

Nov. 12, 1940.

F. S. COOPER

2,221,670

GAS INSULATED ELECTRIC DEVICE

Filed July 27, 1937

2 Sheets-Sheet 1

Fig. 1.

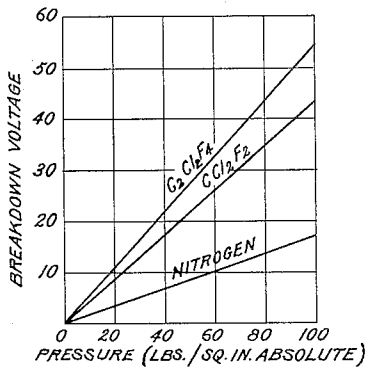


Fig. 2.

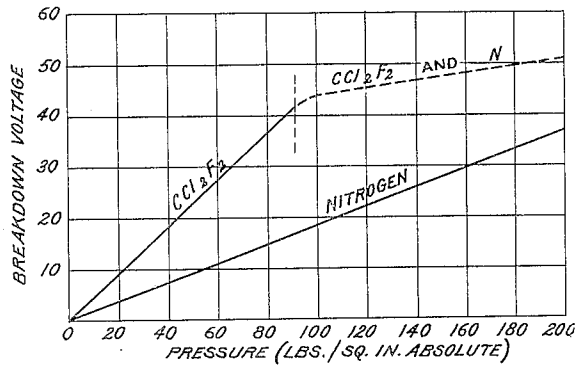


Fig. 4.

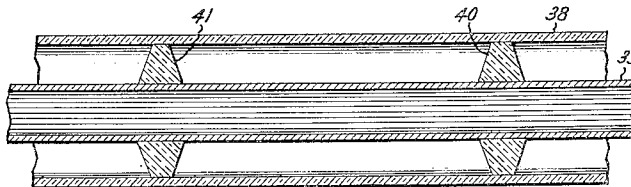


Fig. 5.

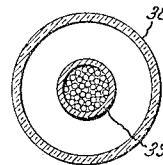
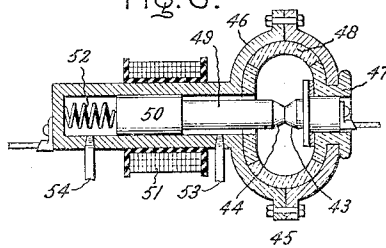


Fig. 6.



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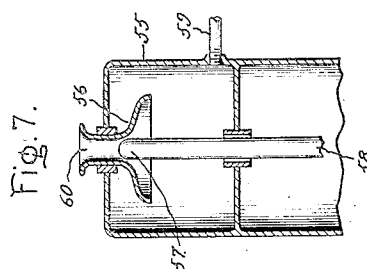
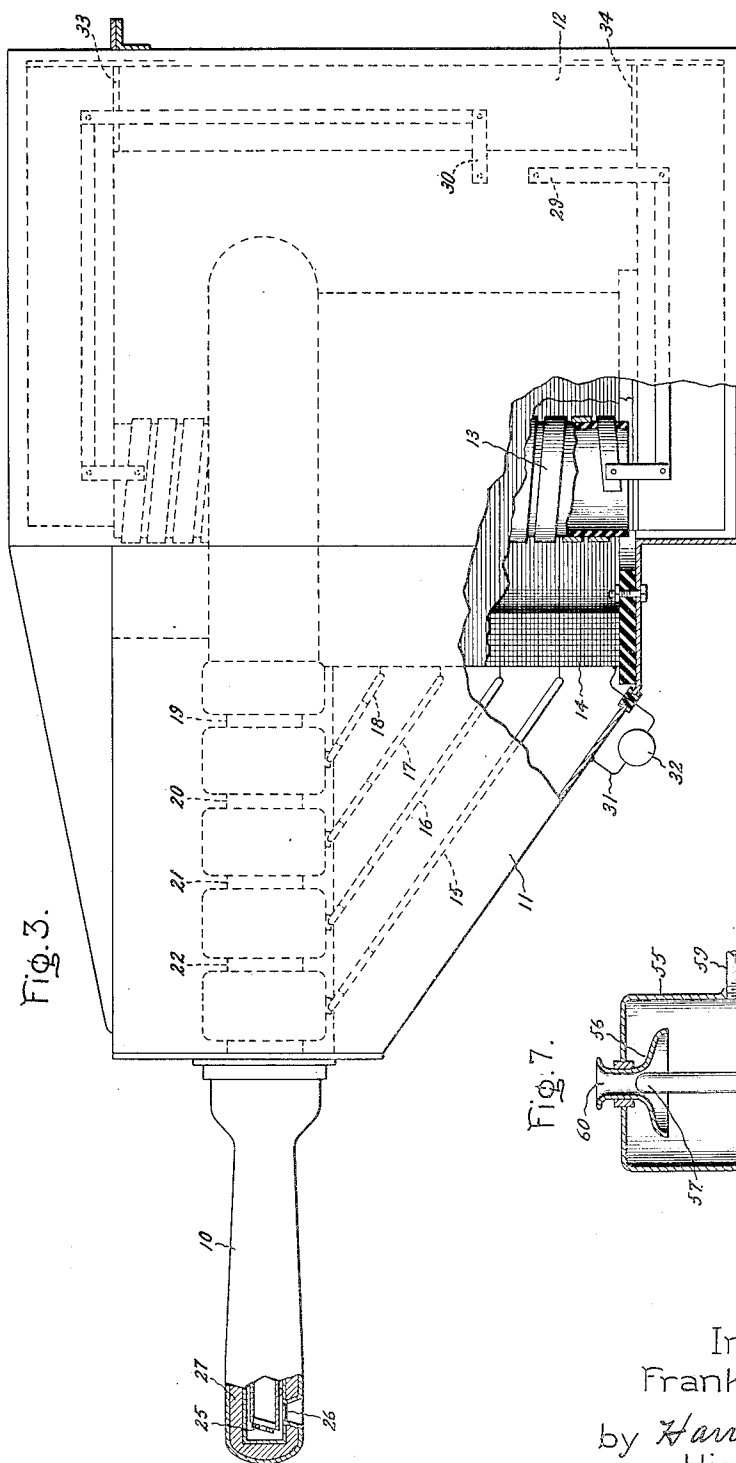
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GAS INSULATED ELECTRIC DEVICE

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2 Sheets-Sheet 2



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## UNITED STATES PATENT OFFICE

2,221,670

## GAS-INSULATED ELECTRIC DEVICE

Franklin S. Cooper, Schenectady, N. Y., assignor  
to General Electric Company, a corporation of  
New York

Application July 27, 1937, Serial No. 155,943

4 Claims. (Cl. 175—361)

The present invention relates to gaseous insulation and its object is to provide gaseous insulation having a materially higher electrical breakdown strength than ordinary air insulation, and particularly it relates to gaseous insulation which is capable of advantageous use at superatmospheric pressures.

It has been suggested to employ for insulating purposes in an electric transformer mixtures of compressed nitrogen and helium, but the gain in insulation obtainable with such gases has not been great enough to warrant the increased cost entailed by gas-tight containers and the means for keeping them charged.

I have discovered that unexpected and markedly superior results are obtained by employing as insulating and dielectric materials in high voltage electric devices gaseous compounds containing combined fluorine, and preferably compounds containing both combined chlorine and fluorine, such gas being used either alone or with an associated diluent gas, which preferably should be inert chemically with respect to the fluorinated compound and not readily condensible. By "high voltage" I means to include potentials materially higher than those in use in ordinary domestic electrical appliances.

Although gases containing combined fluorine as a class are electronegative in character this fact alone does not determine the high dielectric strength of such gases. Other characteristics appear to play important parts and such other characteristics may operate to require higher voltages to be impressed before free electrons in the gas can acquire sufficient energy to initiate processes leading to electric breakdown. The molecular characteristics of such gases may increase the breakdown voltage by complicated phenomena involving capture or attachment of free electrons by molecules, or loss of their energy as by dissociation of a molecule by collision or by inelastic collisions.

I prefer for the purposes of my invention to employ a chlorine-fluorine derivative of aliphatic hydrocarbons, and particularly chlorine-fluorine derivatives of hydrocarbons containing one or two carbon atoms, that is, of methane or ethane. Such halogenated hydrocarbons have a substantial gaseous phase over the range of temperatures normally encountered in the operation of electric devices.

In the accompanying drawings, Figs. 1 and 2 are graphs in which electric breakdown voltages are plotted for different pressures of such gaseous insulation; Fig. 3 is a side elevation, partly

in section, of a device consisting of a transformer and X-ray tube contained in a sealed housing charged with gas under pressure; Figs. 4 and 5 respectively are longitudinal and cross-sections of a cable length embodying my invention; and Figs. 6 and 7 illustrate in section circuit-breaking devices embodying my invention.

A preferred fluorinated gaseous hydrocarbon used in accordance with my invention is dichlorodifluoro methane although other hydrocarbon derivatives may be used. Preferably the chosen compounds should have an appreciable gaseous phase at the ordinary operating temperatures of the electrical device and in many cases should remain gaseous even when subjected to considerable compression at such temperatures. The following additional gases and vapors are available for use in accordance with my invention, the choice of a particular gas depending on the conditions of the service for which the gas is intended; monochlorotrifluoro methane,  $\text{CClF}_3$ , trichloromonofluoro methane,  $\text{CCl}_3\text{F}$ , dichlorotetrafluoro ethane,  $\text{C}_2\text{Cl}_2\text{F}_4$ , trichlorotrifluoro ethane,  $\text{C}_2\text{Cl}_3\text{F}_3$ , and carbon tetrafluoride  $\text{CF}_4$ . As a class, these compounds, including dichlorodifluoro methane, are stable chemically and electrically, are non-inflammable and have other desirable properties for the present purposes, being substantially non-corrosive with respect to metals.

As shown in the graph of Fig. 1, the voltage values at which electrical breakdown occurs between rounded electrodes immersed in dichlorotetrafluoroethane,  $\text{C}_2\text{Cl}_2\text{F}_4$  and for dichlorodifluoromethane,  $\text{CCl}_2\text{F}_2$ , at pressures, both above and below atmospheric pressure, are higher than the voltage values under corresponding conditions in nitrogen at the same pressures. The ordinates of the graphs, Figs. 1 and 2, are in arbitrary units, one unit being approximately equal to 0.9 kilovolt. The abscissae are in gas pressure units as indicated. As corresponding graphs for other gases would lie close to those shown (for example, for monochlorotrifluoromethane) only two graphs have been shown. At any substantial pressure the breakdown voltage in dichlorodifluoromethane is approximately two and one-half times greater than the breakdown voltage in nitrogen at the same pressure, the breakdown voltage of the ethane derivative being still higher. With a given apparatus the permissible peak operating voltage is increased approximately two and one-half times by the substitution of dichlorodifluoromethane for nitrogen at the same pressure. When no increase in operating voltage is desired for a given service, then the apparatus

for giving this service may be correspondingly decreased in size and, therefore, in cost when using as the insulating medium a gas containing combined fluorine instead of nitrogen at the same pressure. The dichlorodifluoromethane gas has a dielectric strength at 90 pounds per square inch pressure (absolute) which is 15.3 times greater than the dielectric strength of nitrogen at atmospheric pressure. At 90 pounds pressure this gas has substantially the same dielectric strength as nitrogen at 225 pounds pressure.

When it is desirable to use pressures about 90 pounds per square inch, either the operating temperature can be increased, thus increasing the pressure, or an inert gas, such as nitrogen, can be added to any desired total pressure, or a combination of these two steps can be used. The pressure-temperature relations of these gases are known, hence, for the sake of brevity, no numerical examples are stated herein.

Fig. 2 shows the effect on the breakdown voltage of adding nitrogen to dichlorodifluoromethane when the latter is initially present to 90 pounds per square inch (absolute), this being the vapor pressure at room temperature. The breakdown voltage of the mixture is shown by the dotted part of the graph to be greater than that of nitrogen alone at the same pressure. Thus, for example, the dielectric strength of such mixture of dichlorodifluoromethane and nitrogen at a pressure of 200 pounds per square inch (absolute) is 18.1 times greater than it is for nitrogen alone at atmospheric pressure. Trichloromonofluoromethane gives a somewhat greater gain in dielectric strength than dichlorodifluoromethane when operation at atmospheric pressure is desirable. This gas also has good physical and chemical properties and has a dielectric strength three times greater than nitrogen under the same conditions.

For operation at room temperature and moderate pressures dichlorotetrafluoroethane offers special advantages since its vapor pressure lies in a desired range and, as shown in Fig. 1, its dielectric strength is approximately three times that of nitrogen at the same pressure.

In place of nitrogen other fixed gas such as helium, or hydrogen, may be admixed with the fluorine-containing gas. Such mixtures containing hydrogen gas have an almost linear relationship between the dielectric strength and molecular concentration. Upon complete replacement of one atmosphere of hydrogen by one atmosphere of dichlorodifluoromethane, the dielectric strength is increased by a factor of about 4.4. Partial replacement of the fixed gas by fluorinated vapor results in more than proportional improvement in dielectric strength. However, in the event of an electric discharge in a mixture of such a fluorinated gas and hydrogen, an appreciable gaseous product is formed which is corrosive in nature. Hence, hydrogen-containing mixtures may be less advantageous than mixtures containing only chemically inert gases.

The high dielectric strength of the gas or gaseous mixture chosen in accordance with my invention may be advantageously employed in a device such as shown in side elevation in Fig. 3 comprising a high voltage transformer and an X-ray tube. Except for an outwardly-projecting tubular extension 10 of the X-ray tube, the transformer and the X-ray tube are housed within a sealed tank 11, which is charged with the chosen fluorine-containing gas or gaseous mixture. The transformer consists of a core 12, a primary wind-

ing 13 and a secondary winding 14, sections of the latter being connected by conductors 15, 16, 17 and 18 to intermediate conductive segments of the X-ray tube. These segments serve to couple intermediate non-conductive sections 19, 20, 21 and 22 to form a segmented sealed envelope as described more fully in Patent No. 2,144,517, issued January 17, 1939, to Willem F. Westendorp, and assigned to the same assignee as the present application.

The portion of the X-ray tube within the casing 11 is provided with a thermionic cathode (not shown), the tube portion projecting exteriorly and the exterior portion 10 is provided with an artificially-cooled target 23 of suitable refractory metal for radiating X-rays when bombarded with high voltage electrons, a window 24 being provided to permit the escape of the useful beam of X-rays. A sheath 27 of lead, or other suitable material impervious to X-rays, is provided, the sheath being connected to the metallic container.

The primary winding 13 of the transformer which may consist of a helix of copper ribbon is connected to an external source of potential (not shown) by the conductors 28, 29, which may be insulatingly sealed to the wall of the metal container 11. The secondary winding 14 is grounded at one end to the container 11 by a conductor 31 which may include a current meter 32. The opposite end of the secondary winding 14 is connected to the cathode of the X-ray tube (not shown). The core 12 of the transformer includes one or more laminae of high magnetic reluctance, preferably consisting of a non-magnetic solid material, such as a phenolic condensation product, in order to increase the transformer magnetizing current to a value commensurate with that of the charging current, such laminae being indicated at 33 and 34.

An electric device, such as described, when filled with a high grade insulating liquid, such as mineral oil, may be operated with a voltage of about 600 kilovolts without likelihood of electrical breakdown during operation. When, however, the casing is filled with a gas selected in accordance with my invention, then the permissible operating voltage may be increased materially. For example, when employing dichlorodifluoromethane or dichlorotetrafluoroethane at a pressure of 30 pounds per square inch absolute, the permissible operating voltage may be increased to 750 kilovolts, a gain of 25 percent. Over the range of 30 to 90 pounds per square inch pressures, the improvement in insulation is even greater as indicated in the graphs.

It should be understood that the advantages of my invention may be obtained in a transformer sealed in a casing and filled with a gas containing substituted fluorine but not associated with an X-ray tube or similar device. Likewise, these gases can be used to insulate an X-ray tube not in the same containing envelope as its voltage source. It is not required that the fluorine-containing compound should be wholly in the vapor phase and in some cases the presence of some liquid phase in the container is a positive advantage. It assists heat transfer by its evaporation and recondensation, and constitutes a reservoir or source of gas. However, it is the gaseous phase of the compound which functions as the dielectric medium.

As already indicated, my invention may be employed in other forms of electrical apparatus. For example, as shown in Figs. 4 and 5, a cable comprising a sheath 35 and a core 36 separated

and insulated from one another by insulators 40, 41 are operated with the space between the sheath 38 and conductor 39 filled with a charge of fluorine-containing gas under pressure in accordance with my invention. It should be understood that the insulators 40 and 41 are only diagrammatic representations of insulators and that various forms of insulators may be used without departing from my invention.

As shown in Figs. 6 and 7, and as claimed and more fully described in an application, Serial No. 198,680, filed by D. C. Prince on March 29, 1933, such a gas may be employed advantageously in a contactor device. In the contactor shown in longitudinal section in Fig. 6, the stationary contact member 43 and a movable contact member 44 are surrounded by housing 45 which comprises a metallic member 46 and insulator 47 and a suitable lining 48. The movable contact member 44 is mounted on a magnetic core member 49, which moves in a slotted guide 50, is operated by the magnetic coil 51. When the coil 51 is energized the movable contact 44 may be drawn away from the stationary contact 43, the spring 52 being thereby placed under compression. The interior of the housing 45 may be charged with a suitable gas, for example, dichlorodifluoro methane, through a tube 53. An outlet tube 54 may be provided to permit the discharge of the gas with greater facility.

The circuit breaking device shown in Fig. 7 consists of a sealed container 55 containing the stationary contact 56, through which passes an exhaust orifice for the container 55. A movable contact 57 can be moved in and out of engagement with the fixed contact 56 by means (not shown) operating on the stem 58 of this contact. A suitable gas is introduced by the tube 59. When the contacts 56 and 57 pull apart, thereby striking an arc between them, then the charge of gas in the container 55 escapes through the orifice 60 and puts out the arc. The fluorin-

ated gas causes rapid extinguishment of the arc between the contacts 56 and 57, when the voltage goes to zero and the high dielectric strength of such gas prevents reformation of the arc when the voltage again rises. In said application, Serial No. 198,680 (which is assigned to the same assignee as the present application), are described various forms of apparatus for advantageously utilizing the arc-extinguishing characteristics of fluorinated hydrocarbon gases. While such apparatus is not part of my present invention, it is shown as illustrative of the generic character of my invention.

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

1. An electric apparatus comprising the combination of a closed container, a high voltage electric device therein, and a compressed gaseous insulating medium for said device, said medium having as a principal and essential ingredient gas of the group consisting of dichlorodifluoro methane, monochlorotrifluoro methane, trichloromonofluoro methane, dichlorotetrafluoro ethane, trichlorotrifluoro ethane, and carbon tetrafluoride.

2. An electric apparatus comprising the combination of a closed container, a high voltage electric device therein, and an insulator consisting of compressed dichlorodifluoro methane for said device.

3. An electric transformer comprising the combination of a closed container, inductively related high voltage windings therein, and a gaseous insulator for said windings consisting of dichlorodifluoro methane at superatmospheric pressure.

4. An electric transformer comprising the combination of a closed container, inductively related high voltage windings therein, and a gaseous insulator for said windings consisting of dichlorodifluoro methane at a pressure of about 30 to 90 pounds per square inch.

FRANKLIN S. COOPER.