Oct. 15, 1968 W. H. FISCHER 3,406,269

FLUID-BLAST CIRCUIT BREAKERS HAVING MEANS FOR INCREASING THE DENSITY OF THE FLUID DURING INTERRUPTION

Filed Feb. 26, 1965 3 Sheets-Sheet 1

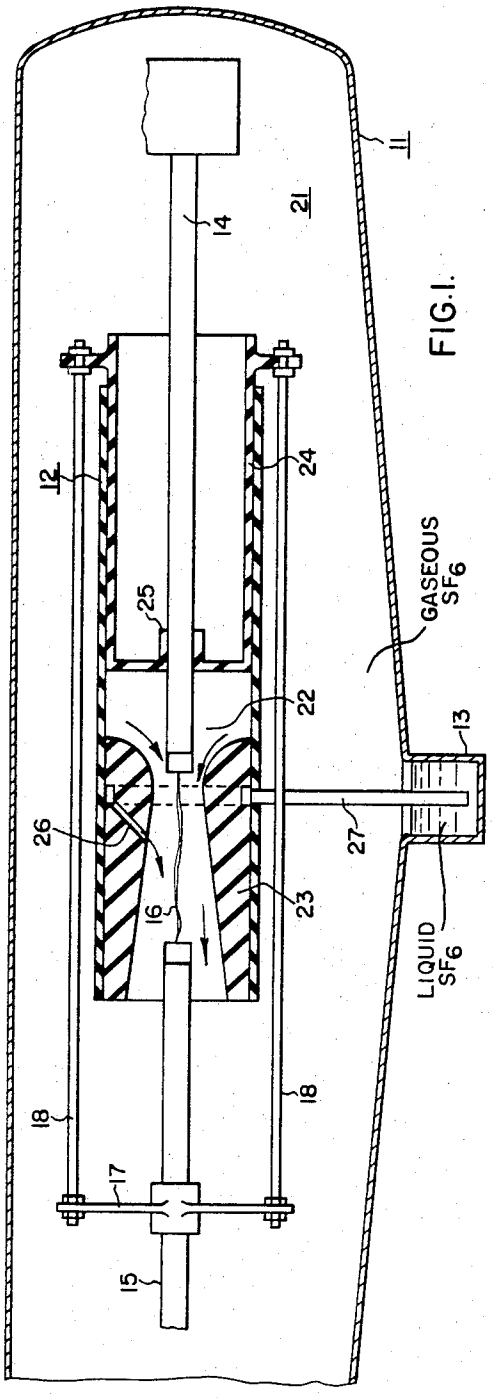


FIG. 1.

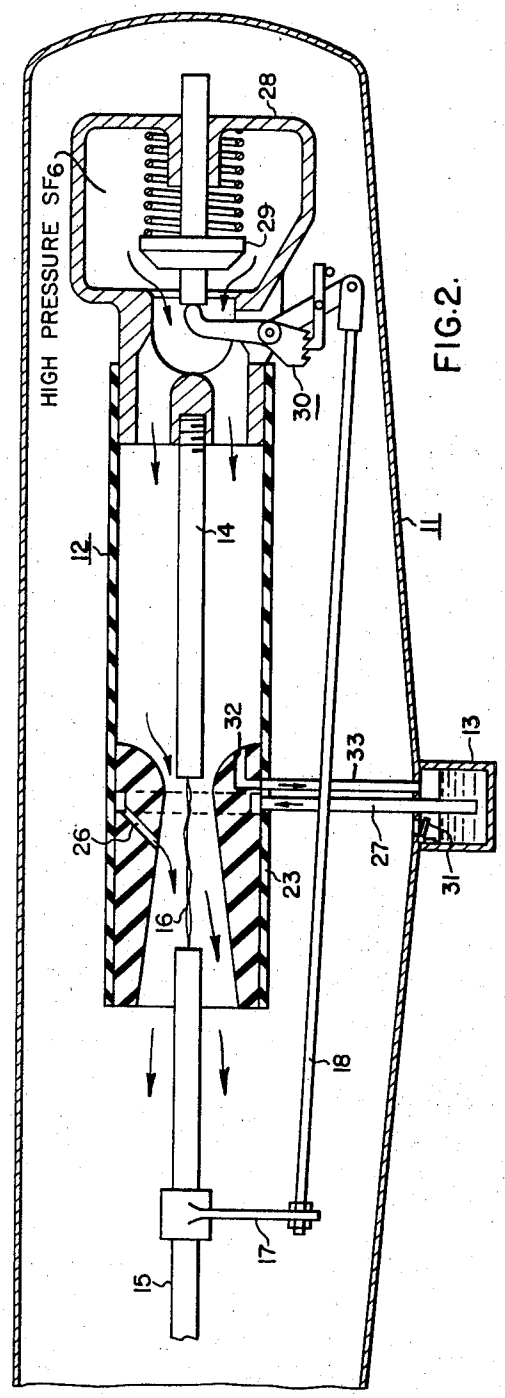


FIG. 2.

WITNESSES

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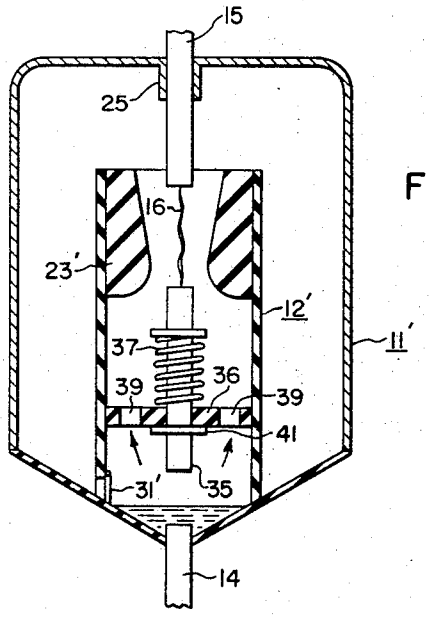

15
25
16
23'
12'
11'
37
36
39
39
41
31'
35
14

FIG.3.

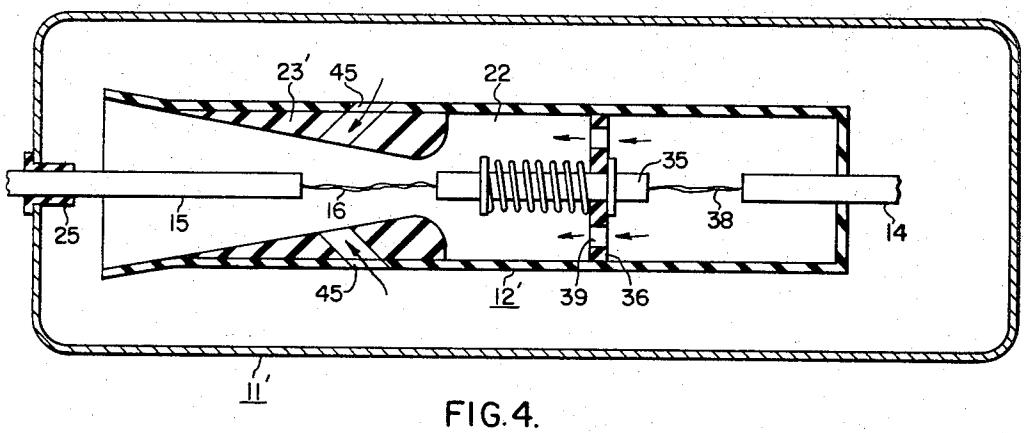

23'
45
22
35
25
15
16
38
14
45
12'
39
36
11'

FIG.4.

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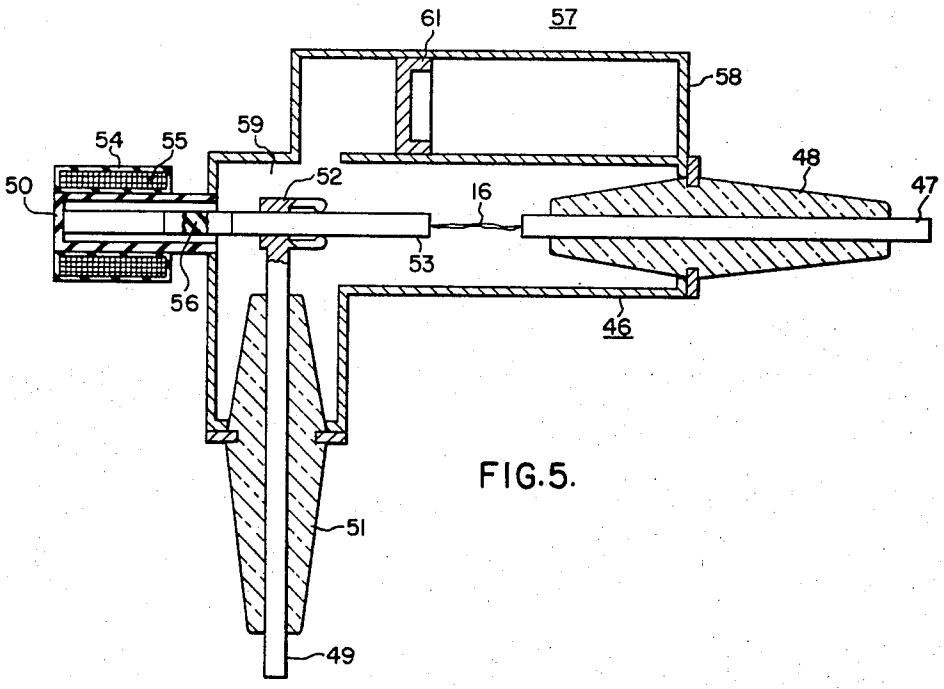


FIG.5.

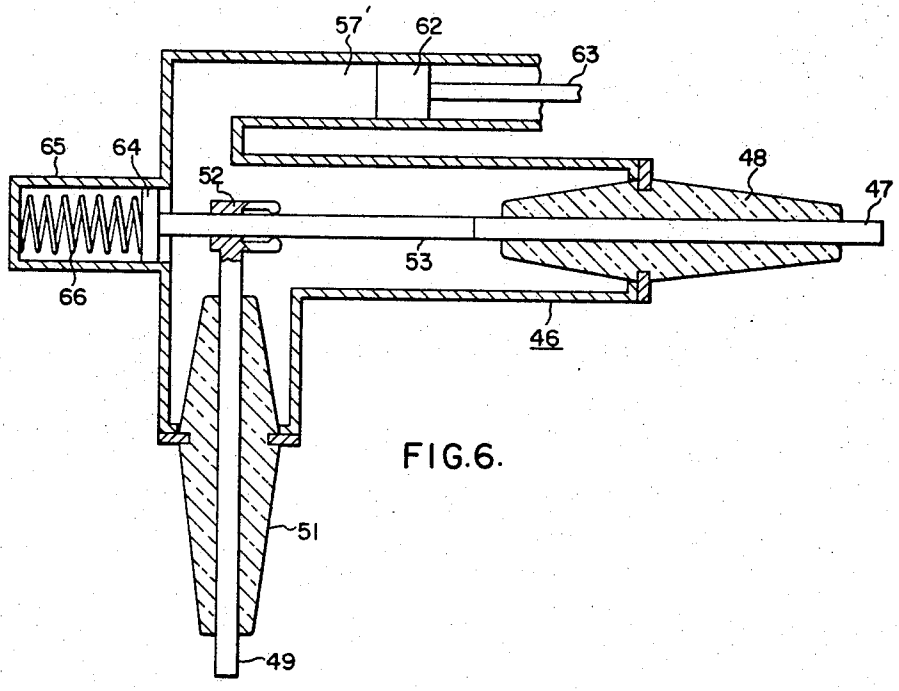


FIG.6.

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3,406,269

FLUID-BLAST CIRCUIT BREAKERS HAVING MEANS FOR INCREASING THE DENSITY OF THE FLUID DURING INTERRUPTION

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10 Claims. (Cl. 200—148)

ABSTRACT OF THE DISCLOSURE

A gas-blast type of circuit interrupter using an electronegative arc-extinguishing gas or liquid increases the density of the fluid along the established arc path by injector means or piston means, and hence the arc voltage at the time of interruption.

This invention relates, generally, to circuit breakers, and, more particularly, to circuit breakers utilizing an interrupting medium having an electronegative characteristic.

One of the important reasons that sulfur hexafluoride, SF_6, is such a good interrupting medium is its electronegative or "electron sponge" characteristic. Therefore, an efficient circuit interrupter should have the most dense and un-ionized SF_6 possible along the entire length of the interrupting break. The more molecules of SF_6 there are present at the arc, the greater will be the capacity of the interrupter to absorb electrons and the faster will be the de-ionization process at current zero. The difference in performance between liquid and gas SF_6 interrupters illustrates this point. The liquid breaker contains SF_6 at a higher density. Because of this, the size of the interrupter, and hence the breaker, can be made considerably smaller when liquid SF_6 is utilized as the interrupting medium.

An object of this invention is to provide for utilizing a high density electronegative interrupting medium in circuit breakers of a gas, liquid, or gas and liquid type.

One of the reasons that pressures greater than 60 p.s.i. at 70° F. have not been extensively used in SF_6 breakers is that the vapor pressure of SF_6 gas is such that at higher pressures it begins to condense out at moderately low temperatures. This results in the need for utilizing resistors to heat the SF_6. Utilizing resistors for this purpose is not desirable because they cannot be utilized at high potential, they use power, they require control equipment and they are subject to failure.

Accordingly, another object of the invention is to eliminate the need for resistance heaters in high pressure SF_6 breakers.

A further object of the invention is to provide a circuit breaker having a tank which is small enough in diameter to be exempt from the ASME Boiler and Pressure Vessel Code.

Still another object of the invention is to increase and control the pressure in a circuit breaker containing an electronegative interrupting medium.

A still further object of the invention is to provide for raising the pressure and the density of the interrupting medium to the required value only at the time of interruption.

Another object of the invention is to utilize the injector principle to improve the performance of circuit breaker interrupters containing an electronegative interrupting medium.

Other objects of the invention will be explained fully hereinafter or will be apparent to those skilled in the art.

In accordance with one embodiment of the invention,

the injector principle is utilized to maintain high density un-ionized SF_6 along the entire length of an interrupting break, thereby improving the performance of the interrupter. Also, high density of the SF_6 is maintained by means of an accumulator connected to the tank of a breaker containing liquid SF_6. The accumulator prevents an excessive rise in the pressure during an interruption. Another method utilizes auxiliary means to raise the pressure and the density of the SF_6 to the required value only at the time of interruption.

For a better understanding of the nature and objects of the invention, reference may be had to the following detailed description taken in conjunction with the accompanying drawings, in which:

FIGURES 1, 2, 3 and 4 are diagrammatic views of circuit interrupters embodying features of the inveniton for maintaining high density of an interrupting medium, such as SF_6 gas; and

FIGS. 5 and 6 are diagrammatic views of interrupters having means for maintaining high pressure and density of liquid SF_6.

Referring to the drawings, and particularly to FIG. 1, the structure shown diagrammatically therein comprises a generally cylindrical housing or tank **11** having an interrupting chamber **12** disposed inside the tank **11**. The tank contains an electronegative interrupting medium, such as sulfur hexafluoride (SF_6), which is normally in a gaseous state. However, as explained hereinbefore, the vapor pressure of SF_6 is such that at pressures above 60 p.s.i. it begins to condense out at moderately low temperatures. Therefore, a collector **13** is provided at the bottom of the tank **11** to collect the liquid SF_6 that condenses from the gaseous SF_6.

As shown, a relatively stationary contact member **14** and a movable contact member **15** are disposed inside the interrupting chamber **12** when in their closed position. The movable contact member **15** may be separated from the stationary contact member **14** to draw an arc **16** therebetween in the interrupting medium. The contact member **15** may be actuated by a cross member **17** connected between two spaced operating rods **18** which may be moved longitudinally by a suitable operating mechanism (not shown), such as, for example, the one described in a copending application, Ser. No. 61,284, filed Oct. 7, 1960, now United States Patent 3,154,658, issued Oct. 27, 1964 to R. G. Colclaser and R. N. Yeckley and assigned to the Westinghouse Electric Corporation.

In order to extinguish the arc **16** drawn between the contact members, a puffer mechanism **21** is provided to create a blast of the interrupting medium through an orifice **22** in the interrupting chamber **12**. The orifice **22** is formed by a liner **23** which is preferably composed of polytetrafluoroethylene which is sold under the trade name "Teflon." The puffer **21** includes a piston **24** which is slidably disposed inside the cylindrical interrupting chamber **12**. A bushing **25** surrounds the stationary contact member **14** where it passes through the head of the piston **24**. The piston is actuated by the operating rods **18** the ends of which are attached to the piston. Thus, when the contact members are separated, the piston causes the interrupting medium SF_6 to flow through the orifice **22** at a relatively high velocity.

As explained hereinbefore, if a portion of the SF_6 in the tank **11** has condensed into a liquid, the density of the gas is reduced. As also explained hereinbefore the reduction of the density of the SF_6 lessens its interrupting ability. In order to increase the density of the interrupting medium during the interrupting operation, the well-known injector principle is utilized to introduce some of the liquid SF_6 in the collector **13** into the interrupting chamber. As shown, openings **26** are provided in the orifice member **23**. A tube or pipe **27** having its lower end dis-

posed in the collector **13** is connected to the openings **26**. Thus, the high velocity of the gas forced through the orifice **22** by the puffer mechanism **21** causes some of the liquid SF_6 to be drawn up from the collector **13** and into the orifice in a manner similar to the operation of an atomizer. In this manner, the density of the interrupting medium along the interrupting break in the chamber **12** is increased, thereby improving the interrupting ability of the medium.

The structure shown in FIG. 2 is in general similar to that shown in FIG. 1. However, a storage tank **28** contains some of the interrupting medium, such as SF_6, at a high pressure. A blast valve **29**, which is opened in conjunction with the separation of the contact members, admits high pressure gas from the tank **28** into the interrupting chamber **12**. The valve **29** may be operated by a ratchet mechanism **30** which is operated by the operating mechanism for the movable contact member **15**. The ratchet mechanism **30** may be of the type described in a copending application Ser. No. 102,176, filed Apr. 11, 1961 now U.S. Patent 3,214,545, issued Oct. 26, 1965 to C. F. Cromer and assigned to the Westinghouse Electric Corporation.

Also, the collector **13** is a closed vessel and a check valve **31** is provided at the entrance to the collector. An additional opening **32** is provided in the orifice member **23** and connected to the collector **13** by means of a tube **33**. When the high pressure gas is admitted into the interrupting chamber from the tank **28**, some of the gas flows through the tube **33** into the collector **13**, thereby increasing the pressure in the collector. The check valve **31** is closed and some of the liquid is forced upward through the pipe **27** and into the orifice through the openings **26**, thereby increasing the density of the interrupting medium.

The interrupter shown in FIG. 3 is of the self-generating type. In addition to the fixed contact member **14** and the movable contact member **15**, an intermediate contact member **35** is provided. The member **35** is slidably mounted in a partition **36** in the interrupting chamber **12'**. The member **35** is biased upwardly by a compression spring **37**.

During the opening operation, the contact member **35** is first separated from the contact member **14**, thereby establishing a pressure generating arc **38** between these contact members. The heat of the arc **38** vaporizes some of the liquid SF_6 at the bottom of the tank **11** and creates a pressure which causes the vaporized gas to flow through openings **39** in the partition **36** into the upper part of the interrupting chamber **12'**, where the arc **16** is drawn between the contact member **35** and the contact member **15**. The upward travel of the contact member **35** is limited by a pin or flange **41** which engages the partition **36**. A check valve **31'** at the entrance to the collector compartment is closed by the increase in pressure in the compartment. The density of the interrupting medium in the interrupting chamber is increased during the interrupting operation, as previously explained.

The interrupter shown in FIG. 4 is also of the self-generating type. In this case, it is assumed that the interrupting medium in the tank **11'** remains in a gaseous state under the operating conditions encountered by the breaker. Since the gas forced through the orifice **22** by the pressure generating arc **38** is relatively hot and ionized, it is desirable to mix un-ionized gas with the ionized gas in the interrupting chamber. This is accomplished by utilizing the injector principle. As shown, openings **45** are provided in the orifice member **23'**. Thus, the velocity of the gas flowing through the orifice past the openings **45** draws un-ionized gas from outside the interrupting chamber **12'** through the openings **45** into the chamber where it assists in extinguishing the main arc **16**.

One of the reasons SF_6 breaker tanks are expensive is the requirement of adhering to the ASME Boiler and Pressure Vessel Codes. The code rules not only add to the initial cost of the breaker, but for most designs require a yearly inspection by a qualified inspector. The code does, however, exempt all pressure vessels which are six inches inside diameter and under. Thus, by providing tanks which are six inches or less in diameter and utilizing high pressure, high density liquid SF_6 as the interrupting medium, circuit breakers can be provided which are smaller and cheaper than prior breakers.

The circuit breaker shown in FIG. 5 is of the self-contained type. It comprises a generally cylindrical interrupting chamber **46** which is of a diameter of six inches or less. The chamber **46** contains liquid SF_6. A stationary contact member **47** enters one end of the chamber through an insulating bushing **48**. Likewise, a conductor **49** enters the chamber through a similar bushing **51**, which is mounted at the other end of the chamber and at right angles to the bushing **48**. The upper end of the conductor **49** is provided with contact fingers **52** which support and engage a movable contact member **53**. The contact member **53** may be actuated by any suitable operating means, such as a solenoid having a coil **54** and a core **55**, which is attached to one end of the contact member **53** by an insulating member **56**. The core **55** is disposed inside an extension **50** of the chamber **46**.

A generally cylindrical accumulator **57** has a closed end **58** and an open end which is connected to the interrupting chamber **46** at **59**. A floating piston **61** is disposed inside the accumulator **57**. Thus, the piston **61** divides the accumulator into two chambers or compartments one of which contains liquid SF_6 and the other of which contains an inert gas, such as nitrogen, at a relatively high pressure, for example 2,000 p.s.i. Thus, the pressure of the nitrogen on the piston **61** increases the pressure and the density of the SF_6 in the interrupting chamber **46**. Other compressible means, such as a spring, could be utilized to apply pressure on the piston **61**.

When the contact members are separated to draw the arc **16** in the interrupting medium between the contact members, the nitrogen in the accumulator may be compressed slightly by the initial interrupting shock. However, the resiliency of the compressed gas continues to force the piston **61** in the direction to maintain high pressure and high density of the interrupting medium in the interrupting chamber, thereby improving the interrupting ability of the interrupter.

The breaker shown in FIG. 6 is in general similar to the one shown in FIG. 5. The accumulator **57'** has a piston **62** therein which is connected to a suitable actuating means (not shown) by a connecting rod **63**. The actuating means may be of a type well known in the art such as, for example, a hydraulic mechanism or a spring operated mechanism.

An operating piston **64** is disposed inside a cylinder **65** which is connected to the end of the interrupting chamber **46** opposite the end having the bushing **48** therein. The piston **64** is attached directly to the movable contact member **53**. A compression spring **66** is disposed in the cylinder **65** between the piston **64** and the closed end of the cylinder. Other compressible means, such as air or a gas, may be utilized in place of the spring **66**.

The contact members are shown in the closed position. When it is desired to open the contact members, the piston **62** in the accumulator **57'** is driven to the left by the external actuating mechanism. This forces additional liquid SF_6 into the interrupting chamber, thereby increasing the pressure in the chamber. The increase in pressure forces the piston **64** to the left, thereby opening the contact members. It will be noted that the increase in pressure and density of the SF_6 occurs only at the time of interruption, thereby improving the interrupting ability of the interrupter. When it is desired to close the contact members, the piston **62** is moved to the right by the actuating mechanism, thereby decreasing the pressure in the interrupting chamber **46** and permitting the spring **66** to drive the piston **64** to the right to close the contact members.

In the foregoing structure SF_6, or other media, is utilized at a pressure and density higher than that obtained at room temperature vapor pressure. As an example, the room temperature (70° F.) vapor pressure of SF_6 is 300 p.s.i.g. The density is 12.5 pounds per cu. ft. at this pressure and temperature. In the present case the density is higher than 12.5 pound per cu. ft. for SF_6. Thus, the interrupting medium is utilized at extra high density.

The increased SF_6 density results in higher arc voltages. A structure such as that shown in FIG. 6 would have a high arc voltage since arc voltage increases rapidly with pressure. High arc voltage, together with the other outstanding arc interrupting characteristics of SF_6, results in a quick and efficient arc extinction in an interrupter which is smaller and less expensive than other comparable interrupters. This would find applications in AC circuit breaker interrupters and also DC interrupters and fuses.

The arc voltage has the same effect as an increasing series variable resistor. The high arc voltage reduces the magnitude and rate of rise of recovery voltage. This provides more time to recover the needed dielectric strength.

Furthermore, a high arc voltage reduces the pressure rise during arc interruption. Calculations have been made of the expected pressure rise of a device similar to that of FIG. 5. The following assumptions have been made: system pressure is 2,000 p.s.i., SF_6 volume is 231 cubic inches, nitrogen volume is 231 cubic inches, arcing time is ½ cycle, RMS current at contacts part is 100,000 amperes, current during arcing is 5,000 amperes, system voltage is 500 volts RMS arc voltages 450 volts, and 100% of the heat released is absorbed by the SF_6 alone. A calculated peak pressure rise is 61 p.s.i. The pressure will drop rapidly as the heat is absorbed by the metal parts of a pole unit.

Pressure rise is directly proportional to arcing time, current and arc voltage, and inversely proportional to SF_6 and nitrogen volume. As an example, increasing the system voltage to 11.5 kv., the arc voltage to 10.9 kv., the SF_6 volume to 2 gallons, the nitrogen volume to 3 gallons, changing the current at contacts part to 50,000 amperes, current during arcing time to 2,500 amperes, would result in a peak pressure rise of 125 p.s.i.

The advantages of high density SF_6 in combination with the high arc voltages that will result when it is used are apparent. An interrupting medium is inserted between the contacts which as they part and arcing is initiated will have a very high resistance, and once the current passes through zero (or reaches the point of instability in the case of a DC interrupter) will have the capacity to rapidly recover its dielectric strength, and the medium will have a high dielectric strength. The interrupter is so constructed and applied that a low amount of heat energy is released during a fault interruption. SF_6 is referred to and described is referred to and described herein because of its excellent properties, but other media such as selenium hexafluoride SeF_6, or trifluoromethyl sulfur pentafluoride CF_3SF_5, perfluoro propane C_3F_8, perfluoro butane C_4F_{10}, sulfur monofluoride S_2F_2, sulfurylfluoride SO_2F_2, perchlorylfluoride ClO_3F, perfluorobromomethane CF_3Br, could be utilized.

Since numerous changes may be made in the above-described construction and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all subject matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In a circuit breaker, in combination, an interrupting chamber, separable contact members disposed within the interrupting chamber, a tank surrounding the interrupting chamber, a collector disposed at the bottom of the tank, an electronegative gaseous interrupting medium surrounding the separable contact members, the pressure and temperature conditions within the tank being such as to cause a liquefaction of a portion of said gaseous medium into said collector (**13**), said contact members being separable to draw an arc in the gaseous interrupting medium, means for creating a blast of the gaseous medium through the interrupting chamber and for introducing a quantity of the liquefied medium from the collector into the interrupting chamber to increase the density of the medium in the interrupting chamber and to extinguish the arc.

2. The circuit breaker combination of claim **1**, wherein the arc is drawn through an insulating orifice member, and the blast of gaseous medium occurs through said insulating orifice member.

3. The circuit breaker combination of claim **1**, wherein the blast-creating means includes a storage tank (**28**) containing the electronegative gaseous interrupting medium at high-pressure and controlled by a blast valve (**29**) to force said gaseous interrupting medium at high pressure through the arc.

4. The combination of claim **2**, wherein the blast-creating means includes a storage tank (**28**) containing the electronegative gaseous interrupting medium at high-pressure and controlled by a blast valve (**29**) to force said gaseous interrupting medium at high pressure through the arc.

5. The circuit breaker combination of claim **1**, wherein the blast-creating means includes a piston (**24**) operable within a cylinder and responsive to the contact separation.

6. The combination of claim **2**, wherein a pipe (**27**) leads from the collector (**13**) into the insulating orifice member, and openings (**26**) in the orifice member feed liquid medium into the arcing space.

7. The combination of claim **3**, wherein a pipe (**33**) leads from the down-stream region of the blast valve (**29**) into the collector (**13**), and an additional pipe (**27**) leads from the collector (**13**) into the region adjacent the arcing space.

8. The combination of claim **7**, wherein an orifice member (**23**) is provided and the pipe (**27**) feeds fluid into said orifice member and through additional openings (**26**) into the arcing space.

9. The combination of claim **1**, wherein the electronegative gaseous interrupting medium is selected from the group consisting of SF_6, SeF_6, SO_2F_2, CF_3SF_5, ClO_3F, C_3F_8, S_2F_2, C_4F_{10} and CF_3Br.

10. In a circuit breaker, in combination, a metallic cylindrical interrupting chamber of **6** inches or less containing only a liquid electronegative interrupting medium, separable contact members disposed inside the chamber, terminal bushings for supporting the separable contact members, an accumulator connected to the chamber and containing the same kind of liquid, a piston (**62**) inside the accumulator, means (**63**) acting on the piston (**62**) to force liquid from the accumulator into the chamber to increase the pressure and the density of the liquid in the chamber, and piston means (**64**) for separating the contact members to draw an arc in the interrupting medium.

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