

Aug. 3, 1943.

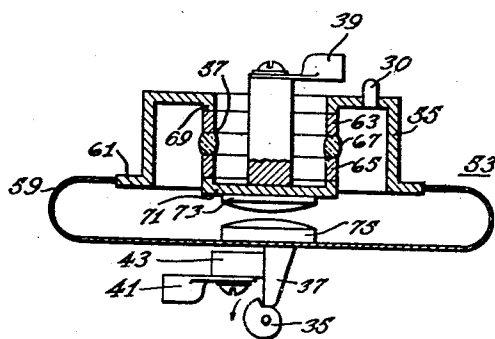
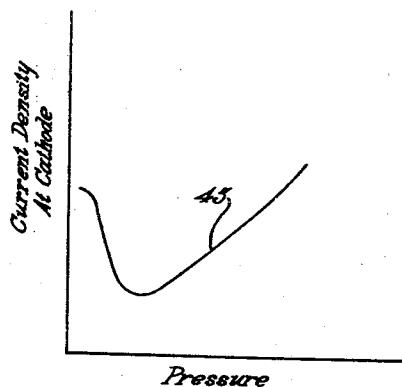
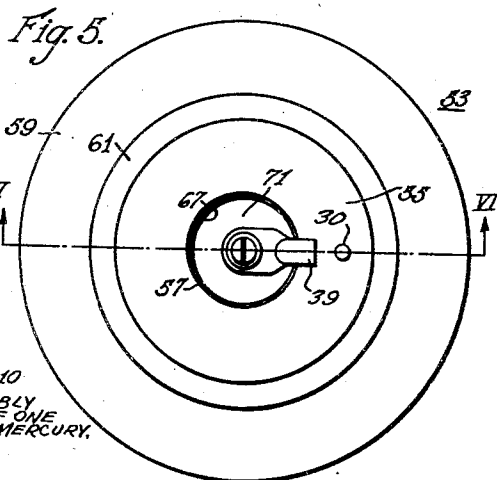
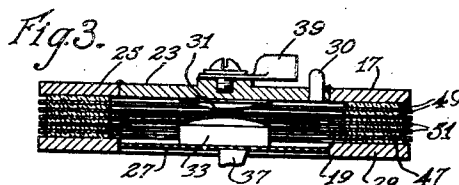
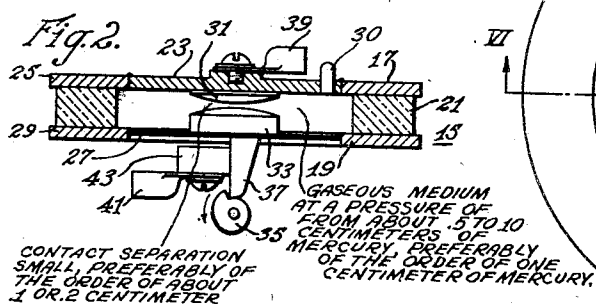
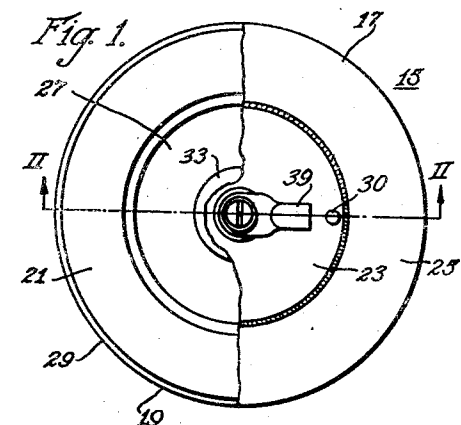
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2,326,074

CIRCUIT INTERRUPTER

Filed Sept. 20, 1939

3 Sheets-Sheet 1



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CIRCUIT INTERRUPTER

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3 Sheets-Sheet 2

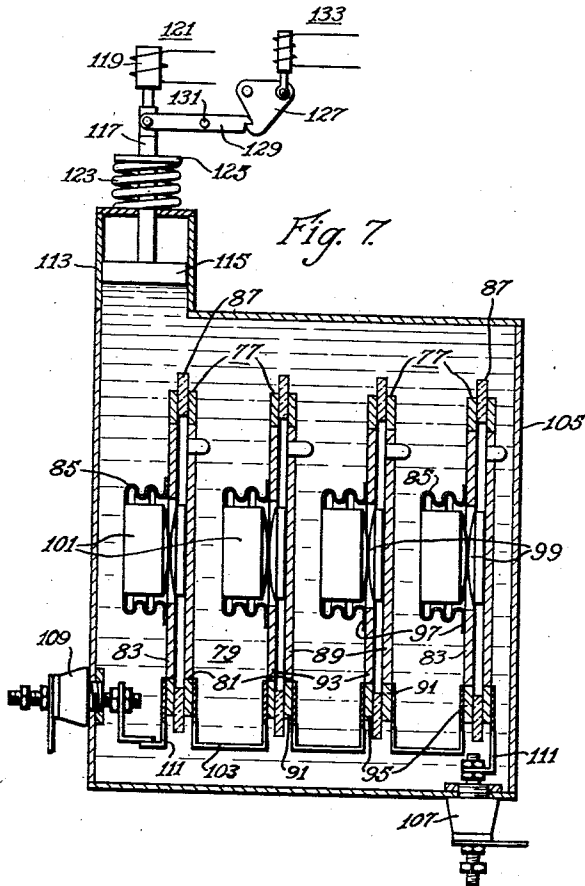


Fig. 7

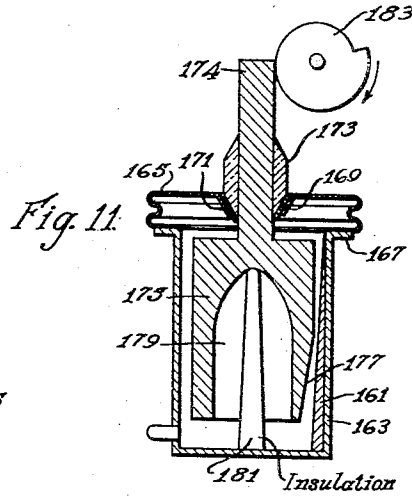


Fig. 11

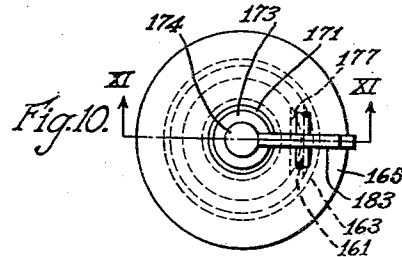


Fig. 10

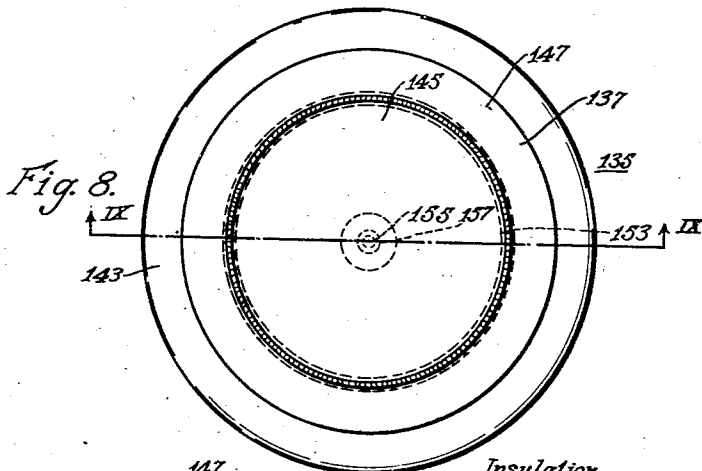


Fig. 8

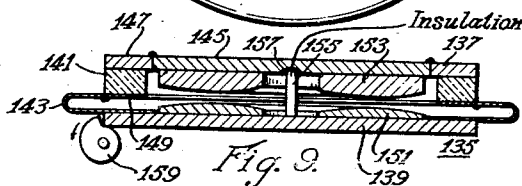


Fig. 9

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CIRCUIT INTERRUPTER
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2,326,074

3 Sheets-Sheet 3

Fig. 12.

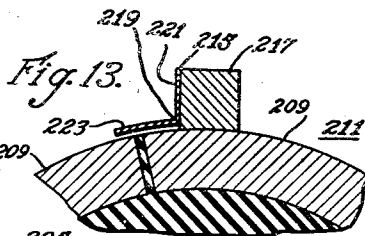
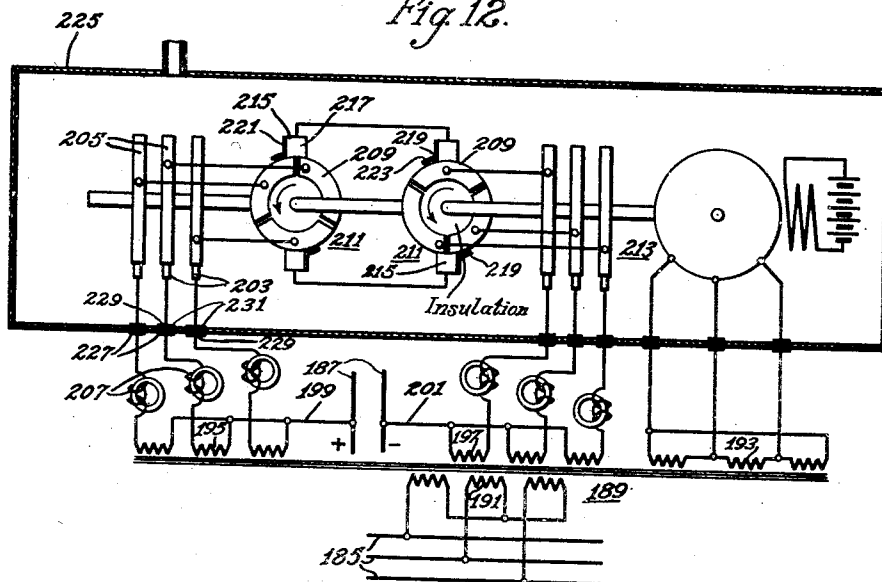
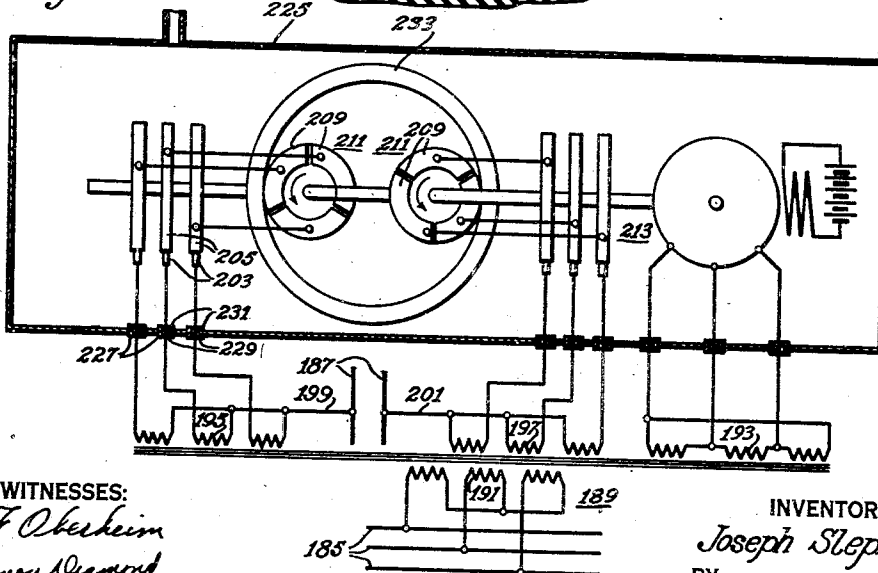


Fig. 14.



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2,326,074

CIRCUIT INTERRUPTER

Joseph Slepian, Pittsburgh, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application September 20, 1939, Serial No. 295,727

20 Claims. (Cl. 200-144)

My invention relates to apparatus involving arc discharges and has particular relation to circuit interrupters in which a short arc is produced when the contacts are disengaged.

In circuit interrupters constructed in accordance with the teachings of the prior art, difficulty is encountered because the contacts are excessively heated. For a semi-infinite solid (which is a solid extending indefinitely in one direction) having specific heat c , thermal-conductivity k , density δ , the rise in temperature T of the surface is given by

$$T = \frac{W}{4.19\sqrt{k\delta}}\sqrt{t}$$

where W is the power input in watts per square centimeter at the surface and t is the time in seconds. The current density at the cathode for an arc flowing between the customary metal electrodes in air at atmospheric pressures is of the order of 10,000 amperes per square centimeter. Since the cathode drop is of the order of 20 volts, the density of the power developed at the cathode is of the order of 2×10^5 watts per square centimeter. If the electrode in question is assumed to be copper

$$k=1, c=.16, \delta=8$$

In such a case,

$$T = 3 \times 10^4 \sqrt{t}$$

If the arc burns for $\frac{1}{2}$ period of an ordinary 60 cycle source, $t = \frac{1}{120}$ and $T = 2800^\circ \text{C}$. Thus, the surface of a copper electrode functioning as the cathode for an arc in air is raised to a temperature substantially above the boiling point of the copper, even if the arc burns for only $\frac{1}{2}$ period of a 60 cycle source.

In accordance with the teachings of the prior art, the heat developed by the arc may be dissipated by magnetically moving the arc over the electrode surface. However, the apparatus required for the movement and the cooling of the arc is relatively complex and considerable expense is involved in its construction and maintenance.

It is accordingly an object of my invention to provide a reliable circuit interrupter of simple structure.

Another object of my invention is to provide a circuit interrupter in which an excessive rise in temperature shall not occur when the contacts are disengaged.

A further object of my invention is to provide a circuit interrupter, the operation of which is dependent on the ignition of a short arc when the contacts are deenergized that shall function satisfactorily without the aid of the usual arc moving and cooling mechanisms.

A more general object of my invention is to

provide an arrangement for use in circuit interrupters or in lightning arresters in which the ignition of an arc shall not result in the development of excessive heat.

5 A more specific object of my invention is to provide a circuit interrupter of simple structure for use in interrupting high potentials.

Another specific object of my invention is to provide a circuit interrupter of the vacuum type in which the force required to actuate the contacts shall be relatively small.

More specifically stated, it is an object of my invention to provide simple and inexpensive arc interrupting means for use in circuit breakers, commutators, lightning arresters, and the like.

15 My invention arises from the discovery that the heat concentration developed at the cathode of an arc is relatively small when the arc is operated in a gaseous atmosphere at a pressure of the order of several centimeters of mercury. Specifically, I have found that the pressure in which the arc is burning should be of the order of 1 cm. for the most propitious results. However, a material improvement over arcs operating at atmospheric pressure or in high vacua is manifested by an arc operating at a pressure as high as 10 cm., on one hand, and as low as .1 cm. on the other hand. When the pressure is lower than .1 cm. difficulties arise because the arc becomes concentrated over small areas of the electrodes.

20 In accordance with my invention, I provide a circuit interrupter in which the contacts are disposed in a gaseous medium at a pressure of the order of several centimeters of mercury. The contacts are disposed in a vacuum tight container in which the pressure is of the desired magnitude. The container is provided with a movable wall and the movement of the contacts is effected by moving the wall. My invention is particularly applicable to short arc structures and for this reason, the distance between the contacts of the interrupter when they are open is preferably of the order of .1 cm.

45 I have found moreover that the energy developed at the contacts may be materially decreased by properly selecting the attenuated gas in which the contacts operate. The current density I of a cold cathode arc I believe is given by

$$I = K \frac{P\sqrt{E_i}}{M}$$

where K is a constant, P is the pressure of the gas, E_i is its ionizing potential, and M is its molecular weight. If gases having a low value of

$$\frac{E_i}{M}$$

are selected the current density is materially reduced. Noble gases such as helium, argon, xenon,

krypton, and nitron have substantially lower values for

$$\frac{E_i}{M}$$

than ordinary gases. Thus, for xenon the value is .1, while it is .74 for nitrogen and .39 for oxygen. In accordance with my invention therefore the gas within the vacuum tight container is preferably a noble gas such as xenon.

Since the contacts in a circuit interrupter constructed in accordance with my invention are maintained in a relatively low pressure medium, atmospheric pressure has a material effect on the mechanical operation of the interrupter. If the volume of the container in which the contacts are disposed is increased or decreased when the contacts are operated, the mechanical work required during the operation is equal to the pressure multiplied by the change in volume. If the change in volume is substantial, the mechanical work and the forces required to produce proper operation are correspondingly large. The difficulty which arises in this connection is suppressed in accordance with a further aspect of my invention by so constructing the container for the circuit interrupter and the mechanism for moving the contacts that the volume of the container remains substantially constant when the contacts are moved.

Because of the short arc ignited in a circuit interrupter in accordance with my invention, the potential rating of a single interrupter is small. Where substantial potentials are to be interrupted, a plurality of individual sets of contacts are connected in series. The contact may be disposed in a tank containing an insulating liquid such as oil and the operation may take place by compressing and relaxing the liquid.

In accordance with a still further aspect of my invention, the commutators of an energy converting arrangement are operated in a medium at a pressure of the order of several centimeters of mercury and arcs are produced between the brushes and the commutator segments when the segments are disengaged from the brushes. Since the energy density at the electrodes generated by the arcs is relatively small, the commutators are not deleteriously affected by the arcs and the rating is materially higher than that for equivalent apparatus designed to operate in air. To further improve the energy conversion arrangement readily saturable chokes may be connected in series with the commutator segments. The chokes of the type preferably used in the practice of my invention saturate at a current of the order of several amperes. Accordingly, during commutation when the current is relatively low, the chokes offer a high impedance to the current flow and decrease the energy developed in the regions in which segments and brushes are separating. When the current is equal to the normal load current, the chokes are saturated and offer substantially no impedance to the current flow.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Figure 1 is a view in top plan of a circuit inter-

rupter in accordance with my invention with the cover partly broken away;

Fig. 2 is a view in section taken along the line II-II of Fig. 1;

Fig. 3 is a view in longitudinal section of a modification of my invention;

Fig. 4 is a graph illustrating the basis of my invention;

Fig. 5 is a view in top plan of a modification of my invention;

Fig. 6 is a view in section taken along the line VI-VI of Fig. 5;

Fig. 7 is a view in section showing a high voltage circuit interrupter in accordance with my invention;

Fig. 8 is a view in top plan of another modification of my invention;

Fig. 9 is a view in section taken along the line IX-IX of Fig. 8;

Fig. 10 is a view in top plan of a further modification of my invention;

Fig. 11 is a view in section taken along the line XI-XI of Fig. 10;

Fig. 12 is a diagrammatic view showing an energy converting arrangement in accordance with my invention;

Fig. 13 is a view in section showing a commutator arrangement used in the apparatus shown in Fig. 12; and

Fig. 14 is a diagrammatic view showing another converting arrangement in accordance with my invention.

The apparatus shown in Figs. 1 and 2 comprises a short cylindrical container 15 formed by composite upper and lower plates 17 and 19, respectively, and an insulating ring 21 between the plates. The upper plate 17 is made up of a central disc 23 of an ordinary metal, such as steel, and a concentric ring 25 of an alloy which forms a vacuum-tight seal with an insulator, such as glass. The ring 25 may, with advantage, be composed of an iron-nickel-cobalt alloy, sold under the trade name Kovar. The lower plate 19 is made up of a central disc-shaped, flexible diaphragm 27 and a concentric alloy ring 29 similar to the upper ring 25.

The alloy rings 25 and 29 are welded to the disc 23 and the diaphragm 27 in such manner that the joints are vacuum-tight. The insulating ring 21 is preferably composed of a glass, which seals to the alloy of which the rings 25 and 27 are composed, and is sealed to the rings. The glass is preferably Corning, G-705-AJ or G-704-AJ. The disc 23 is provided with an outlet tube 30 through which the container is exhausted to a pressure of the order of 1 cm. of mercury and which is thereafter sealed off. Since the seals and the welds are vacuum-tight, the low pressure is maintained indefinitely. Contacts 31 and 33 are welded at the centers of the disc 23 and the diaphragm 27. The thickness of the insulating ring 21 is such that the distance between the contacts 31 and 33 when they are open is of the order of .1 or .2 centimeter. With the contacts so close together the contact surfaces are available to condense the ionized gases which arise in the ignition of an arc when the contacts are separated. However, under certain circumstances this advantage may not be necessary and the broad aspects of my invention may be practiced with the distance between the contacts 1 cm. or more.

The contacts 31 and 33 are closed by moving the diaphragm upwardly and thus causing the contact 33 on the diaphragm to engage the one

secured to the disc 23. The movement of the diaphragm 27 is effected through the cooperation of a spiral-shaped peripheral cam 35 and a cam follower 37 extending from the diaphragm. The follower 37 is a metallic plate in the form of a truncated right triangle with the narrow end engaging the cam 35. As the cam 35 is rotated in a counterclockwise direction from the position shown in the drawings, it raises the follower 37 and the diaphragm 27 and its contact 33 against the resilient force exerted by the diaphragm and urges the contact 33 into engagement with the contact 31. When the cam is rotated in the opposite direction, the contacts 31 and 33 are disengaged by the restoring force exerted by the diaphragm. The contacts 31 and 33 may be connected in a circuit by terminals 39 and 41, respectively. The former (39) is secured to the disc 23 and the latter (41) carries a brush 43 which engages the vertical side of the cam follower 37.

The above-described apparatus may be used with advantage in cases in which an alternating potential of the order of 200 to 400 volts R. M. S. is to be interrupted. The current density of the arc at the pressure in the container 15 is relatively low and, therefore, the heat produced is not such as to deleteriously affect the contacts 31 and 33 when they are disengaged.

In Fig. 4, the relationship between the pressure and the current density at the cathode of an arc is shown graphically. Pressure is plotted horizontally, and current density vertically. As can be seen from the curve 45, the current density is relatively high for pressures of the order of one atmosphere or more. As the pressure is decreased, the current density decreases until it approaches a minimum in the region of pressures of the order of one centimeter of mercury. As the pressure is now further decreased, the current density increases, and for low pressures approaches the values that it has at one atmosphere. In accordance with my invention, the pressure is maintained at approximately one centimeter of mercury and, therefore, the energy consumed at the cathode when an arc is ignited between the contacts is relatively small.

While the energy developed in the arc produced on the opening of the contacts of an interrupter constructed in accordance with my invention is relatively small, the temperature is raised materially. The rise in temperature does not affect the contacts, but may affect the insulating ring 21. This undesirable condition is remedied in accordance with a further aspect of my invention by using a laminated insulating ring 47, as shown in Fig. 3, in lieu of the homogeneous structure 21 of the Fig. 2 arrangement. In the Fig. 3 structure the insulating ring 47 is formed of a series of thin glass rings 49 with alloy laminations 51 interposed. The alloy rings prevent the deterioration of the insulation by the heat developed.

While the laminated insulator has substantial advantages in a switch of the type disclosed herein, its most important function arises in connection with lightning arresters constructed in accordance with my invention. In apparatus of the latter type, an arc is ignited between opposite walls of a region maintained at a pressure of the order of one centimeter when a high potential is impressed on the apparatus protected. The arc has a tendency to move towards the boundary of the region where the insulation is located, and may excessively heat the insulation. When the

insulation is laminated, as in the Fig. 3 arrangement, the heat of the arc has no deleterious effect.

The glass-alloy seals are, of course, not indispensable for the practice of my invention. In lieu of the glass, a ceramic insulator, such as porcelain, with its sealing surfaces metallized may be used, and in lieu of the alloy a suitable metal which seals to the metallized porcelain may be used.

The apparatus shown in Figs. 5 and 6 comprises a container 53 formed by a flanged hollow cylinder 55 from the center of one base of which a reentrant hollow cylinder 57 is suspended, and a resilient shell 59 of horizontal C section welded to the flange 61 of the cylinder 55. The reentrant cylinder has a wall of composite structure comprising a pair of alloy rings 63 and 65 separated by a glass ring 67. The upper alloy ring 63 is welded to an annular tip 69 extending downwardly from the base of the flanged cylinder 55, and the lower ring 65 is welded to a disc 71. The disc 71 and the cylinder 55 may be composed of a metal, such as steel. Contacts 73 and 75 are welded to the disc 71 and the base of the shell 59, respectively. The height of the shell is such that when the contacts 71 and 73 are disengaged the distance between them is of the order of .1 centimeter. The container is evacuated to the same pressure as the corresponding containers in the apparatus shown in Figs. 2 and 4. As in the latter apparatus, contacts 73 and 75 are engaged by the cooperation of a cam 35 and a cam follower 37 which cause the base of the shell 59 to move upwardly. In the apparatus shown in Figs. 2, 4 and 6, the resilient shell or diaphragm should be composed of relatively stiff material since the force, exerted on its surface by reason of atmospheric pressure, is relatively large. In general, the material of which the diaphragm or shell is composed may be constructed of sufficiently heavy material to accomplish this purpose. If the heavy material is for one reason or another not desired, separate springs may be used to supply the necessary force.

Where a higher rating is required than the several hundred volts of which the units shown in Figs. 2, 4 and 6 are capable, a system of the type shown in Fig. 7 is used. In this arrangement a plurality of circuit interrupters 77 are connected in series. Each interrupter comprises a container 79, the walls of which are a solid composite plate 81, and an annular composite plate 83 closed by a Syphon 85 extending from the center, and an insulating ring 87 between the plates. The solid plate 81 is made up of a solid disc 89 of any suitable metal, such as steel, to which a Kovar alloy ring 91 is welded. The annular plate 83 is made up of an annular disc 93 of steel or other suitable metal and alloy ring 95. The Syphon 85 is provided with a flanged opening and the flange 97 is welded to the annular disc 93. The insulating ring 87, which may be composed of glass, is sealed between the alloy rings 91 and 95. The containers 79 are exhausted to the same pressure as the containers in the other modifications of my invention.

The contacts 99 and 101 of the interrupters 77 are secured to the center of the solid disc 89 and the base of the Syphon 85, respectively. The contact 101 is coaxial with the syphon 85 and extends along its length to a point such that when it is disengaged from the contact 99, the distance between the contacts is of the order of .1 centimeter. The interrupters 77 are connected in series by U-

shaped brackets 103, the legs of which are welded to juxtapositioned plates 81 and 83 of adjacent containers 79.

The interrupters 77, together with their connecting brackets 103, are disposed in a vessel 105 filled with an insulating liquid, such as oil. The vessel is provided with terminals 107 and 109 to which the outside plates 81 and 83, respectively, of the interrupters on the ends of the assembly are connected through L-brackets 111 welded to the plates.

From one end of the vessel 105, a cylindrical tube 113 extends and a piston 115 is slidably disposed in the tube. The piston 115 is secured to a rod 117 which is coextensive with the armature 119 of a solenoid 121. When the solenoid 121 is energized, the rod 117 is moved downward against the action of a compression spring 123, which engages a disc 125 secured to the rod and the top of the cylinder 113, and the liquid is compressed. The pressure exerted by the piston 115 is transferred through the liquid to the Sylphons 85 and the contacts 99 and 101 are closed. The contacts are maintained closed by the engagement of a latch 127 with one end of a lever 129, the other end of which is pivotally secured to the rod 117. The lever is rotatable about a fixed pin 131 intermediate its ends and is rotated upward about the pin 131 into engagement with the latch 127 when the closing solenoid 121 is energized. The latch 127 may be disengaged from the lever 129 by energizing an opening solenoid 133. Under such circumstances, the piston 115 moves upwardly under the action of the spring 123 and the contacts are opened.

The hydraulic actuating mechanism is, of course, not the only arrangement which can be used to actuate a plurality of interrupters in accordance with my invention. For example, the movable contacts 99 and 101 may be actuated by a lever mechanically coupled to all of the Sylphons. As is the customary practice, the lever may be latched in the closed position and the latch released when the circuit interrupter is to be opened.

In Figs. 8 and 9, a modification of my invention is shown in which the contacts are operated without changing the volume of the evacuated containers. Because the volume is maintained constant, the effect of atmospheric pressure is eliminated, and the heavy resilient elements in the modifications discussed heretofore may be replaced by relatively light springs.

The apparatus comprises a container 135, the walls of which are a composite upper plate 137, a homogeneous lower plate 139, an insulating ring 141 sealed to the upper plate, and a resilient annular shell 143 sealed to the ring and welded to the lower plate. The composite plate 137 consists of a disc 145 of any suitable metal to which a ring 147 of an alloy suitable for sealing with glass is welded. The lower plate 139 may be composed of the same metal as the disc 145. A flat ring 149 of the sealing alloy is welded to the upper surface of the shell 143 and sealed to the glass ring 149. Contacts 151 and 153 having an annular form are secured coaxially to the lower plate 139 and the disc 145, respectively. From the center of the lower plate, an insulating pin 155 extends. The pin engages in a notch 157 centrally disposed in the disc 145 and provides a bearing about which the lower plate 139 may swivel. The container is exhausted to the same pressure as the containers discussed heretofore.

The contacts 151 and 153 are spaced a distance of the order of .1 centimeter when disengaged. They may be engaged by rotating a peripheral cam 159, the operating surface of which is in engagement with the plate 139 at a point on its periphery. As the cam 159 is rotated in a counterclockwise direction from the position shown, it raises the plate 139 at one end against the force of the resilient shell 143 and the contacts 151 and 153 are engaged. At the same time, the plate swivels about the point of engagement of the pin 155 and the disc 145, and at the opposite end the shell 143 is opened and the distance between the upper and lower plates is increased. The decrease in volume effected on the closing of the contacts 151 and 153 at one end of the container 135 is, therefore, compensated by the opening of the shell at the other end, and the total volume within the container remains constant.

In the modification shown in Figs. 10 and 11, the fixed contact 161 is disposed along a portion of the inner surface of a flanged metallic cup 163. The cup 163 is closed by a Sylphon 165 which is welded to the flange 167. The Sylphon 165 is provided with a central opening bounded by an inwardly extending beveled surface 169 to which an annular beveled plate 171 of a glass-sealing alloy is welded. An insulating cylinder 173 is sealed to the alloy plate 171 and a rod 174 carrying a metallic cylindrical block 175 at its lower end is sealed through the insulator in such manner that the block extends into the cup 163. The rod is composed of the sealing alloy and is secured in any suitable manner to the block. The block 175 has a flat portion 177 in the region of the fixed contact 161, so that the region of engagement of the block and the contact is a surface of substantial area. The container formed by the cup 163 and the Sylphon 165 is evacuated in the same manner as in the other modifications of my invention.

A cavity 179 having the cross-section of an arch is provided in the block 175. The cavity is symmetric about the axis of the block and extends from its base along a substantial portion of the length of the block. An insulating pin 181 fixed centrally in the base of the cup 163 extends into the cavity 179 and engages the block 175 at the apex of the cavity. The pin 181 thus constitutes a pivotal bearing for the block.

The block 175 is pivoted so that the surface 177 engages and disengages the contact 161 by rotating a peripheral spiral cam 183 which engages the upper end of the rod 174. When the cam 183 is rotated in a clockwise direction, the rod 174 and the block 175 are pivoted about the insulating pin 181 in a counterclockwise direction and the contacts are engaged. The pivoting motion causes the Sylphon 165 to be compressed on the left-hand side and tensioned on the right-hand side. The decrease in volume on the left-hand side is thus compensated by a corresponding increase in volume on the right-hand side.

In Figs. 12 and 13, a conversion system constructed in accordance with my invention is shown. While my invention is applicable to the transfer of energy between systems operating at any different frequencies, it is specifically shown as applied to the interchange of power between alternating current line conductors 185 and direct current line conductors 187.

The apparatus comprises a three-phase transformer 189 having a star-connected primary 191

and three secondary sections 193, 195 and 197, one of which (193) is delta-connected to the line conductors leading to a synchronous motor. The neutral conductors 199 and 201 of the star secondaries 195 and 197 are connected to the direct current line conductor 187. At the other terminals, each of the phase windings of the secondary sections 195 and 197 are each connected through a readily saturable choke 207 to a brush 203 which engages a conducting slip ring 205. The choke is so designed that it becomes saturated when the current flow through it is small compared to the load current. In practice, the saturating current for the choke should be of the order of 1 ampere.

The slip rings 205 are each connected to an insulated segment 209 of one or the other of a pair of commutators 211. The segments 209 are uniformly spaced around the periphery of the commutators 211, each commutator having three 120° segments. The commutators 211 and the slip rings 205 are rotated together from a synchronous motor 213 which is supplied from the delta secondary section 193. With each commutator 211 a pair of oppositely disposed brushes 215 is associated. Each brush associated with one commutator is conductively connected to a corresponding brush associated with the other commutator.

The brushes 215 are of composite structure, each comprising a block 217 of conducting material to which an angle 219 of sheet metal is secured. One surface of the block 217 engages the segments 209 as the corresponding commutator 211 is rotated. One side 221 of each angle 219 is secured to a surface of the block 217 which is perpendicular to the engaging surface in a position such that the other side 223 extends substantially parallel to the segment surface in the region of engagement a short distance from the segments. The angles 219 are so positioned at the block 217 that the end of a receding commutator segment 209 passes under side 223 after it passes the block.

The moving parts of the system including the motor 213, the slip rings 205, and the segments 209 are disposed in a container 225 within which a pressure of the order of one centimeter of mercury is maintained. The container may be permanently exhausted or it may be continuously pumped. The supply conductors for the motor and the connecting conductors for the brushes 203 are introduced in the container through eyelets 227. Each eyelet comprises a central glass plug 229, through which the conductors are sealed and an outer alloy ring 231 is sealed to the glass and welded to the adjacent wall of the container 225.

The commutator brushes 215 are so positioned relative to the segments 209 that the junction region between two segments passes under a brush when the potential of the secondary winding to which one of the segments is connected is passing from a magnitude smaller than the potential of the secondary winding to which the other segment is connected to a magnitude greater than this potential. At this point the connection to the brush is transferred from one of the receding windings to the approaching winding and the current flow through the brush and the receding segment falls to zero, while the current flow through the other segment rises from zero to a predetermined value. For rectification, that is, where the direct current conductors 187 constitute the load and the alternating current

conductors 185 constitute the source, the system is adjusted for under commutation in accordance with the preferred practice of my invention. In this case the potential of the receding and the approaching windings become equal after the block 217 disengages the receding segment and the current zero occurs when the receding segment is passing under the angle 219. An arc is ignited between the receding segment 209 and the angle 219 when the brush first disengages the segment since its potential still predominates over that of the approaching segment and as the current zero is approached and passed, the arc is extinguished. The pressure within the container 225 is the same as in the previously described embodiments of the invention and is preferably of the order of 1 centimeter of mercury, and consequently the brushes 219 and the segments 209 are not deleteriously affected by the arcs. The situation is materially improved by the operation of the chokes 207 which are unsaturated when the commutation occurs, and therefore, absorb a substantial portion of the potential tending to maintain the arc.

Of course, in view of the fact that the current intensity in the arc is small because of the low pressure in the container, the chokes need not in all cases be utilized. In many situations, moreover, a relatively inexpensive choke may be used where a relatively expensive choke would be required in a conversion arrangement constructed in accordance with the teachings of the prior art.

In Fig. 14, a modification of my invention is illustrated. In this case the brushes are replaced by a circular ring 233 which is tangential to the segments 209. The tangential ring 233 functions as a brush, and when one segment is being disengaged and the succeeding segment is being engaged, the arcing takes place between the circular ring and the receding segment.

As described herein, the containers involved in the various modifications of my invention are merely exhausted until the desired pressure is attained. Improved operation is attained if the residual gas in the containers is xenon. If the improvement is desired, the containers may be first exhausted and treated to produce a high vacuum and then the necessary quantity of xenon may be introduced.

A divisional application Serial No. 467,761 was filed December 3, 1942, to cover the embodiments of the invention shown in Figs. 12-14.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. A circuit interrupter comprising a confined fluid medium, a vacuum-tight container having a pressure of from about one to ten centimeters of mercury therein disposed in said medium, cooperative contacts disposed in said container and means for compressing and relaxing said fluid medium to engage and disengage said contacts.

2. A circuit interrupter comprising a confined fluid medium, a plurality of vacuum-tight containers each having a pressure of from about one to ten centimeters of mercury therein disposed in said medium, cooperative contacts disposed in each of said containers, means for connecting the contacts of said containers in series and means for compressing and relaxing said medium to

close and open said contacts simultaneously, the contact portions of each pair of contacts when said contacts are open being spaced a distance no greater than .1 of a centimeter.

3. A circuit interrupter comprising a confined fluid medium, a plurality of vacuum-tight containers each having a pressure of from about one to ten centimeters of mercury therein disposed in said medium, cooperative contacts disposed in each of said containers, means for connecting the contacts of said containers in series and means for compressing and relaxing said medium to close and open said contacts simultaneously, the distance between said contacts when they are open being of the order of .1 centimeter.

4. A circuit interrupter comprising a confined fluid medium, a plurality of vacuum-tight containers each having at least one movable wall and a pressure of from about one to ten centimeters of mercury therein disposed in said medium, cooperative contacts disposed in each of said containers, said contacts being actuable to engage and disengage by the movement of said movable wall, means for connecting the contacts of said containers in series and means for compressing and relaxing said medium to close and open said contacts simultaneously.

5. A circuit interrupter comprising a confined fluid medium, a plurality of vacuum-tight containers each having at least one resilient movable wall and a pressure of from about one to ten centimeters of mercury therein disposed in said medium, cooperative contacts disposed in each of said containers, said contacts being actuable to engage and disengage by the movement of said movable wall, means for connecting the contacts of said containers in series and means for compressing and releasing said medium to close and open said contacts simultaneously.

6. A circuit interrupter comprising a vacuum-tight container, relatively movable cooperative contacts disposed in said container between which an arc is initially established and plays with its terminals on said contacts, said contacts being relatively movable into and out of engagement and having a maximum distance of separation no greater than .2 of a centimeter, and a gaseous medium in said container at a pressure such that the current density at the cathode is substantially a minimum.

7. A circuit interrupter comprising a vacuum tight container having a noble gas therein at a pressure of from one-tenth of a centimeter to ten centimeters of mercury, and arc terminal members disposed in said container and between which an arc is initially established and plays with its terminals on said members.

8. A circuit interrupter comprising a vacuum tight container having a noble gas therein at a pressure of the order of one centimeter of mercury, and cooperative contact members disposed in said container relatively movable into and out of engagement and between which an arc is initially drawn and plays with its terminals on said members, said contact members having a maximum distance of separation no greater than .2 of a centimeter.

9. A circuit interrupter for interrupting relatively large values of currents comprising a vacuum tight container, arc terminal members disposed in said container between which an arc is initially established and plays with its terminals on said members, said container being evacuated to a pressure of from one-half a centi-

meter of mercury to ten centimeters of mercury to reduce burning of said arc terminal members, said members being spaced apart a distance no greater than .2 of a centimeter.

10. A circuit interrupter for interrupting relatively large values of current comprising a vacuum tight container, arc terminal members disposed in said container between which an arc is initially established and plays with its terminals on said members, said container having a noble gas therein at a pressure from one-half a centimeter of mercury to ten centimeters of mercury to reduce burning of said arc terminals.

11. A circuit interrupter for interrupting moderate to relatively large amounts of current comprising a vacuum-tight container having solid arc terminal members therein between which an arc is initially established and plays with its terminals on said members, said arc terminal members being spaced apart a distance no greater than .2 of a centimeter, and a gas in said container at a pressure of from one-tenth of a centimeter to ten centimeters of mercury to reduce burning of said arc terminals to a very small amount.

12. A circuit interrupter comprising a vacuum-tight container having cooperative contacts disposed therein between which an arc is initially drawn and plays with its terminals on said contacts, means for engaging and disengaging said contacts, said engaging and disengaging means including a movable wall of said container, and a gas in said container at a pressure of from one to ten centimeters of mercury for reducing burning of said contacts to a small amount.

13. A circuit interrupter for interrupting moderate to relatively large amounts of current comprising a vacuum-tight container having relatively movable cooperative contacts disposed therein between which an arc is initially established and plays with its terminals on said contacts, said contacts when open being spaced a distance no greater than .2 of a centimeter, and a gas in said container at a pressure of from one to ten centimeters of mercury to reduce burning of said contacts to a small amount.

14. A circuit interrupter comprising a rigid element forming one contact of said interrupter, a resilient element carrying another contact of said interrupter, an insulating member insulating said elements from one another and so connected with them that the region bounded by said elements and member is sealed vacuum-tight against the external space, means for moving said resilient element to open and close said contacts, the contact portions of said contacts when opened under load conditions initially drawing an arc which plays with its terminals on said contacts, said contacts when open being spaced apart a distance no greater than .2 of a centimeter, and a gas disposed in the region bounded by said elements and member at a pressure of the order of one to two centimeters of mercury to reduce burning of said contacts to a small amount.

15. A circuit interrupter comprising a vacuum-tight container having cooperative relatively movable contacts disposed therein between which an arc is initially drawn and plays with its terminals on said contacts, said contacts when open being spaced a distance no greater than .2 of a centimeter, and a gas in said container having a pressure of the order of one centimeter of mercury.

16. A vacuum-tight container comprising parallel walls having terminal members thereon be-

tween which an arc is initially drawn and plays with its terminals on said members, an insulating spacer consisting of laminations of metal separated by strips of insulation between said walls, and a gaseous medium at a pressure of from one-tenth of a centimeter to ten centimeters of mercury within said container, said arc terminal members being spaced apart a distance no greater than .2 of a centimeter.

17. A vacuum-tight container having cooperative contact members therein relatively movable into and out of engagement and between which an arc is initially established and plays with its terminals on said contact members, and a noble gas in said container at a pressure of from one-tenth of a centimeter to ten centimeters of mercury to reduce burning of said contact members, said contact members having a maximum separation no greater than .2 of a centimeter.

18. A circuit interrupter comprising a vacuum-tight container having at least one movable wall, cooperative contacts in said container actuated to open and closed position by the movement of said wall and between which an arc is initially drawn and plays with its terminals on said contacts, means for moving said wall while maintaining the volume within said container unchanged to actuate said contacts, said contacts when opened being spaced a distance no greater than .2 of a centimeter, and a gaseous medium in said con-

tainer at a pressure of from one-tenth of a centimeter to ten centimeters of mercury.

19. A circuit interrupter comprising a vacuum-tight container having a movable wall which is pivoted adjacent its center, a fixed contact within said container, a movable contact within said container actuated to engage and disengage said fixed contact by the movement of said wall, and means for applying a force to said wall at a point spaced from the pivot point for moving said wall to actuate said movable contact, said contacts when opened under load conditions initially drawing an arc which plays with its terminals on said contacts, a gaseous medium in said container at a pressure of from one to ten centimeters of mercury for reducing burning of said contacts, the contact portion of said contacts when the contacts are open being spaced a distance no greater than .2 of a centimeter.

20. A circuit interrupter for interrupting moderate to relatively large amounts of current comprising a vacuum-tight container, cooperative contacts in said container relatively movable into and out of engagement, and a gas in said container at a pressure of from one-tenth to ten centimeters of mercury to reduce the arc terminal current density of the arc drawn between said contacts.

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