July 14, 1931. D. C. PRINCE 1,814,851

CIRCUIT CONTROLLING APPARATUS

Filed March 23, 1928

Fig. 1.

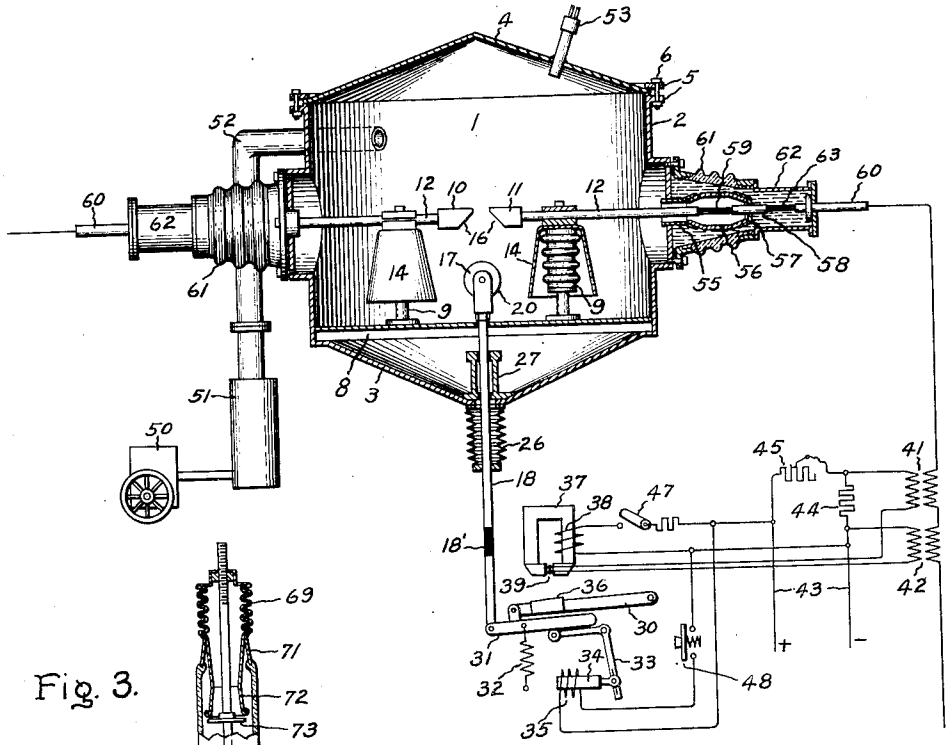


Fig. 3.

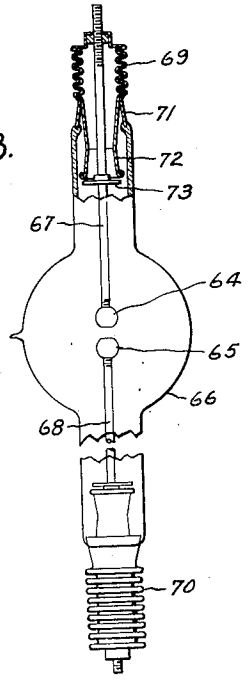


Fig. 2.

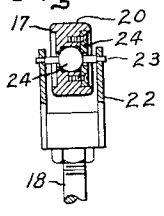
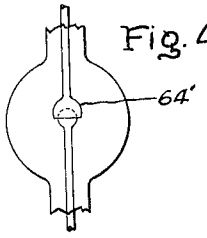


Fig. 4.



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UNITED STATES PATENT OFFICE

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CIRCUIT CONTROLLING APPARATUS

Application filed March 23, 1928. Serial No. 264,114.

My invention relates to electric circuit controlling apparatus adapted for the control of relatively high potential large capacity power circuits.

When a short circuit or heavy overload of a predetermined amount comes on a transmission line or distribution system, the sooner the circuit can be opened and the source of trouble thereby cut off, the less will be the effect upon the stability of the line and the damage to the system and apparatus to be protected. In the case of an alternating current system the circuit should be opened at the time the current wave is passing through zero, that is, at the end of a half cycle. If the circuit is interrupted at a relatively high part of the current wave, a large amount of power will be cut off and surges of voltage of several times normal line voltage may occur.

With the usual types of oil switch the fixed live parts must be adequately spaced to prevent arc-over by reason of the conducting gases and vapors produced when the switch opens; the inertia due to the size and weight of the main and auxiliary contacts and the size and weight of the other moving parts necessary to give them the requisite mechanical strength, and the relatively great distance by which the moving contacts must be separated from the fixed contacts to interrupt the circuit, all militate against getting the circuit open in a very short time interval. As the contacts of an oil switch separate, an arc is drawn which usually persists for several half cycles. The resistance of the arc stream is of such value that a large voltage drop is present between the separating switch contacts and such a large amount of energy must be dissipated in the switch that the contacts are subject to such severe arcing that the American Institute of Electrical Engineers standard duty cycle is merely that the switch shall stand closing and opening twice on a short circuit before overhauling. During the separation of the contacts the arc does not go out at the end of the first half cycle but usually reestablishes itself several times. As the current in any half wave decreases, the resistance of the arc stream increases and the inductive reactance of the system which tends to keep the current flowing produces peaks in the voltage wave which are sufficient to start the current again so that energy must be dissipated for several half cycles before the flow of power ceases. Oil switches must be made large because of these reasons and the severe arcing volatilizes and dissociates the oil producing great pressures which must be provided against.

While my switch may be specially modified to open direct current circuits, it is one of the main objects of my invention to provide a simple, sturdy, reliable and comparatively cheap switch peculiarly adapted for controlling alternating current circuits of considerable power and relatively high voltage which shall be capable of operating to open the circuit within the time of a half cycle of a 60 cycle system, for example, and which shall, moreover, always permit current to continue to flow to the end of such half cycle, whereby the circuit may be interrupted at the end of the first half cycle following the application of a short circuit or other excessive load and interrupted always at substantially the zero point of the current wave thereby avoiding voltage surges on the system and the dissipation of large amount of energy in the switch while opening the circuit.

Briefly, my circuit controlling apparatus includes an interrupting device in which the contacts separate in a high vacuum and need to move but a very small distance and in which the moving parts are of light construction, hence having small inertia and mechanism for operating the device which mechanism is capable of making an exceedingly quick response to the excessive load on the circuit controlled by the apparatus.

My invention will be better understood from the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring to the drawings, Fig. 1 is a view showing an embodiment of my invention partly in cross section and partly diagrammatic; Fig. 2 is a detail of the movable con-

tact shown in Fig. 1; Fig. 3 shows a modification, and Fig. 4 indicates a further modification.

That form of my invention which I have chosen to illustrate in Fig. 1 is characterized by certain features by which it is particularly adapted for the interruption of alternating currents, the arrangement being such that the circuit is interrupted substantially at the zero point of the alternating current wave and within an interval of one half cycle following the occurrence of a sudden overload and independently of the instantaneous direction of the current at the time the overload occurs.

The circuit interrupting device which I have shown comprises a vacuum chamber or casing 1 enclosing the circuit interrupting contacts and formed of a metal cylinder 2 having a bottom 3 and a top 4. The cylinder and top are shown each provided with lugs 5 engaged by clamping bolts 6. Various means may be employed to make the joint between the cylinder and the top vacuum tight, but for greater permanence I prefer to weld the two parts together. While aluminum or lead gaskets or sealing wax make a good seal after the parts are cool they will not stand the heat necessary to bake the occluded gases out of the inside walls of the vessel. Within the casing I have shown a supporting member 8 in the form of a channel upon which are mounted in spaced relation the two contact supporting insulator posts 9. The two fixed contacts 10 and 11 preferably of copper are mounted on adjacent ends of conducting rods 12 forming parts of the leads to the contacts and each rod is firmly clamped to the top of a supporting insulator post 9. The contacts thereby are firmly supported in the casing. Each insulator post is provided with a cap or shield 14 to prevent it from becoming coated with a metallic deposit and hence short circuited. The adjacent faces 16 of the two contacts are oppositely inclined so as to make an opening to receive the movable contact member 17 which is shown as a roller flexibly mounted on the end of the operating rod 18. I have found that in a vacuum such as I employ in my switch it is much more difficult to cause the switch contacts to slide over each other than it is for example in an air switch, the difference probably being due to the absence of a film of air between the adjacent faces. I have therefore provided a contact arrangement which requires a minimum sliding between the cooperating contacts. The angle formed by the fixed contact faces is preferably substantially a right angle, each face making an angle of about 45° with the line of movement of the contact roller 17. The contact face 20 of the roller 17 being a cylinder, the roller readily adjusts itself to make line contact with each of the two fixed contacts. An example of how the roller may be flexibly mounted on the operating rod is shown in Fig. 2. The clevis 22 secured to the end of the operating rod carries the shaft 23 comprising the ball 24. On this ball is mounted the roller 17 being retained thereon by the plate 24, the roller thus being free to rotate on its axis and to have a limited rocking movement on the ball. Where the operating rod passes through the bottom of the casing a vacuum tight joint is made by means of the sylphon bellows 26, the ends of which are welded or otherwise secured respectively to the tank bottom and the rod 18 in a gas-tight manner. Within the casing the rod passes through the guide 27. The operating rod preferably is constructed in part at least of insulating material as diagrammatically shown at 18′ to protect the operating mechanism from the line voltage. It also has some resilience which further facilitates the proper contacting of the roller and the fixed contacts.

For operating the movable contact I have shown by way of example a trip free solenoid actuated mechanism comprising the lever 30 to which is pivoted lever 31 connected with the operating rod 18 and to which is attached the strong switch opening spring 32. Bell crank 33 has one arm engaging lever 31 and the other arm operated by the plunger 34 within solenoid 35. On the lever 30 is the armature 36 of magnet 37 which is normally energized by winding 38. In the gap between the pole pieces of magnet 37 is the conducting loop 39 which is connected as shown to the secondaries of the two similar transformers 41 and 42. These transformers have saturated or nearly saturated cores and have their primaries connected in series with the vacuum switch in the circuit controlled thereby. The other secondary terminals are connected by leads 43 to a suitable source of direct current, the leads being bridged by the resistance 44. A limiting resistance 45 is also shown in the direct current connection with the secondaries. The transformers are poled such that the electromotive force of the secondary of one opposes that of the other. Winding 38 is controlled by switch 47 and solenoid 35 is controlled by switch 48. The winding and solenoid are connected to a source of direct current which may be the same or a different source than that to which loop 39 is connected. In the drawing I have shown it connected to the same source. This operating mechanism is described and claimed in the Tritle Patent No. 1,560,440, November 3, 1925, and in the Tritle reissue Patent No. 15,441, August 29, 1922, the circuit arrangement being described and claimed in a patent of Jacob W. McNairy, No. 1,756,924, April 29, 1930.

To close the vacuum switch, switch 47 is first closed energizing magnet 37, then

switch 48 is closed. Through the solenoid and bell crank, levers 30 and 31 are raised until armature 36 reaches magnet 37 where it is magnetically retained. Roller contact 17, however, has not yet made contact with the fixed contacts 10 and 11 but this occurs as soon as the switch 48 is released when spring 32 rotates the lever 31 clockwise pushing the roller into final contact position. Since the two transformers have their cores saturated or nearly so by the direct current in their secondaries and since they are connected with their secondaries in opposition, an abnormally high current wave in either direction in the circuit controlled by the switch will result in a unidirectional impulse in the loop 39 which will always be in the same direction regardless of whether the abnormally high current wave was a positive or a negative wave. The loop 39 is so arranged that the effect of this impulse is to cause a redistribution or shifting of the flux between the poles of magnet 37 resulting in the instant release of the armature 36. The switch contacts thus immediately start to separate and are quickly moved at high speed to the open circuit position by the strong spring 32. Since the moving contact member of my switch is the single roller 20 which with its supporting and actuating rod is relatively small and light, the quick movement of the contact to a safe open circuit position is greatly facilitated. Other factors which are favorable to the quick opening movement of the switch are the short length of stroke necessary for the movable contact and the fact that no separate secondary or arcing contacts are required in addition to the main contact. Inasmuch as the contacts in my switch are not subject to any oxidizing effect, but rather to a reducing effect, the contact surfaces remain bright and clean. Because of the resulting better electrical connection between cooperating contacts due to freedom of any scale or surface oxide on the contact faces, smaller contacts may be used than in other common types of switches where the contact faces are not always free of scale or oxide.

For the proper operation of this switch it is essential that a high vacuum be maintained in the casing. I have obtained good results in interrupting commercial voltages with a switch having a glass vessel as indicated, for example, in Fig. 3, hereinafter described, having a vacuum of the order of .01 of a micron but, since the voltage necessary to break down a gap steadily increases when the pressure is decreased beyond a few microns, the excellence of the switch improves as the pressure is further reduced and a condition of perfect vacuum is approached. For producing this high vacuum, I employ the rough pump 50 such as an oil pump which will reduce the pressure from atmospheric to about 1 micron connected to the mercury vapor pump 51 which has a range from about 8 mm. to an extremely high vacuum. The pumping apparatus preferably is permanently connected to the casing as for example by pipe 52 and is adapted for use continually or whenever the pressure in the casing rises to a predetermined value for, even though the casing is vacuum tight, a certain amount of occluded gases may be liberated from the walls of the vessel and particularly the contacts by the bombardment thereof when the switch is put into service.

Where a metal vessel, as well as where a glass vessel is used, it is important to free the inner walls of same and the parts within the vessel from occluded gases. The vessel should be baked in a suitable furnace or otherwise heated at a temperature considerably above 100° C. during exhaust. In brief, the best technique of heating and exhausting for producing a vacuum which will remain at an extremely high value should be availed of. The parts in the vessel such as the contacts may be deprived of their occluded gases before they are assembled in the switch. As pointed out in Letters Patent to Langmuir, No. 1,558,436, dated October 20, 1925, metal which has been freed from occluded gas will not readily reabsorb gas although exposed to the air or other gases. After the assembled device has been properly baked out and exhausted, it should be subjected to further treatment during exhaust before the switch is put into service. One good way of cleaning up the contacts and interior parts is by bombardment during exhaust. By making one of the contacts the cathode of a direct current circuit and maintaining a relatively small current flow between that contact and another, the other, the anode, will be bombarded and brought to a high temperature. The connections may then be reversed and the other contact bombarded. Then before putting the switch in service at its rated duty it is desirable to operate it a number of times with a protective device in series, for example a reactor for alternating current work, which limits the current to a moderate value. For measuring the vacuum, I provide the casing with a suitable gage 53 which in the present case I have illustrated, by way of example, as a thermo-couple vacuum gage. If desired, the pumping apparatus may be arranged to be started and stopped automatically in accordance with the degree of vacuum.

In view of the high vacuum maintained in the switch casing it is essential to provide insulating seals for the contact leads which are thoroughly reliable and which will safely withstand the rough treatment to which an interrupting device in ordinary commercial use may be subjected. The seal which I have provided comprises the metal cylinder or

thimble 55 tightly secured in the opening in the side of the casing through which passes the lead 12. The vitreous insulating tube 56, preferably glass, has its ends fused respectively to the thimble 55 and to the thimble 57 which latter is tightly secured to the short rigid section 58 of the lead 12. The thimbles 55 and 57 are constructed of copper or of a suitable material which has a thermal expansion approximately the same as the glass forming the tube 56, examples of such materials now being well known in the art. A flexible resilient portion 59 in the lead permits the free expansion and contraction of that portion of the lead within the vacuum chamber. To prevent damage to the seal thus described I firmly support the terminal portion 60 of the lead 12 from the casing. For this purpose I have shown the hollow insulator 61 secured at one end to the casing and having its other end connected with the terminal 60 through the metal sleeve 62. Between portions 58 and 60 of the lead, I provide a second flexible portion 63 to relieve the seal of any strains due to the terminal support. The space between the support and the lead with its seal I preferably fill with an insulating fluid as oil both for insulating and cooling purposes, suitable gaskets being employed when necessary to make the support oil tight.

From the foregoing description it will be clear that the switch is simple and rugged and that it will operate to separate the contacts within a time less than a half cycle, but before pointing out why it is that the flow of current will be interrupted only at substantially the zero point of the current wave, I shall refer to Fig. 3 which shows a different form of vacuum vessel.

In Fig. 3 I have shown a high vacuum switch in which the contacts 64 and 65 are operable in a vessel 66, made of insulating material such as glass. The leading in and contact supporting rods 67 and 68 respectively extend through the sylphon bellows member 69 and 70 which protect the vessel from shocks and jars. These bellows are of thin metal such as copper. As illustrated for the bellows 69, the lower end is extended to provide a collar 71 which is sealed to the vessel. A thin copper collar which will be stretched by glass or suitable alloys such as a chrome-iron alloy or a nickel-iron alloy with a copper brazed surface, examples of which are well known to those skilled in the art, may be used. A shield 72 and a plate 73 protect the seal between the collar 71 and the glass and protect the collar and the bellows from injury from bombardment during evacuation of the vessel and during operation of the switch. A similar shield and plate are provided at the end of the vessel at which the bellows 70 is located. As illustrated, the bellows 69 is made shorter than the bellows 70 so that the flexibility of the bellows 70 is greater, it being assumed that the operating mechanism, which may be like that of Fig. 1 is secured to the rod 68.

The construction shown in Fig. 3 is disclosed and claimed in my copending application Serial No. 264,115 filed concurrently herewith and assigned to the same assignee as the present application.

Since the vessel of Fig. 3 is designed to be permanently sealed off from the exhausting means, it is important that all parts within the vessel and the inner walls thereof be thoroughly freed of occluded gases during the exhaust. The best technique including baking, high frequency heating and bombardment, should therefore be availed of in order that the vacuum may remain at the highest practicable value throughout the life of the switch.

For heavier current values a metal tank is preferable and the contacts of Fig. 3 may be mounted in such a vessel making use of the principles of seals such as shown in Letters Patent to Kruh et al. No. 1,564,690, December 8, 1925, and Housekeeper Patent No. 1,294,466, February 18, 1919. In such a metal tank a current of 11,500 amperes at 14,000 volts has been successfully interrupted.

As heretofore stated, one of the important features of my switch is that it will interrupt the flow of power in the circuit at or so close to the zero point of the current wave that there will be no voltage surges on the system. The reason for this may be explained by the fact that when the contacts separate at some point of the current wave other than the zero point, the current will be carried by electron emission until the zero point of the wave is reached and will not be started again for the next half cycle. By making the contacts of a low-melting-point metal, such as copper, electron emission from the cathode (or negative contact) at the time the contacts separate will supply, even with a low voltage across the contacts, an ample supply of electrons to form a very good conducting path to carry the current. When the current stops, however, the electron emission ceases almost instantly, and the conditions are such that with the contacts separated a small distance a discharge cannot start in the reverse direction.

This may be better understood by considering the two types of electron emission, namely, the hot cathode or thermionic emission, which takes place from a high-melting-point metal such as tungsten and the cathode spot emission which takes place from a low-melting-point metal such as silver, copper, aluminum, or mercury.

Thermionic emission is produced by heating a metal to the point where the electrons in it have sufficient energy to break through the metal boundary into the space. This

emission phenomenon is described by the Richardson law. The second kind of electron emission we will call the cathode spot. If we have a vacuum switch having electrodes of some soft metal such as copper between which a current is flowing, as we begin to separate the electrodes the last points in contact will be vaporized by the current flowing. That is, as long as the current is spread over the entire surface no point was seriously heated. But just before the final separation the points in contact are so limited in area that the current brings them up to the point where the metal melts and vaporizes. At the same time that the contacts are separating but are still very close together the potential drop between the two contacts, although quite small, is still millions of volts per centimeter, that is, a small drop in potential divided by an extremely small space gives a high potential gradient. A gradient of the order of millions of volts percentimeter will draw electrons from a relatively cold metal, that is, a metal too cold to emit an appreciable number of electrons in accordance with Richardson's law. These electrons will form collisions with the vaporized metal in the space. These collisions will ionize some of the metal vapor thus producing additional electrons which join those already produced and travel toward the anode or positive electrode. The positive ions travel toward the cathode or negatively charged electrode. Due to their much greater mass the motion of the positive ions is relatively slow so that positive charges accumulate in the region adjacent to the cathode and these positive charges produce a very high potential gradient at the cathode surface thus continuing to pull out electrons even though the anode has meanwhile been withdrawn to a considerable distance. The positive ions continue to move towards the cathode and as they strike it they heat the cathode surface to a point where the metal is vaporized thus maintaining a supply of metal vapor to be ionized by collision from the electrons, the process once initiated can therefore be maintained even though the anode has been removed to a considerable distance. In the region not immediately adjacent to the cathode there will be no high potential gradient as such regions will be filled with electrons and positive ions in substantially equal numbers so that for copper electrodes a voltage of approximately 50 volts with an electrode spacing of the order of an inch is entirely adequate to maintain a large current and at the same time a gradient at the cathode of the order of a million volts per centimeter.

In the case of thermionic emission with a metal such as tungsten a large amount of heat is stored in the hot cathode so that even though the voltage is withdrawn momentarily, upon its being again applied the emission continues. In the case of the cathode, spot emission, as with copper, the emission is due to the combination of a high potential gradient and the presence of metal vapor. If the voltage is momentarily withdrawn the positive ions disappear almost instantly and the metal vapor diffuses so that when voltage is again applied to the anode the conditions required for the formation of cathode spots are no longer present and no current is carried. The extinction of a cathode spot occurs in a time of the order of one or two micro-seconds.

When the electrodes are those of a vacuum switch used to interrupt alternating current the cathode spot is formed on the electrode which is negative at the time of electrode separation. When the current carried by the cathode spot comes to zero as it does at the termination of a half cycle the cathode spot on this electrode will be extinguished and the conditions required for a restarting will no longer exist. At this time the voltage between the two electrodes will reverse so that the electrode which in the first half cycle was positive will now be negative. However the conditions required for the formation of a cathode spot do not exist at the surface of this electrode so that no cathode spot is formed. A considerable fraction of a half cycle is available during which the cathode spot on the other electrode now positive can be extinguished and all of the attendant ionization and metal vapor dissipated. If the cathode spot extinction requires two micro-seconds, say, the switch will still be operative if the frequency is raised to a point where a half cycle occupies two micro-seconds, that is, a frequency of 250,000 cycles per second. Or, viewing it from the other angle an extinction in two micro-seconds will mean that a 60 cycle variation will have progressed through about three minutes of arc during the time required for the cathode spot to be extinguished.

If a switch is intended to operate on direct current, soft materials, such as copper, are less suitable for the electrodes because a cathode spot is easily maintained for an indefinite period with a voltage of the order of 50 volts and currents as low as 50 or 60 amperes. Therefore if direct current is to be interrupted by a vacuum switch the kind of metal which should be chosen should be of the kind which does not favor the formation and maintenance of cathode spots. Tungsten is such a metal. Because of the extremely high melting point of this metal it is very difficult to secure sufficient metal vapor to maintain a cathode spot. Several hundred amperes at 250 volts have been tried and found insufficient for this purpose. If the switch is made up having a tungstn electrode for its cathode, that is, the electrode

which will be negative after the separation of the electrodes the last points to separate will be raised to incandescence and some metal vapor will be given off but not enough to form a cathode spot. However the contact tips will be left in an incandescent condition so that either one would be able to emit electrons. Electrons will accordingly be emitted by the cathode and drawn toward the anode. These electrons tend to heat the anode and to cool the cathode from which they are emitted. With direct current the cathode will continuously be cooled by the emission of electrons and by conduction through and radiation from the metal until the temperature is too low to emit further electrons after which the circuit will be open and the anode will subsequently cool down also. If an attempt be made to employ such a switch to open a high voltage alternating current circuit the heating effect on the anode due to bombardment by electrons from the cathode may store sufficient heat in the anode so that after reversal of the voltage the electrode which was at first anode but subsequently becomes a cathode will emit electrons thus renewing the temperature of that electrode which was the cathode during the first half cycle. Thus alternately each electrode is heated by a bombardment of electrons from the other and the conductivity of the switch persists and the circuit is not opened. Of course if the tungsten electrodes are large and possess no projections the amount of current necessary to maintain the electrodes in emitting condition may be quite large but the phenomenon nevertheless exists.

Once the electrodes in a vacuum switch are separated a voltage of the order of a million volts per centimeter in the gap between the electrodes is required to break down the gap, that is, to cause current to flow across it. This value is the theoretical limit which would determine the amount of spacing which must be provided between the contacts of the open switch. Switches have been tested in which an alternating current of approximately one thousand amperes at 84,000 volts and approximately 25 cycles has been interrupted with a gap of 7/8 of an inch between the contacts with the switch in the open position.

It is thus readily seen that the contacts may be separated to the requisite distance within the short time necessary to open a 60 cycle system within a half cycle, and it will be understood how the current will be interrupted only at substantially the zero point of the current wave.

It will also be understood that the switch is applicable to the control of direct current circuits, where the cathode or negative contact is made of such a metal as tungsten, the controlling circuits for the operating mechanism being arranged in any suitable way, examples of which are well known in the art, one example being given in the reissue patent to Tritle No. 15,441 above referred to. For direct current service I prefer to make the anode relatively large and in the form of a cup-shaped contact, as indicated at 64' in Fig. 4, better to shield the walls of the vessel and the anode seal from electron bombardment. Such construction is disclosed and claimed in my copending application Serial No. 264,116 filed concurrently herewith and assigned to the same assignee as the present application.

I have chosen the particular embodiment described above as illustrative of my invention and it will be apparent that various modifications may be made without departing from the spirit and scope of my invention all of which modifications I aim to cover by the appended claims.

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

1. A vacuum switch comprising an enclosing casing, a pair of fixed contacts therein, means firmly supporting the contacts in spaced relation, said contacts having opposed faces arranged at approximately right angles to each other, and a movable bridging member for said contacts comprising a flexibly mounted roller adapted simultaneously to engage said opposed faces.

2. A vacuum switch comprising an enclosing metal casing, a pair of fixed contacts therein, a supporting insulator mounted in said casing for each contact, protective shields covering the insulators for preventing the formation thereon of a short circuiting coating of metal from said contacts, terminal leads for said contacts having vacuum tight seals, and a movable contact member for bridging said contacts.

3. A vacuum switch comprising an enclosing vacuum tight casing, a pair of contacts fixed therein in spaced relation, said contacts having opposed contact faces arranged at approximately right angles to each other, a movable contact roller, a carrier therefor and means flexibly connecting the roller to the carrier whereby when the switch is closed a line contact is made between the roller and each of said contacts.

4. A vacuum switch comprising a metallic vacuum tight casing, a fixed contact therein having a lead extending outwardly through a wall thereof, a vacuum tight seal for the lead, means supporting the contact independently of the seal, resilient means for preventing transmission of shock from said supporting means to said seal, a movable contact adapted to engage said fixed contact, an operating rod therefor extending through a wall of the casing, and a sylphon bellows connecting the operating rod and the casing.

5. A vacuum switch comprising a vacuum tight metallic casing, contacts separable

therein, a contact lead extending from one of the contacts through a wall of the casing, a seal for the lead comprising a sleeve-like vitreous member sealed at one end with respect to said lead and at its other end to said casing, a hollow insulating member spaced from and surrounding said vitreous member, said insulating member secured to the metallic casing and provided with means for engaging the lead beyond the seal, and resilient means for precluding transmission of shock from said lead to said vitreous member.

6. In a vacuum switch having a vacuum tight casing, a contact therein, a lead extending from the contact through a wall of the casing, a seal for the lead comprising a vitreous sleeve, a hollow supporting member for said lead enclosing said seal and secured at opposite ends respectively to the casing and the lead, said lead having a flexible portion between the seal and the point of engagement of the supporting member.

7. In a vacuum switch having a vacuum tight casing, a contact therein, a lead extending from the contact through a wall of the casing, a seal for the lead comprising a vitreous sleeve, an insulator bushing enclosing the sleeve and secured at opposite ends respectively to the casing and to the lead, and an insulating liquid in the bushing surrounding the seal and the lead.

8. A vacuum switch comprising a vacuum tight casing, a plurality of fixed contacts and a cooperating movable contact therein, a support for each of the fixed contacts, leads extending from the contacts out through the casing, and a seal for each lead comprising a vitreous sleeve, and an insulator bushing enclosing the sleeve and secured at opposite ends respectively to the casing and to the lead, said lead having a flexible portion between the contact support and the seal and a flexible portion between the seal and the point of connection with the insulator bushing.

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

DAVID C. PRINCE.