

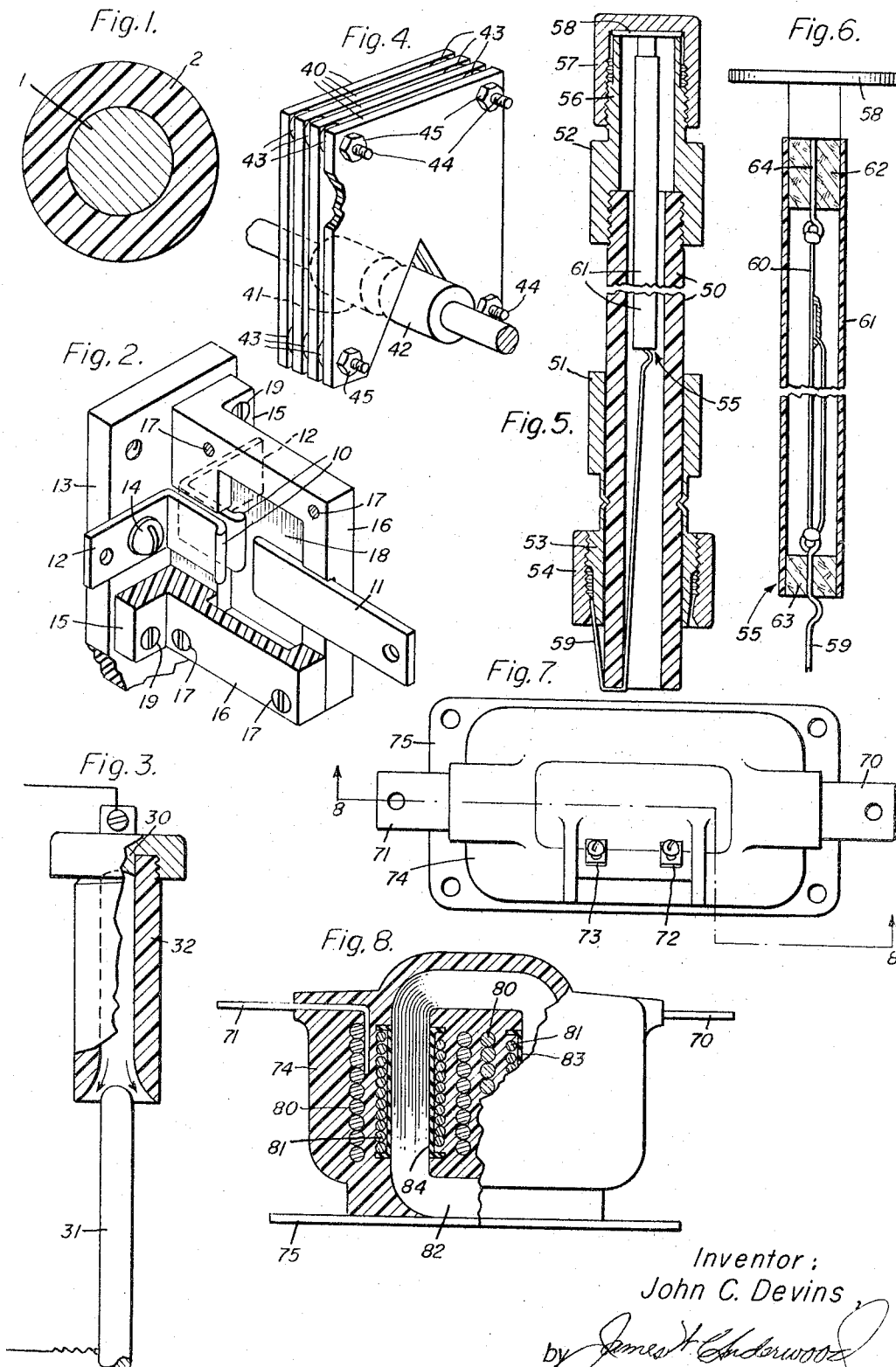
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ELECTRICAL INSULATION CONTAINING A MOLECULAR SIEVE HAVING
ADSORBED PERHALOGENATED FLUID

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ELECTRICAL INSULATION CONTAINING A MOLECULAR SIEVE HAVING ADSORBED PERHALOGENATED FLUID

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The present invention relates to improvements in insulation for electrical apparatus and, more particularly, to improved organic insulation which protects electrical devices subject to electrical discharge conditions and to methods for making such insulation.

Certain types of electrical equipment frequently experience electrical discharges between points of different potentials. Illustrative of the causes of such discharges are the conditions of over-voltage, opening of the circuit, for example as by a switch, blowing of a fuse due to overload on the circuit, etc. Such electrical discharges cause arcs to form which permit the current to continue to flow in the opened circuit. It is highly desirable to distinguish such arcs as rapidly as possible, to stop the flow of the current.

Other types of electrical equipment are subject to corona discharge in the insulation separating an electrical conductor from a source of higher or lower electrical potential. This corona discharge causes deterioration of the insulation so that finally failure of the electrical apparatus occurs, unless the load on the equipment is reduced below those conditions causing corona discharge. This means that the capacity of the electrical apparatus to perform its function is seriously reduced. Corona discharge starts in the voids formed either during the fabrication of the insulation or later due to stresses and strains developed during fabrication or during operation. Therefore, it is highly desirable to increase the dielectric strength of such voids so that corona discharge will not occur in normal operation of the equipment at its rated capacity.

Organic resinous materials, including both the natural and synthetic resinous material, generally have good electrical insulating properties. However, the methods of which they are fabricated into the desired shape, for example, by compression, injection, and extrusion molding, laminating, melt or solution coating, etc., have the inherent disadvantage that they tend to create voids in the fabricated part which seriously affect their insulating properties. It would be desirable to increase the dielectric strength of such voids so as to increase the insulating properties of these materials. Furthermore, some of these organic resinous materials have good arc extinguishing properties due to their ability to evolve a gas when an electrical arc is directed over their surface. However, it would be desirable to increase the arc extinguishing properties of these materials by increasing the amount of gas which is given off by a given weight of such materials under the heat of the arc, as well as supplying a gas which has better arc extinguishing properties.

Accordingly, it is one object of this invention to provide electrical apparatus having organic insulating components which have increased ability to extinguish arcs occurring in such electrical apparatus.

It is another object of the invention to provide an improved electrical apparatus having organic insulating components having improved corona starting voltage characteristics.

It is another object to provide a method of preparing such improved electrical insulation.

These and other objectives are obtained in accordance with the present invention by incorporating in such synthetic resinous materials a perhalogenated fluid having a

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dielectric strength greater than air adsorbed on a molecular sieve dispersed in the organic resinous material. The scope of the invention also includes the methods whereby these compositions are made.

Although the features of this invention which are novel are set forth in the appended claims, greater detail of the invention in its preferred embodiments and the further objects and advantages thereof may be readily comprehended through reference to the following description, taken in connection with the accompanying drawings, wherein:

FIG. 1 is a cross-section of an insulated electrical conductor embodying my invention;

FIG. 2 is an isometric view partly broken away, showing a portion of disconnect switch having an associated arc suppressing shield embodying my invention;

FIG. 3 is an elevational view partly in section of an electric circuit breaker of the expulsion type having an arc suppressing shield embodying my invention;

FIG. 4 is an isometric view showing a schematic view of a switch having an arc chute embodying my invention;

FIG. 5 is a sectional view of an expulsion fuse unit consisting of a fuse holder of conventional design and a removable fuse link having an arc suppressing shield embodying my invention;

FIG. 6 is an enlarged sectional view of the fuse link shown in FIG. 5;

FIG. 7 is a perspective view of a molded-casing type transformer embodying my invention; and

FIG. 8 is a cross-sectional view of the transformer along line 8—8 of FIG. 7.

In FIG. 1 there is shown by way of example a solid conductor 1 surrounded by an insulation 2. The conductor 1 may be either of a solid, tubular or multiple-strand type of electrical conductor such as copper, silver, aluminum, etc. As is conventional in the art, conductor 1 may be electro-plated with another metal, e.g., nickel, if desired. Insulation 2 may be either tightly bound to the conductor as when the insulation 2 is extruded or wound onto the electrical conductor 1, or it may be of the sleeve type which is slipped over the conductor 1 in a loose fitting relationship. Insulation 2 comprises a composition of this invention hereinafter described in further detail.

FIG. 2 illustrates one set of contacts of a disconnect switch comprising a fixed contact in the form of a pair of opposed spring jaws 10 and a movable contact in the form of a blade 11 insertable between the jaws 10 when the switch is closed. Each of the jaws 10 conveniently forms one leg of an L-shaped strip of metal, the other leg 12 of which is secured to a switch base 13 as by a bolt 14. The arc suppressing composition forms a simple shield comprising a pair of L-shaped parts each having a short leg 15 and a long leg 16. The longer legs of the two parts are held in engagement with each other as by bolts 17 and have their opposed faces recessed to receive the contact jaws 10 and the switch blade 11 and to provide a chamber 18 into which the contact jaws 10 and switch plate 11 extend. The shorter legs 15 are recessed to clear the legs 12 of the stationary contacts and the heads of the bolts 14 and are secured to switch base 13 by bolts or screws 19. The arc which forms upon separation of the movable and stationary contacts is enclosed in a chamber the walls of which are molded of the composition hereinafter described.

There is shown merely by way of example in FIG. 3 a circuit breaker having means such as the stationary contact 30 and the movable rod contact 31 for opening the circuit causing an arc to form and an insulating structure 32 forming an arc chamber for closely confining the arc between the contacts. The insulating structure 32 comprises a tubular member closed at the one end by contact

30 and open at the other end for receiving the rod contact 31. On opening of the circuit, separation of the contacts 30 and 31 causes formation of an arc the heat of which releases some of the gas adsorbed on the filler in the material of the arc chamber walls, the composition of which is hereinafter described in more detail. The air already in the arc chamber and the gas emitted from the chamber walls 32 is under considerable pressure when released by the arc formed between contacts 30 and 31, due to the close fit of the rod contact 31 in the tube 32, with the result that when the rod leaves the tube a blast of gas is released as indicated, causing the arc to be interrupted.

FIG. 4 shows an alternative construction of a switch and arc-interrupting device wherein the two contacts 41 and 42 are moved relative to each other to make and break electrical contact. On separation of electrodes 41 and 42 an arm forms which is magnetically deflected by a conventional blow-out coil (not shown) so that the arc plays into the space between the arc chute plates 40 formed of the composition hereinafter described in detail, which are held together in spaced relationship by spacers 43 acting in cooperation with bolts 44 and nuts 45. The heat of the arc playing on the surface of plates 40 causes a gas adsorbed in the composition to be released, extinguishing the arc.

FIG. 5 is an illustration of a fuse holder having within a main tube portion an inner or auxiliary expulsion tube surrounding a removable fuse link. The casing or fuse holder of the expulsion fuse unit consists of a fuse tube 50 comprising or having an insulating base material surfaced with the composition of this invention, hereinafter described in more detail. The contacts 51 and 52 are mounted at either end of the fuse tube 50 for connecting the fuse unit in the circuit by mounting in a suitable fuse support or otherwise. The cap 57 which closes one end of the tube 50 is screwed onto the contact 52, providing a clamped electrical contact with the button-head 58 of the fuse link 55. Other suitable clamping means 53 and 54 are provided for similarly clamping the lower terminal 59 of the fuse link 55 to the contact 51. The explosion chamber of the fuse holder consists of the central bore of the fuse tube 50 and the chamber formed by the contact 52 and its extension 56. The walls of the fuse tube 50 are of sufficient thickness to withstand the gas pressure generated when the fuse is blown.

As shown in FIG. 6, the fuse link 55 of FIG. 5 comprises a fusible element 60 enclosed in a thin-walled tube 61 comprising a highly insulating base material described hereinafter. The fusible element 60 may be of tin or other fusible metals or alloys, either in wire or strip form, so shaped that blowing occurs near the upper end of the tube 61. The tube 61 is closed at one end by a stopper 62 which is cemented in position to seal the end of the tube. The stopper 63 is placed in the bottom of the tube 61 with a snug fit to permit gas pressure to build up within the tube when the fuse link is blown by light current. However, this stopper is not indispensable and may be omitted. The fusible link 60 is connected by means of a hard metal wire 64 which passes through stopper 62 to the button 58. The other end of the fusible element 60 is connected to the terminal wire 59 which passes through the stopper 63. The chamber formed by the bore of tube 61 is small enough to produce the necessary gas pressure to extinguish the arc when the fuse blows on light currents. When a heavy current fault occurs, the extremely high gas pressure generated in a manner such as hereinafter described, bursts this tube and permits the gas to expand within the larger explosion chamber, thus reducing the gas pressure to a safe value and furnishing the normal arc extinguishing action of the larger chamber. Thus, the combination of the small tube 61 of the fuse link 55 with the larger tube 50, produces an expulsion fuse which has improved operating characteristics on small currents and yet operates with equally satisfactory characteristics on high short-circuit current values.

FIGS. 7 and 8 show a current transformer having primary terminals 70 and 71 and secondary terminals 72 and 73. The positioning of the primary windings 80 and the secondary windings 81 will be apparent from the view of FIG. 8. These windings are electromagnetically linked with a core 82 of magnetic material which is provided with a pair of tubular separators 83 and 84, which serve to insulate the core from the windings. The transformer includes a molded or cast component 74 which encapsulates the various components, as shown, and thereby provides a complete physical enclosure as well as electrical insulation. A support plate 75 facilitates mounting.

FIGS. 1, 7 and 8 are typical of the electrical devices in which a massive amount of insulation is in contact with an electrical conductor so that, in use, when a current is flowing in the conductor, electrical discharge between the conductor and a potential of higher or lower value is prevented by the insulating characteristics of the insulation. During such use, the insulation is subject to voltage stress, which if great enough, causes corona discharge to occur in any voids which may be present in the insulation. As mentioned previously, the means of providing the insulation for such electrical apparatus has the inherent disadvantage that it is practically impossible to produce such a solid mass of insulation without incorporating the voids due either to the entrapment of air or to the creation of voids due to physical stresses created during the formation of the insulating member, or caused by operating conditions.

For example, one method of making the insulated electrical conductor shown in FIG. 1 is that wherein the conductor 1 is passed through an extrusion machine and insulation 2 is extruded onto the electrical conductor. Since the insulation is fed to the extrusion machine in the form of comminuted material, air is occasionally entrapped in the insulation in the form of extremely minute bubbles which escape visual inspection and therefore form weak spots in the insulation. In another method of making such insulated conductor, the insulated electrical conductor as a solid rod or tube is used as a mandrel and the insulation is wound onto the conductor in the form of a fibrous web such as cloth or paper, which has either been previously impregnated with a solution of the organic resinous material acting as the insulation, or the fibrous web is passed over a heated apron and the organic resinous material melted onto the heated web to impregnate it as it is wound onto the conductor. Entrapment of air can occur in such a process, or voids are created during the curing process. If the organic resinous material is a thermosetting resin, the strains caused during the curing process cause voids to form between the convolute wrappings of the web around the conductor. Sleeve-type insulation is also made by either extruding a tubing of the insulation or by stripping the tube from the mandrel on which the insulation is wound in the form of a laminated tube.

In making electrical apparatus such as encapsulated apparatus, as illustrated by the encapsulated current transformer of FIGS. 7 and 8, a synthetic resinous material is used to encase the apparatus either in a molding operation whereby the fluidized resinous material is caused to flow under pressure around the components of the apparatus, for example, the windings and core of the transformer, or the organic resinous material in the form of a liquid is used to impregnate and encase the component parts using a mold as a container to give the desired shape. In either of these two methods, it is practically impossible to insure that the resinous material completely displaces all of the void space, especially around wires or other components such as metal strips which are closely spaced together, even though the molding is carried out under high pressures, or the impregnation with a liquid is carried out under vacuum. Furthermore, during the curing operation, gases or vapors of the insulating material are sometimes given off due to the vapor pressure of the

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components of the resinous material itself which likewise cause voids to form in the resin. Furthermore, when such apparatus is operated, heat is generated within the metallic components of the electrical apparatus which causes differential expansion between the metal parts and the organic resinous material which causes voids when the apparatus cools.

Since the air, gases or even the vacuum created by such voids has a lower dielectric strength than the insulation itself, such voids form a weak spot in the insulation which can cause premature failure of the equipment or at best require the equipment to be operated at a lower rating than would be possible if the insulation were free of such voids, or if the voids had increased dielectric strength.

In the making of electrical devices where arc extinguishing characteristics are desired, for example, as illustrated by the apparatus in FIGS. 2, 3, 4, 5, and 6, although certain organic resinous materials are capable of producing a gas when subjected to an arc, the gas is produced by actually thermally decomposing the organic resinous material and the amount of gas available for the arc extinguishing function is limited by the amount of material thermally decomposed by the arc. Since the arc interrupting capacity of these devices could be increased if either or both the amount of gas released and the arc extinguishing ability of the gas were increased, it is highly desirable to increase either or both the gas producing ability of the organic resinous materials and the ability of the evolved gas to extinguish an electric arc.

I have now found that both of these problems facing electrical equipment manufacturers can be readily overcome by incorporating in the synthetic resinous material a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air. Such materials can be used as molding compounds to either make molded parts or used in the form of fluids to make cast or impregnated parts. Now, even if voids are formed in the insulation, the adsorbed perhalogenated fluid desorbs from the molecular sieve and diffuses into the void space, increasing the dielectric strength. Under the heat of an electric arc, the adsorbed perhalogenated fluid is also desorbed from the molecular sieve and forms a gas which greatly increases the amount of gas available to extinguish the arc. At the same time, the high dielectric strength of the gas from the perhalogenated fluid enables it to more rapidly extinguish the arc than the gas given off by the decomposition of the organic resinous material.

The types of organic resinous materials may be either naturally occurring gums, for example, rosin, shellac, kauri, copal, tars, i.e., from coal tar distillation, distillation of tree pitches, etc., natural rubber, etc.; synthetic organic resinous materials, both thermoplastic and thermosetting, for example, phenolic resins, urea resins, melamine resins, polyethylene, polypropylene, polybutene, polytetrafluoroethylene, polytrifluoroethylene, polyvinyl chloride, polyvinylidene chloride, chlorinated polyethylene, chlorosulfonated polyethylene, polymethylmethacrylate, etc., including the various polymers, copolymers and mixed polymers of these materials, for example, blends and copolymers of polyethylene and polypropylene, blends of phenolic resin with synthetic rubber; synthetic rubbery polymers, e.g., polybutadiene, polyisoprene, polychloroprene, etc., including the various copolymers and mixed polymers of these materials, for example, butadiene-acrylonitrile copolymers, butadiene-styrene copolymers, isoprene-butadiene copolymers, butadiene-butene-1 copolymers, etc.; epoxy resins, polyester resins, including the solventless varnish type of polyester resins, wherein a polymerizable monomer for example styrene is used as the solvent for an unsaturated polycarboxylic acid ester of a polyhydric alcohol, polycarbonate resin, etc. The choice of the particular organic resinous material for a particular application is based solely upon its physical and chemical properties.

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The molecular sieves useful for my invention as well known, commercially available materials both of the natural and synthetic type. They are crystalline zeolites having good sorption characteristics for various fluids because of the myriad of pores or capillaries present in their crystal structure. They are available in various grades determined by the pore size. Depending on the pore size, these materials vary in capacity to adsorb various fluids, i.e., liquids and gases. The ability of these various materials to adsorb a wide variety of fluids has been the subject of many investigations and is well documented in the literature, for example, in the book, "Molecular Sieves," by Charles K. Hersh, Reinhold Publishing Corporation, New York, New York (1961), and the literature references cited therein. Because of their ability to adsorb various fluids, they have found extensive use as drying agents, as carriers for various chemical reagents, for example, curing agents in the compounding of moldable compositions, as the carrier of foaming agents in the compounding of foamable, moldable compositions, etc. In these applications, the adsorbed material is released during the molding operation to perform the function of either curing or foaming the molded material during the molding operation.

The ability of a particular molecular sieve to adsorb a particular molecule is related to the pore size of the molecular sieve and the critical dimension (width, depth or diameter; length is not critical) of the material to be adsorbed. If the critical dimension of the molecule to be adsorbed is greater than the pore size of the molecular sieve, little or no adsorption takes place. However, if the reverse is true, then the molecular sieve can readily adsorb the other material. When the pore size of the molecular sieve is considerably greater than the critical size of the molecule of the material to be adsorbed, then the material is very easily adsorbed and the actual quantity adsorbed is greater than for a molecular sieve whose pore size is only slightly greater than the dimensions of the molecule to be adsorbed. Conversely, however, the ease with which the adsorbed material is desorbed under the influence of either heat or reduced pressure increases when the pore size of the molecular sieve is increased in relation to the critical size of the molecule of the adsorbed material. Increasing the vapor pressure of the fluid and decreasing the temperature at which the adsorption is performed increases the amount of adsorption of a given fluid on a particular molecular sieve, and vice versa. The influence of temperature, which governs the quantity of fluid adsorbed or desorbed, appears to be greater than the influence of vapor pressure of the fluid which governs the rate of adsorption and desorption.

In the specification and claims, I use the term "perhalogenated fluid" to describe the various liquids and gases having the maximum amount of halogen associated with the compound, i.e., a perhalogenated alkane has all the possible hydrogens replaced with a halogen. Because of their ready availability and excellent dielectric strength, I prefer to use as the perhalogenated fluid one or more of the following: sulfur hexafluoride, selenium hexafluoride, and the fluid perhalogenated alkanes. Of the various perhalogenated alkanes, I prefer those having from 1 to 8 carbon atoms and especially those in which the halogen is fluorine or chlorine. Of these, only carbon tetrafluoride does not have a dielectric strength greater than air. Typical of the various perhalogenated alkanes which I may use are, by way of example, carbon tetrachloride, trichlorofluoromethane, dichlorodifluoromethane, chlorotrifluoromethane, bromotrifluoromethane, trichlorotrifluoroethane, dichlorotetrafluoroethane, dibromotetrafluoroethane, chloropentafluoroethane, hexafluoroethane, hexafluorocyclobutane, dodecylfluoropentane, tetradecylfluorohexane, octadecylfluorooctane, pentafluorothiotrifluoromethane (CF_3SF_5), etc. These compounds are either gas or liquid and have a boiling point no greater

than 90° C. and therefore have sufficient vapor pressure that they will supply a gaseous atmosphere at the temperature at which they are used in my applications. In addition, they are excellent dielectric fluids.

The choice of the particular perhalogenated fluid and the particular molecular sieve is based on the application of the combination of the two as a filler in the organic resinous material, and the method by which the particular component of the electrical apparatus is to be fabricated. For example, if the composition is to be used for making insulation, for example, an insulated electrical conductor, or the encapsulation of the piece of electrical apparatus, for example, a transformer where the purpose of the adsorbed perhalogenated fluid is to occupy any voids created in the apparatus either during fabrication or use, then one desires to choose a combination of molecular sieve and adsorbed perhalogenated fluid that would desorb the perhalogenated fluid at the temperature at which the apparatus is normally operated, so that the perhalogenated fluid will be able to fill such void spaces, thereby increasing their dielectric strength and overcoming the defect in the apparatus which would be present if the void were filled with air or if the void were a vacuum. In the absence of voids, the solid resinous material surrounding the molecular sieve acts as a closed container retaining the adsorbed perhalogenated fluid on the molecular sieve. On the other hand, if the application for the composition is for making arc extinguishing devices, then one would want to choose a combination of molecular sieve and adsorbed perhalogenated fluid which would not desorb any of the perhalogenated fluid at the normal operating temperature of the equipment but only during those times when an arc is formed in the apparatus so that only the heat of the arc causes desorption of the perhalogenated fluid from the molecular sieve.

Likewise, if the molecular sieve containing the adsorbed perhalogenated fluid is to be incorporated into the organic resinous material, by compounding on a set of differential rolls, whereby the composition is not under pressure, then one must choose a combination of molecular sieve and perhalogenated fluid which does not desorb the perhalogenated fluid at the temperature of mixing the molecular sieve containing the adsorbed perhalogenated fluid with the organic resinous material. However, if the compounding is carried out in a pressure apparatus which permits the pressurized atmosphere of the perhalogenated fluid to be maintained over the composition while it is being compounded, it is possible to compound the composition without causing desorption of the perhalogenated fluid from the molecular sieve. Another alternative method can be used whereby the molecular sieve is first compounded with the organic resinous material and thereafter subjected to a pressurized atmosphere of the perhalogenated fluid for a time sufficient to cause the perhalogenated fluid to be adsorbed on the molecular sieve dispersed in the organic resinous material. Various alternatives can be used to decrease the time required to saturate the molecular sieve such as for example by having the organic resinous material containing the molecular sieve in extremely finely divided form, by heating, etc. If the organic resinous material is a thermoplastic resin, it is preferable to heat the compounded thermoplastic resin and the molecular sieve to a temperature where the thermoplastic resin is soft and then cooling the composition while maintaining the pressurized atmosphere of the perhalogenated fluid until the composition is cooled below the temperature at which the perhalogenated fluid is desorbed from the molecular sieve.

Whether a particular perhalogenated fluid will be adsorbed and at what temperature it will be rapidly desorbed from a particular molecular sieve may be readily determined by consideration of the pore size of the molecular sieve and the critical dimension of the molecule of the perhalogenated fluid, and the readily determined adsorp-

tion and desorption isotherm of the particular perhalogenated fluid on the particular molecular sieve.

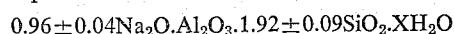
If the compounding of the molecular sieve with the organic resinous materials is to be done with a liquid organic resinous material such as a casting resin, for example a liquid phenolic resin, a liquid epoxy resin or a liquid polyester resin, for example one of the solventless varnishes, or a polymerizable monomer, then compounding can take place at room temperature and there is no problem involved in the mixing of the molecular sieve already having the perhalogenated fluid adsorbed on it.

Once the mixture of the organic synthetic resin and the molecular sieve having the perhalogenated fluid adsorbed on it has been made, the actual fabrication of the insulation for the electrical apparatus can be readily carried out using the conventional techniques. For example, the compound can be extruded onto an electrical conductor, molded into the plates for an arc chute, or for the fuse or arc chamber, or can be used as a molding compound to encapsulate electrical apparatus such as a transformer. Since these fabrication techniques are carried out under pressure and the objects can be cooled under pressure, no desorption of the perhalogenated fluid occurs during the molding operation. If a liquid resin such as those mentioned above is used to encapsulate electrical apparatus, the actual curing of the liquid organic resinous material with heat can be carried out using a pressurized atmosphere of the perhalogenated fluid above the liquid which is maintained until the polymer has been cured to the solid state and cooled below the temperature where desorption of the perhalogenated fluid would occur from the molecular sieve. If the insulation is to be in the form of a rolled tube of a fabric such as paper or cloth, by rolling the sheet of fabric around a removable mandrel and impregnating the paper by melting of the resin as the rolling operation takes place, then it is necessary to use a combination of molecular sieve and perhalogenated fluid which does not desorb at the temperature at which the tube is rolled. However, this is the type of combination that would be desirable for such a fabrication technique, since the use of such tubes is for arc chambers, fuse tubes, etc., where it is desired to have the generation of gas occur under the influence of an electrical arc.

In order that those skilled in the art may better understand how the present invention may be practiced, the following examples are given by way of illustration and not by way of limitation.

Example 1

The molecular sieve designated as 5A, is made by replacing 75 percent of the sodium ions with calcium ions of the molecular sieve designated as 4A, having the chemical composition:



where X represents the number of molecules of water associated with the crystal structure which is removed prior to adsorption. In the fully hydrated form X is 27. The structure is cubic, $a=12.32 \text{ \AA}$, space group $\text{O}1/h \text{Pm}3m$. This molecular sieve was outgassed to remove the water of hydration at 350° C. for 15 hours and allowed to cool in vacuum, after which an atmosphere of 2,000 millimeters pressure was obtained by admitting dichlorodifluoromethane at room temperature and allowing the adsorption of the dichlorodifluoromethane on the molecular sieve to come to equilibrium over a period of 7 days. A total of 0.193 gram of the dichlorodifluoromethane per gram of molecular sieve was adsorbed. This perhalogenated fluid was so tightly held by the molecular sieve that when this combination was submitted to a vacuum of 0.01 micron, no desorption of the dichlorodifluoromethane occurred. Likewise, when a sample of this molecular sieve was heated no desorption of the gas occurred until a temperature of 290° C. was reached,

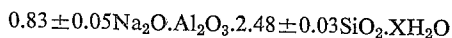
after which gas begins to desorb and becomes rapid at approximately 310° C.

Dichlorodifluoromethane has a molecular size, expressed in angstroms, of a width of 4.93, a depth of 4.90 and a length of 6.64. Since the molecular sieve used is generally designated as having a uniform pore size of 5 angstroms, the critical dimension of this molecule is its width, which is just slightly smaller than the pore size of the molecular sieve. The use of high pressure has therefore forced these molecules of dichlorodifluoromethane into the pores of the molecular sieve, in much the same way as one forces a cork into a bottle where the molecules are now tightly held as shown by the high temperatures required to cause desorption of these molecules. The critical dimensions of some of the other perhalogenated alkanes also have approximately the same critical dimension and therefore are also tightly held on this molecular sieve.

This combination of molecular sieve and perhalogenated fluid is ideally suited for compounding into molding compositions which do not require processing temperatures exceeding 290° C., since no desorption will occur during such processing steps. Such a combination therefore is admirably suited for incorporation into such organic resinous materials as phenolic resins, urea resins, melamine resins, and all of the thermoplastic types of resins, all of which can be compounded at temperatures under 290° C., with this combination of molecular sieve and perhalogenated fluid, to yield molding compositions, or impregnating compositions, which can be fabricated into insulating components of electrical apparatus by usual molding or impregnating techniques. This combination of molecular sieve and adsorbed perhalogenated fluid can also be mixed with solutions of the above type resins or with liquid or semi-solid casting resins, for example, polymerizable monomers, liquid phenolic resins, epoxy resins, polyester resins including the so-called solventless varnishes, etc., even at room temperature, to disperse the molecular sieve with its adsorbed perhalogenated fluid in the resinous material. Such filled compositions can be used to impregnate various types of fibrous or fabric materials, for example, paper cloth, matted or woven glass fibers, which can be molded into laminated sheets, wound into tubes, rods, etc., or molded to a desired shape. The liquid filler containing compositions can also be cast into any desired shape or used to encapsulate or encase a desired piece of electrical apparatus to provide insulation therefor. Such liquid compositions are readily polymerized or cured to the solid state by use of heat, catalysts, etc., at temperatures well under 290° C., so that no precautions have to be taken to prevent desorption of the perhalogenated fluid from the molecular sieve dispersed in the resin. All such fabricated parts make ideal arc extinguishing devices which will rapidly desorb the perhalogenated fluid when exposed to the heat of an electrical arc.

Example 2

A molecular sieve designated as 13X has the chemical composition:



and has the cubic structure, $a=24.95 \text{ \AA}$, space group $O7/hF\bar{d}3m$. It is regarded as having a uniform pore size of 13 angstroms. Sulfur hexafluoride has a spherical shape and has a critical diameter of 5.8 angstroms. It can be readily adsorbed on the molecular sieve 13X after it has been dehydrated, to remove the water. A sample of molecular sieve 13X was dried in vacuo for several days at 300–400° C. to remove the water. A molding powder was prepared from this molecular sieve by mixing it with polymethylmethacrylate powder in the ratio of 40% by weight of the molecular sieve and 60% by weight of the polymethylmethacrylate, by grinding the two components together in a ball mill for 16 hours.

Sheets were then molded of this material in a compression type mold at 200° C., using a ram pressure of 1,000 p.s.i.g., to give sheets 3 x 4 inches x $\frac{1}{16}$ inch thick. A portion of these molded sheets was used to prepare a test blank and the balance of the material was cut into small strips and placed in a glass-lined pressure vessel and heated for 88 hours at 170° C. under pressure of 750 p.s.i.g. of sulfur hexafluoride. At the end of this time, the pressure vessel was cooled to room temperature. The strips were removed and molded into sheets using a compression type mold at 170° C. and 1500 p.s.i.g. pressure, and cooled to room temperature while maintaining pressure on the molded part. Analysis of a sample of this molded material showed that it contained 0.94% by weight of sulfur hexafluoride. In another impregnation run, a sample was heated for 168 hours at 190° C. using a pressure of 300 p.s.i.g. of sulfur hexafluoride. This sample was molded at a temperature of 200° C. using a ram pressure of 700 p.s.i.g. and cooling to room temperature before removing the pressure. Analysis of this molded part showed that it contained 1.3% by weight sulfur hexafluoride. The blank and the two materials containing the adsorbed sulfur hexafluoride on the molecular sieve were fabricated into arc chute components 1½ inches wide x 2 inches high, having a triangular notch 1 inch wide x 1 inch high in the lower edge. Four of each of such segments spaced $\frac{1}{8}$ inch apart were assembled as illustrated in FIG. 4 such that the V-notch of each piece was made to straddle the arcing electrodes which were two $\frac{3}{4}$ inch cylindrical copper electrodes with a normal gap of $\frac{3}{8}$ inch when open. A high voltage pulse from a 60-cycle power source was used and on interruption by opening of the electrodes, an electric arc formed which was magnetically deflected over the surface of the arc chute segments. The average arc recovery strength of the gap between the open electrodes was determined for currents of both 400 and 1400 amperes. For 60-cycle operation, the arc recovery strength in about 2 milliseconds is important. Both of the samples containing the 0.94 and 1.3% adsorbed sulfur hexafluoride had a higher arc recovery strength than the arc chute material prepared from the polymethylmethacrylate containing only the molecular sieve with no adsorbed sulfur hexafluoride when measured 2 milliseconds after opening of the electrodes.

Example 3

A molecular sieve designated 13X and described in Example 2 was milled on a set of differential rolls with polyethylene to give a molding composition containing 40% by weight of the molecular sieve. This composition was molded into 25- and 40-mil thick sheets. Part of this material was cut into 1-inch strips and placed in a pressure vessel heated to 150° C. under a pressure of 570 p.s.i.g. of sulfur hexafluoride for 27 hours and then cooled to room temperature while maintaining the pressure. The material was pressed into 25- and 40-mil sheets by pressing at 115° C. under a pressure of about 2000 p.s.i.g. Analysis of this material showed that it contained 8.9% by weight of adsorbed sulfur hexafluoride. To test the ability of this composition to fill a void with sulfur hexafluoride and raise the corona starting voltage, the composition containing only the molecular sieve and the composition containing the molecular sieve with the adsorbed sulfur hexafluoride were each made into a test part having a standard void. The test parts were made by placing a 2-inch diameter x 25 mil circular disc with a $\frac{3}{8}$ -inch hole in the center between two 2-inch diameter x 40-mil discs and then heat-sealing the edges of the three discs, to provide a central void $\frac{3}{8}$ inch x 25 mils in each of the test parts. One-inch diameter electrodes were painted on the upper and lower faces of each of the samples with a silver paint. A 60-cycle voltage was then applied to the electrodes with the voltage being increased until corona

pulses were detected in a standard test circuit at room temperature.

The test part having no sulfur hexafluoride adsorbed on the molecular sieve had an average corona starting voltage of 1.88 KVRMS (kilovolts, root mean square), whereas the test piece containing the adsorbed sulfur hexafluoride had an average corona starting voltage of 2.50 KVRMS, immediately after fabrication of the test parts. After heating at 37° C. for 15 hours, the corona starting voltage for the sample containing no sulfur hexafluoride was still the same, whereas the sample containing the sulfur hexafluoride had risen to 3.16 KVRMS. The test pieces were then placed in an oven at 105.5° C. for 5.25 hours and re-measured, but again the sample containing no sulfur hexafluoride showed no change in corona starting voltage, whereas the sample containing sulfur hexafluoride had increased to an average of 6.31 KVRMS. After standing an additional 2 weeks at room temperature, the test part containing no sulfur hexafluoride still had the same corona starting voltage, whereas the sample containing the sulfur hexafluoride had an average corona starting voltage of 5.28 KVRMS.

When the molecular sieve of this example was loaded with sulfur hexafluoride prior to compounding with the polyethylene, and then fabricated as described above, it was found that the compound only contained 1.2% sulfur hexafluoride, showing that for this combination of molecular sieve and perhalogenated fluid, a higher content of adsorbed perhalogenated fluid could be obtained by adsorbing the perhalogenated fluid after, rather than prior to, the formation of the molding compound, but that either method could be used to obtain a composition containing adsorbed perhalogenated fluid.

Example 4

A molecular sieve designated as 5A described in Example 1 was dried for 24 hours at 300° C. under vacuum. After cooling to room temperature, the vacuum was broken by admitting dichlorodifluoromethane to give a pressure of 760 millimeters. As the gas was adsorbed on the molecular sieve, the pressure slowly decreased, additional dichlorodifluoromethane was admitted to raise the pressure to 760 millimeters several times until the pressure remained constant at 760 millimeters, all pressures being in terms of millimeters of mercury. Analysis of the molecular sieve showed that a total of 9.6% by weight of dichlorodifluoromethane had been adsorbed.

A mixture of 40% by weight of the above molecular sieve containing the adsorbed dichlorodifluoromethane and 60% by weight of powdered polymethylmethacrylate were ball-milled together for 24 hours to give a uniform dispersion of the two ingredients. This mixture was molded at 178° C. in a flash-type mold for 2 minutes and cooled to room temperature to form sheets 6 x 6 inches square x 60 mils thick. Analysis of the molded parts showed that they contained 4.27% by weight of the dichlorodifluoromethane. Correcting for the methyl methacrylate component of the sample, this value shows, within the experimental accuracy of the analysis, that during the ball-milling and molding operation none of the dichlorodifluoromethane had been desorbed from the molecular sieve. Such a molding composition is suitable, therefore, for the production of molded parts where release of the dielectric fluid is desired at temperatures higher than those used in the production of the molded parts.

While several embodiments have been illustrated in the above examples, it will be apparent to those skilled in the art that various modifications are contemplated to be within the scope of this invention. For example, other fillers, dyes, pigments, plasticizers, stabilizers, etc., may be incorporated in the compositions. Therefore, the appended claims are intended to cover all such equivalent variations as come within the true spirit and scope of the invention.

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

1. A fabricated electrical insulating body comprising an organic resinous material having dispersed therein a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air, said body being free of porosity caused by desorption of said fluid from the molecular sieve.

2. The composition of claim 1 wherein the perhalogenated fluid is sulfur hexafluoride.

3. The composition of claim 1 wherein the perhalogenated fluid is a perhalogenated alkane.

4. In an electrical device having spaced elements adapted to have an electrical potential developed therebetween, an insulating member interposed between said spaced elements comprising an organic resinous material having dispersed therein a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air, said insulating member being free of porosity caused by desorption of said fluid from the molecular sieve.

5. In an electric arc extinguishing apparatus having spaced elements adapted to have an electrical arc established between the spaced elements, an arc extinguishing element whose surface is contacted by said arc, said arc extinguishing element being formed of a composition comprising an organic resinous material having dispersed therein a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air, said arc extinguishing element being free of porosity caused by desorption of said fluid from the molecular sieve.

6. An electrical conductor in contact with insulation comprising an organic resinous material having dispersed therein a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air, said insulation being free of porosity caused by desorption of said fluid from the molecular sieve.

7. The process of producing an electrical insulating member which comprises shaping under heat and pressure a composition comprising an organic resinous material having dispersed therein a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air, and cooling the shaped composition while maintaining sufficient pressure on the shaped composition that the fluid adsorbed on the molecular sieve is prevented from expanding and thereby causing porosity of the shaped composition.

8. The process of producing a moldable organic resinous material containing a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air which comprises blending said organic resinous material with said molecular sieve having adsorbed thereon said perhalogenated fluid, said blending being carried out at a temperature where said resinous material will fuse and coat the molecular sieve but below the temperature which will cause the perhalogenated fluid to be desorbed from the molecular sieve.

9. The process of claim 8 wherein the perhalogenated fluid is sulfur hexafluoride.

10. The process of claim 8 wherein the perhalogenated fluid is a perhalogenated alkane.

11. The method of making moldable thermoplastic organic resinous material containing a molecular sieve having adsorbed thereon a perhalogenated fluid having a dielectric strength greater than air which comprises (1) heating said resinous material containing the molecular sieve dispersed therein to a temperature where said resinous material is fluid in a pressure vessel, (2) pressurizing said vessel with said perhalogenated fluid while maintaining said resinous material in the fluid state, and (3) maintaining the pressure while cooling said resinous material to a temperature below that which would cause said perhalogenated fluid to be desorbed from said molecular sieve.

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12. The process of claim 11 wherein the perhalogenated fluid is sulfur hexafluoride.

13. The process of claim 11 wherein the perhalogenated fluid is a perhalogenated alkane.

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