held in the raised position in which the contacts 43 and 45 are carried into circuit closing engagement with the cooperating contacts 42 and 44 when the toggle mechanism 49 is extended as shown in the drawing. The toggle mechanism 49 is latched in the extended position by the latch 51 which is controlled by the tripping winding 52. The tripping winding 52 is energized in response to excessive current in the supply line L_1 through the agency of the transformer T when the supply L_1 is intended to carry alternating current. It will be understood however that the tripping winding 52 may be connected directly in the circuit of the supply line L_1 for direct current circuits or energized by means of a suitable shunt if desired.

The operation of the circuit controlling system shown in Fig. 2 is as follows: With both vacuum switches closed as indicated the circuit is completed for the supply line L_1. When an excessive current occurs in the supply line L′ the tripping winding 52 is energized to release the latch 51. This permits toggle mechanism 49 to operate under the strain of the biasing spring 50 to quickly lower the operating member 46 and in this way simultaneously move the contacts 43 and 45 out of engagement with the cooperating contacts 42 and 44. Thus irrespective of the direction of current flow in the circuit of the supply line L′ at the instant of separation of the contacts of the vacuum switches, one or the other of the electrodes 43 and 45 will be negative with respect to the corresponding electrodes 42 and 44. Hence the cathode spot phenomena previously described will occur and the electron emission from the negative electrode will be concentrated upon the cooperating positive electrode in one of the switches. Consequently this switch is effective to interrupt the circuit, even though the conditions in the other switch are not so favorable for interrupting the circuit.

Thus it will be seen that with the arrangement of the vacuum switches in the reverse order in the circuit as shown in Fig. 2, an effective interruption of the circuit is obtained irrespective of the direction of the current in the circuit.

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

1. An alternating current circuit interrupter comprising an evacuated envelope and cooperating circuit interrupting electrodes within the envelope having dissimilar electrode faces formed so that the electrode face of one electrode substantially envelops the electrode face of the other electrode to restrict the flow of electrons from said last-named electrode during the interruption of current, and means responsive to said alternating current only when said last-named electrode is negative for causing separation of said electrodes.

2. An alternating current circuit interrupter comprising an evacuated envelope having oppositely disposed tubular extensions from a central enlarged portion, cooperating relatively movable circuit controlling electrodes sealed in said tubular extensions of the envelope and each having an enlarged electrode located in said enlarged portion of the envelope, means for operating the elctrodes into and out of engagement to establish and interrupt the circuit, one electrode having a convex electrode face and the other electrode having a concave electrode face whereby the flow of electrons from the convex electrode face is concentrated upon the concave electrode face during the interruption of the circuit, said operating means causing separation of said electrodes only when said convex electrode face is negative.

3. A circuit interrupter for alternating currents comprising an evacuated envelope, cooperating circuit interrupting electrodes within the envelope having dissimilar electrode faces tending to cause interruption of current in a predetermined direction between the electrodes, and means responsive only to current in the alternating current circuit in said predetermined direction for separating the electrodes to interrupt the circuit.

4. An alternating current circuit interrupter comprising an evacuated envelope having relatively movable cooperating circuit interrupting electrodes within the envelope, the negative electrode having a convex electrode face and the positive electrode having a concave electrode face formed to substantially envelop the convex face of the negative electrode upon the separation of the electrodes to interrupt the circuit, and means responsive only to current in the alternating current circuit in the direction to cause electron flow from said negative electrode for separating the electrodes.

5. An alternating current circuit interrupter comprising an evacuated envelope, cooperating circuit controlling electrodes mounted within the envelope to permit operation of the electrodes into and out of circuit closing engagement, the positive electrode having an enlarged electrode face for receiving the flow of electrons from the negative electrode during the interruption of current in a corresponding direction between the electrodes, a biasing spring for operating the electrodes out of engagement, an electromagnet for holding the electrodes in engagement, and current responsive means energized in accordance with current in the alternating

current circuit for controlling the holding effect of the electromagnet to permit operation of the electrodes to interrupt the circuit only when the current in the alternating current circuit is in said corresponding direction.

6. An alternating current circuit interrupter comprising an evacuated envelope, relatively movable circuit interrupting electrodes within said envelope having dissimilar electrode faces favoring the interruption of current in a corresponding direction between the electrodes, and means responsive only to current in the alternating current circuit in said corresponding direction for separating the electrodes to interrupt the circuit.

In witness whereof I have hereunto set my hand this 14th day of March, 1928.

DAVID C. PRINCE.