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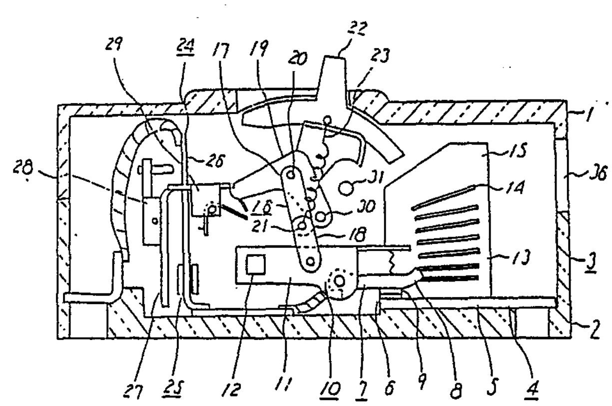
(54) SWITCH.

(57) When the contactor of a switch is opened an arc is produced. It has been determined that when a large quantity of energy is injected into the arc, a high proportion of the radiated energy is optical energy. In experiments, it was as high as approx. 70%. In this switch, a light absorber formed of a highly porous inorganic material with an apparent porosity of inorganic fibrous material or porous material of at least 35% is disposed at a position at which it receives the optical energy of the arc, thereby effectively absorbing the light emmitted by the arc to reduce the temperature in the gas space and lowering the pressure in the switch.



EP 0 098 308 A1

SPECIFICATION

TITLE OF THE INVENTION

SWITCH

TECHNICAL FIELD

This invention relates to the suppression of a pressure in a housing of a switch. Now the term "switch" referred to in the present invention indicates what generates an electric arc in the housing and usually the small-sized housing of a circuit interrupter, a current limiting device, an electromagnetic switch etc.

BACKGROUND ART

Hereinafter the present invention will be described by taking the case of a circuit interrupter.

Figs. 1 through 3 are sectional views showing a prior art circuit interrupter and illustrating the different operating states respectively. (1) is a cover, and (2) is a base. The cover (1) and base (2) constitute a housing (3). (4) is a stationary contactor having a stationary conductor (5) which has a stationary contact (6) provided at its one end, and the other end thereof is formed into a terminal unit so as to be connected to an external conductor (not shown). (7) is a movable contactor having a movable conductor (8) which has at one end a movable contact (9) opposing to the stationary contact (6). (10) is a movable contactor assembly, and (11) is a movable contact arm fixed to a cross bar (12) with the each pole arranged to be simultaneously opened and closed. (13) is an arc extinguishing compartment in which arc extinguishing plates (14) are supported by a lateral plate (15). (16) is a toggle linkage which is composed of an upper link (17) and a lower link (18). One end of the upper link (17) and the other end thereof are connected to a cradle (19) and to one end of the lower link (18) by means of shafts (20) and (21) respectively. The other end of the lower link (18) is further connected to the movable contact arm (11) of the movable contact assembly (10). (22) is a turnable operating handle, and (23) is an operating spring spanned between the shaft (21) of the toggle linkage (16) and the operating handle (22). (24) and (25) are respectively a thermal and an electro-magnetic trip mechanism. In operation, they are arranged to rotate a trip bar (28) in a counter-clockwise direction by a bimetal element (26) and a movable iron core (27) respectively. (29) is a latch which has one end engaging the trip bar (28) and the other end engaging a cradle (19). With the cradle 19 engaged by the latch (29), and when the operating handle (22) is turned to a closed position, the toggle linkage (16) is stretched to engage shaft (21) with the cradle (19) and to connect the movable contact (6) to the stationary contact (6). This state is shown in Fig. 1. Then the operating handle (22) is turned to a open position, the toggle linkage (16) is crooked to separate the movable conyact (9) from the stationary contact (6) and engage the movable contact arm (11) with a cradle shaft (30). This state is shown in Fig. 2. Also when an overcurrent flows through the circuit in the closed state as shown in Fig. 1, the thermal trip mechanism (24) or the electromagnetic trip mechanism (25) is operated to release the engagement between the cradle (19) and the latch (29). The cradle (19) is thus rotated in a counterclockwise direction about the cradle shaft (30) to engage a stopper pin (31). Since the connecting point between the cradle (19) and the upper link (17) passes over the line of action of the operating spring (23), the toggle mechanism (16) is crooked by means of the spring force of the operating spring (23) to interlock the respective poles by the cross bar (12) thereby to effect an automatic interruption. This state is shown in Fig. 3.

Subsequently, the behavior of an electric arc generated upon interrupting a current by the circuit interrupter will be described.

Where the movable contact (9) is now contact with the stationary contact (6), its electric power is supplied from the side of an electric source to the side of a load through the stationary conductor (5), stationary contact (6), movable contact (9) and the movable conductor (8) in series order. If a large current such as a short-circuit current flows through this circuit in this state, then the movable contact (9) is caused to be separated from the stationary contact (6) as described above. At that time, an electric arc is generated between the stationary and movable contacts (6) and (9) and an arc voltage is generated between the stationary and movable contacts (6) and (9). That arc voltage is raised in proportion to an increase in distance of the movable contact (9) separated from the stationary contact (6) and further raised because the electric arc (32) is simultaneously attracted toward the arc extinguishing plates (14) by means of a magnetic force to extend. In this way, an arc current reaches a current zero to extinguish the electric arc resulting in the completion of an interruption. That injected enormous arc energy, however, is eventually put in the form of heat energy and completely escapes to the outside of the housing. However, a temperature of a gas within the limited housing is transiently raised which, in turn, results in a sudden rise of a gas pressure. Thus there have been the significant disadvantages such as the deterioration of the insulation of the interior of the circuit interrupter, an electromagnetic short-circuit fault due to an increase in amount of an electric spark emitted to the outside of the circuit interrupter, the breakage of the circuit interrupter proper etc.

The description will be made in conjunction with an arc energy consumption mechanism which has formed the basis on which the present invention has been created.

Fig. 4 is a view showing an electric arc A generated between the contactors (4) and (7). In the Figure, T indicates a stream of heat energy escaping from the electric arc through the conduction through the contactors, m a stream of energy of metal particles escaping from an arc space, and R indicates a stream of energy due to light escaping from the arc space. In Fig. 3, energy injected into the electric arc is mostly consumed by the three energy streams T, m and R as described above. Among them, the heat energy T escaping to the electrode is very slight, and a major porportion of energy is carried away by the streams m and R. In the arc energy consumption mechanism the energy R in the Figure has been previously almost ignored while the energy m is overwhelming. From recent researches conducted by the inventors, however, it has been found that the energy R that is the consumption of energy due to the emission of light is so enormous as reaching approximately 70% of the energy injected into the electric arc.

That is, the consumption of energy injected into the electric arc can be analyzed as follows:

$$P_W = V \cdot I = R_K + P_{th} + P_R$$

$$P_k = \frac{1}{2} mv^2 + m \cdot C_p \cdot T$$

where P_w : instantaneous injected energy,

V : arc voltage,

I: current,

V·I : instantaneous electrical energy injected into electric arc,

P_k : instantaneous consumed energy carried away by metal particles,

$\frac{1}{2} mv^2$: instantaneous consumed energy carried away when mg of metal particles fly away at a speed v,

$m \cdot C_p \cdot T$: instantaneous consumed energy carried away when gas (gas of metal particles) with a constant pressure specific heat C_p escapes at temperature T,

P_{th} : instantaneous consumed energy escaping from arc space to electrodes, through heat conduction and

P_R : instantaneous consumed energy directly emitted from electric arc by means of light.

The consumption of energy as described above varies depending upon the shape of electrodes and length of electric arc, but P_k = 10 to 20%, p_{th} = 5%, and P_R = 75 to 85% hold with an arc length of 10 to 20 mm.

Then Fig. 5 shows an electric arc which is confined in a housing. the confinement of the electric arc in the housing, results in a status in which a space in the housing is filled with an electrode metal and is at a high temperature. This status is particularly pronounced in a gas space Q surrounding the positive column A of the electric arc (the space Q being shown hatched in the Figure). Light originating from the electric arc is emitted from the positive column A thereof to irradiate and be reflected from the walls of the housing (3). Reflected light is scattered to and passes again through the high temperature space filled with electrode particles and iradiates again the walls. Such a process is repeated until the amount of light becomes zero. The path of light in this process is indicated by RA-Rb-Rc-Rd in the Figure.

In the prcess as described above, the consumption of light originating from the electric arc is in the following two respects:

(1) Absorption by the wall surface

(2) Absorption by the arc space and surrounding gas space, (at high temperature) that is, absorption by the gas space. Also, light from the electric arc covers the entire wavelength range from far ultraviolet wavelengths of not larger than 2,000 Å to faar infrared wavelength of not less than 1 micron and consists of continuous and line spectra. The wall surface of general housings, even though the surface would be of black color, has only the ability to absorb light in a range of about 4,000 to about 5,500 Å alone but in other ranges it only partly absorbs and substantially reflects light. However, the absorption of light in

the arc space and surrounding high temperature gas space is as follows:

When a gas space with a length L having a uniform composition and a uniform temperature is irradiated with light having a wavelength λ, an amount of light absorbed by the gas space can be calculated as follows:

$$I_a = A \cdot n \cdot L \cdot Iin \quad \ldots\ldots(1)$$

I_a : energy absorbed by gas,

A : probability of absorption,

Iin : irradiating light energy,

n : particles density, and

L : length of optical path through which light passes.

Here the expression (1) represents a quantity of absorbed energy for a specific wavelength λ. A is the probability A of absorption for the specific wavelength λ and a function of the wavelength λ, a temperature of the gas and a kind of particles.

In the expression (1) and according to the teachings of the quantum dynamics, the abosrption coefficient A has the greatest value with a gas which is in the same states as a light source gas emitting light (that is, the same in the kind of particles and temperature) for continuous and line spectra. That is, light originating from the arc space is most absorbed by the arc space and surrounding gas space.

In the expression (1) the quantity I_a of absorbed energy of light is proportional to the length L of the optical path. Where light from the arc space is reflected from the wall surface as shown in Fig. 5, L in the expression (1) is increased by a number of reflections thereof resulting in an increase in quantity of light energy absorbed by a high temperature portion of the arc space.

This means that energy of light from the electric arc is absorbed by the gas in the housing thereby to incerase the gas temperature, thus increasing the gas pressure.

DISCLOURE OF THE INVENTION

The present invention provides a switch comprising at least a pair of contactors composed of conductors and contacts fixed thereto, and performing the opening and closing operations, a housing for accomodating said contactors, and an optical absorber disposed at a position where it receives light energy of light from an electric arc occurring upon said contactors performing the opening operations, said optical absorbers being formed of at least one or more of the kinds of inorganic high porous materials having the apparent porosity of not less than 35% of inorganic fibrous system materials and porous balnks.

According to the present invention, said optical absorber effectively absorbs energy of light occupying a greater part for the consumption of energy injected into an electric arc to reduce a temperature of a gas space in the housing of the switch thereby to reduce a pressure within the housing of the switch.

If there is particularly used, as the optical absorber, an inorganic fibrous system material having a percentage of voids of not less than 40% of a fibrous blank or an inorganic high porous material having an apparent porosity of from 40 to 70% of a porous blank then light energy generated from an electric arc can be more effectively absorbed, and the housing of the switch can reduce in pressure.

Also, if the surface of the optical absorber is further densified then powders can be prevented from falling the optical absorber which is an inorganic high porous material or an inorganic fibrous system material.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 through 3 are sectional views of a conventional circuit interrupter and illustrate the different operating states respectively; Fig. 4 is an explanatory view showing a manner in which an electric arc is generaged between contacts; Fig. 5 is an explanatory view showing a manner in which an electric arc is generated between contacts in a housing; Fig. 6 is a perspective view showing an inorganic high porous blank; Fig. 7 is a fragmentary enlarged sectional view of Fig. 6; Fig. 8 is a diagram of curves showing changes in pressure in a housing to apparent porosities of various inorganic high porous materials upon the generation of an electric arc; Fig. 9 is a perspective view of a fibrous system blank; Fig. 10 is a fragmental enlarged sectional view of Fig. 9; Fig. 11 is another embodiment of the present invention and a sectional view of a circuit interrupter using an inorganic high porous material as an optical absorber; and Figs. 12 to 16 show another embodiment of the present invention, wherein Fig. 12 is a perspective view of an external appearance of the whole; Fig. 13 is a perspective view showing the inner surface of a cover; Fig. 14 is a sectional view on line A-A of Fig. 14; and Fig. 16 is a sectional view on the line B-B of Fig. 15.

BEST MODE FOR CARRYING OUT THE INVENTION

Porous blanks are generally materials having a multitude of pores in the solid structure and exist in materials within many ranges including metals, inorganic systems, organic materials etc. In view of the relationship between the quality of the material and the pores, they are distinguished one from the other, the one being what has been sintered and solidified at points where solid particles are contacted by one another and the other being what has holes as the main contituent formed of portions which are of a solid material. Further the blank referred to in the present invention is a raw material before a shaping process without adhering to its shape.

When further finely classified, they can be divided into what has gaps between particles existing as pores, what has jointly gaps between particles and pores in holes within the particles, what includes foamed holes in the interior thereof and others. Also they may be roughly divided into what has a gas and a water permeability and what includes pores independent therein and does not have a gas permeability.

The shape of said pores is much complicated and broadly classified into an open pore and a closed pore. Its structure is indicated by a pore volume or a porosity, a pore diameter and a distribution of pore diameters a specific surface area etc.

A porosity has a true polosity made of what indicates a proportion of a pore volume of all open and closed holes included in a porous blank by a percentage of voids to the total volume (a bulk voltage) of the blank, that is, a percentage. A measurement method depends upon a substitution and a abosrption method based on a liquid or a gas but as a simple and easy way (as defined by a method of measuring a specific weight and porosity of a fire-resistant brick according to JIS R2614), it is calculated as follows:

$$\text{True Porosity} = \left(1 - \frac{\text{Bulk Specific Weight}}{\text{True Specific Weight}}\right) \times 100\%.$$

Also an apparent porosity is made of what indicates a proportion of valumes of open holes alone by a percentage of voids to the total volume (a bulk volume) of the balnk that is, a percentage and, as defined by a method of measuring an apparent porosity, an absorption factor and a specific weight of a fire-resistant brick according to JIS R 2205, it is calculated as follows: The apparent porosity is also called an effective porosity.

$$\text{Apparent Porosity} = \frac{\text{Water Saturated Weight} - \text{Dried Weight}}{\text{Water Saturated Weight} - \text{Weight in water}} \times 100\%.$$

The pore diameter is obtained from measured values of pore volumes and the specific surface area but the pore diameters ranges from what approximates a size of an atom or an iron to a boundary gap of a particle cluster so that the pore diameter ranges from what approximates a size of an atom or an ion to a boundary gap of a particle cluster so that the it is distributed between a few angstrom units and a few millimeters. However it is generally defined by the mean value of the distribution thereof. For porous blanks, the shape and size of the pores and the distribution thereof pores can be measured by a method based on a microscope or a mercury instrusion method. However, in order to accurately determine the complicated shape and distribution of the pores, the use of the microscope is desirable because of the direct observation.

In the measurement of the specific surface area the BET method is in many cases, used which utilizes adsorption isothermal lines of various adsorbed gas matters at each temperature, and a nitrogen gas is frequently used.

Then absorption of light energy by inorganic high porous materials which are the optical absorbers will be described and herewith the state in which the gas reduces in pressure due to the inorganic high porous materials will be described on the basis of embodiments.

Fig. 6 is a perspective view showing an inorganic high porous blank and Fig. 7 is a fragmentary enlarged sectional view of Fig. 6. In the Figures, (33) designates the inorganic high porous blank, and (34) designates an open pore communicating with the surface of the inorganic matter. The pore diameter, of the open pore (34) indicates various distributions indluding large and small sizes ranging from a few microns to a few millimeters.

Now when light is incident upon on this inorganic high porous blank (33) as shown by the arrow R in Fig. 7, the light is incident upon the open pore (34) whereupon the light is struck against and reflected from the wall surface of the inorganic matter to be subjected to multiple reflections within that pore (34) unitl substantially 100% is absorbed by the wall surface. That is to say, light incident on the open pore (34) is directly absorbed by the surface of the inorganic matter to change to heat in the pore.

Fig. 8 shows a curve diagram for a change in pressure within a modelled housing into which various inorganic high porous materials have been selectively entered, due to an electric arc when that inorganic high porous material has changed in apparent porosity. In Fig. 8 the axis of abscissas represent the apparent porosity and the axis of ordinates is normalized so that the pressure due to the electric arc is of one when the inner wall of the housing is formed of a metal such as Cu, Fe, Aℓ or the like. As the experimental conditions, AgW contacts are disposed at a constant gap of 10mm within the enclosed housing of a cube having one side of 10cm, and an electric arc with a sinusoidal wave having the peak of 10KA is generated for 8 milliseconds to measure a pressure within the housing caused by energy at that time.

Example 1

As an inorganic high porous material, a raw potttery material of a cordeirite matter was molded as by a method of adding an inflammable or a foaming agent thereto and sintered into porous potteries rendered high porous. Various samples of 50mm x 50mm x $4mm^t$ which had the mean pore diameter ranging from 10 to 300 microns and apparent porosities of 20, 30, 35, 40, 45, 50, 60, 70, 80 and 85 of the porous blank respectively were used to be disposed on the wall surface of the housing so as to cover 50% of the surface area of the inner surface of the housings. A change in pressure at that time is shown at curve a in Fig. 8.

Example 2

As an inorganic high porous material insulating fire bricks of an alumina matter having the means pore diameter ranging from 50 to 100 microns and the apparent porosities of 30, 40, 50, 60 and 65% of a high porous blank respectively were machined to $4mm^t$ (thickness of 4mm). They were disposed on the wall surface of the housings so as to cover 50% of the surface area of the inner surface of the housings. A change in pressure at that time is shown at curve b in Fig. 8.

Example 3

As an inorganic high porous material Na_2O-B_2O_3-SiO_2 system Vycor glasses with through pores normally used as a filtering filter and having a pore diameter of from 100 to 200 μ and an apparent porosity of 30%, a pore diameter of from 20 to 30 μ and an apparent porosity of 40%, a pore diameter of from 50 to 300 μ and an apparent porosity of 60%, and a pore diameter of from 50 to 300 μ and an apparent porosity of 70% respectively were used with $4mm^t$. They were disposed on the wall surface of the housings so as to cover 50% of the surface area of the inner surface of the housings. A change in pressure at that time is shown at curve c in Fig. 8. Further, similar experiments were conducted with what has a pore diameter changed to from 40 to 50 μ for the apparent porosity of 30% and what had a pore diameter changed from 40 to 50 μ, for the apparent porosity of 40% but there was no change in pressure with such a change in pore diameter.

Example 4

As the inorganic high porous material, gypsums which were cement cured members and had a pore diameter of not larger than 30 microns and apparent porosities of 45%, 50 and 60% respectively were used with $4mm^t$ to be similarly disposed on the wall surface of the housings so as to cover 50% of the surface area of the inner surface of the housings. A change in pressure at that time is shown at curved in Figure 8.

As understood from Fig. 8, the pores in the inorganic high porous material absorb light energy to exhibit the effect that a pressure in the interior of the switch decreases and this is enhanced with an increase in apparent porosity of the inorganic porous blank. The effect is particularly noticeable with the apparent porosities of not less than 35% and has been confirmed in a range up to 85%. If the porosity is further increased then countermeasure is required by more increasing the thickness of the high porous material. In the case of porous glass, however, even the apparent porosity of 30% is effective because the glass itself penetrates light therethrough and has a relatively large specific surface area so that it is easy to absorb energy of light through a boundary surface thereof and the effect is large even with what has a small porosity.

In view of the relationship between the apparent porosity and mechanical strength thereof the porous blanks increased in apparent porosity become brittle and decrease in thermal conductivity to be easily melted by hot heat. Also in the case of a small apparent porosity the effect of decreasing the pressure within switches is scanty. Accordingly the high porous materials are optimum with the apparent porosity of the high porous blanks ranging from 40 to 70% for practical purposes.

The characteristic tendency is applicable to general inorganic porous materials which can be conjectured from the foregoing description concerning the absorption of light.

As to the pore diameter the problems are present in the mean pore diameter somewhat exceeding a region of wavelengths of absorbed light and a proportion of pores occupying the surface, that is to say, an amount of the specific surface area of the pores. Also for the absorption of light within the pore, what has deep pores has the effect and communicating pores are desirable. Since light emitted from an electric arc in a switch is distributed between a few handred angstrom units and 10,000 Å (1 μm), the extent somewhat exceeding this, that is, the mean pore diameter of from a few thousand angstrom units to a few thousand μm is suitable. High porous materials having the area of the pores occupying the surface to be equal to or larger than the apparent porosity of 35% are suitable for absorbing light emitted from the electric arc. The larger the specific surface area of the pores having the pore diameter lying in a range of from a few thousand angstrom units to a few thousand μm and preferably having its upper limit lying in a range of not larger than 1,000 μm the more the effect is found. It has been confirmed by experiments that, the mean pore diameter of from 5μ to 1mm exhibites the good absorption characteristic to light emitted from the electric arc.

While inorganic materials may be used with conventional swtiches, the purpose of their use is mainly to protect organic housings against the electric arc and the characteristics thereof require the arc resistance, lifetime, thermal conductivity, mechanical strength insulation and countermeausre to carbonization. The inorganic materials fulfilling them are necessarily constituted in an intention of densification and different in purpose. The apparent positly thereof is of about 20%.

As high porous blanks there are inorganic, metal and organic systems etc. The inorganic system is characterized by the insulating matter and high melting points. Those two properties are suitable as materials disposed within the housing of switches. Since they are electrically insulating matters, they do not bad affect the interruption and also are optimum as pressure suppressing materials because, even when exposed to hot heat, they are not melted nor evolve a gas or gases. Among this inorganic system there are involved and used what includes an inorganic material as the principal constituent and uses an organic material as a binder or the like.

Porous materials of the organic system encounter the problems in the heat resistance and the generation of a gas or gases and those of the metallic system are at issue in the electrical insulation and the pressure resistance. Thus the organic and metalic system are limited as to the position where they are disposed.

As inorganic high porous materials, there can be used porous maters other than said examples, pottery particles uniform in particle diamerer in potteries, for example, metal oxides or alumina, silica, zircon, magnesia and zironia; powder of special pottery materials such as mullite, forstelite, steatite, lithia, spinel etc. other than a cordeirite matter; powder of usual pottery materials of alumina silicate and feldspar matters and others, clay, quarts, feldspar and pottery stone and mixed and sintered with solvents the alumina silicate matter prepared by mixing and sintering clay, quartz, feldspar and pottery ston; or what increases in number of pores as by a method of adding said raw pottery materials with an inflammable or a foaming agent; and furthermore what increases in number of pores by mixing and sintering a raw porous pottery material such as diatomaceous earth with clay or the like.

Also there may be generally used porous pottery materials of calcic, hard, clayish, silicic and dolomitic matters prepared by mixing and sintering a raw clayish materials with quartz, pottery stone, limestone, dolomite and a small amount of feldspar, and unglazed earthwaves and others prepared by firing raw clayish materials as the principal component at low temperatures.

In porous refractory materials there may be used, as insulating fire bricks, magnesia, zirconia, cordeirite, silicon carbide, vermiculite, and chromium magnesia matters in which pores are formed by mixing and firing sawdust or polystyrene beads or the like with castable raw refractory materials except for an alumina matter, pearlite and vermiculate matters foamed by firing, and vermiculite diatomaceous earth matter etc using an artificial foaming agent such as alumina or zirconia bulbbling agent or a natural pore forming agent such as diatomaceous earth.

A heat generating material having caron silicate as the principal component, a grind sstone quality and others may be applied.

As porous glasses there may be also used, in addition to the Example sintering a high silicate glass powder, foam glasses and others prepared by firing mixtures of glass powders and foaming agents by utilizing transmission to light.

As porous cured cement materials cured cement materials themselve, such as concretes, mortars, slates etc. generally used with civil engineering works or as building materials have porosities and may be used. As high porous materials however, what increases in number of pores by mixing and curing a cement surry with small pieces of inflammable wood or a powdered resinous material follows by the sintering, such as heater plates and light weight concretes or a cement slurry caused to include a multitude of air bubbles and cured like a porous cement is preferable.

As the light absorber used with the present invention the description will be made in conuunction with a fibrous blanks that is another example.

The fibrous blank is composed of an an aggregate of fibers or a combination of fibers and a surface treating agent or a binder and includes a multitude of through or open voids in the interior thereof. Its form includes generally spun and woven products such as yarns, ropes tapes (ribbons), cloths etc. molded products such as blankets, felts, sponges or molding etc. and products manufactured according to paper making technique, for example, paper, mats etc. on the basis of raw cotton or bulk materials having the fiber diamerer of from a few μm to several ten μm. It is generally identified by a bulk specific gravity (a bulk density), a size and a shape such as a thickness. a width, a length, a thickness etc. and a weight per unit area or length and others. The bulk specific gravity (a bulk density) indicates a proportion of the weight of the fibrous blank to a bulk volume (an apparent volume) thereof.

In the present invention a percentage of voids is also indicated which much concerns the absorption of optical energy. The percentage of voids has a true porosity made of a proportion of a void volume to a bulk volume. As described above, it is calculated as follows:

$$\text{True Porosity (Percentage of Voids)} = \left(1 - \frac{\text{Bulk Specific Weight}}{\text{True Specific Weight}}\right) \times 100\%$$

Hereinafter the description will be made in conjunction with the absorption of light energy by the fibrous blank and a manner in which a pressure of a gas decreases due thereto by taking the case of Fig. 9 and Fig. 10.

Figure 9 is a perspective view illustrating a fibrous blank and Figures 10 is a fragmental enlarged sectional view of Fig. 9. In the Figures (33) shows a fibrous blank and (34) shows a void pore communicating with the surface of the blank. The shape of void pore

(34) indicates various distributions including large and small size in accordance with the shape of the fiber itself, a composition of the surface treating agent or the binder and the form of the blank 78.

When a light ray is incident upon the fibrous blank (33) and on the void pore (34) communicating with the surface of the blank as shown by R in Figure 10, the light strikes against a boundary surface of the blank (33), is reflected therefrom and and subjected to the multiple reflection within that void pore (34) until substantially 100 % has been absorped in the interior of the blank. In other words, the light incident upon the void pore (34) is directly abosrbed by the surface of the blank to change to heat within that void resulting in the extinction of light energy.

As described abobve, the very excellent pressure supporessing effect is exhibited with a switch of a structure having a fibrous blank with a multitude of communicating voids disposed in that space thereof receiving light energy of an electric arc struck but this performance is much governed by the type and shape, the percentage of voids, and the specific surface area of the fibrous blank. Thus the selection of the fibrous blank is a significant problem.

The fibrous blank is roughly stored into an inorganic, fibrous system, a metallic fibrous system and an organic fibrous system. In each of them there exist a natural system and an artificial system artificially worked. In the natural inorganic fibrous system there is asbestos as a mineral fiber, and in the artifificial fibrous system glass fibers, ceramic fibers, mineral fibers, carbonaceous fibers and various whisbers are used. In the metallic fibrous system there are iron and copper systems.

In the natural organic fibrous system there are used vegitable fibers such as cotton, hemp etc., animal fibers such as wool, silk etc. and as the artificial fibrous system there are synthetic fibrs such as nylone, vinylon, tetron etc., smei-synetic fibers of acetate and regenerated fibers or rayon.

Since the fibrous blank as the pressure suppressing material or the light absorber in the present invention is disposed within a housing receiving receive light energy of an electric arc and exposed to hot heat from the considerably large electric arc, it is required that the closure of the void pores communicating with the surface of the blank and a change in shape due to the melting or decomposition of the surface of the material are not occur, the comsumption and disappearance of and damage to the material itself be small and an amount of evolved gas be small. Also it is important to render the electrical insulation high and to cause no rupture with respect to mechanical shocks. Thus, the pressure suppressing material should meet various conditions.

In the fibrous blanks as described above, however, the organic system has the problems in heat resistance, incombustibility and the generation of a gas or gases and the metallic fibers cause the problems in electrical insulation and withstanding voltage so that the conditions for use and usable ranges are limited. Thus as the pressure suppressing material or the light absorber in the present invention, the inorganic fibrous system is most suitable which is excellent in heat resistance, insulation and mechanical strength and scarcely enolves gases even when exposed to hot heat of an electric arc.

Hereinafter inorganic fibrous system materials composed of various inorganic fibrous blanks will be described in detail on the basis of examples in experiments using the inorganic fibrous system materials put within modelled housings. As the experimental conditions like the foregoing, AgW contacts were disposed at a constant gap of 10mm within an enclosed housing of a cube having one side of 10cm, an electric arc of a sinusoidal current with peak of 10KA was generated for 8ms and a pressure within the housing produced with energy at that time was measured. Its characteristic was expressed by the comparison with a normalized value assumed as 1 for a pressure due to an electric arc with the inner wall of housing composed of a light-reflecting metal such as Cu, Fe, Al or the like.

Example 5

As an inorganic fibrous system material alkali-free glass of lime alumina borosilicate matter (which is generally called an E glass) fibers good in water resistance and electric insulation were used by twisting long fibers thereof having a true specific gravity of 2.55 g/cm^3 and a single fiber diameter of approximately 5 to 9 μm (as standardized according to JIS R 3413 (Glass Yarn)) into a glass yarn of $225\frac{1}{3}$ counts which was woven into a plain fabric having a density (number/25 mm) of warps (length) 34 and wefts (width) 32 (as standardized according to JIS R3414 (Glass Cloth)), a thickness of 0.19 mm, a weight of 181 g/m^2, a bulk specific gravity of 0.953 g/cm^3 and a percentage of voids of approximately 63% to prepare a non-treated cloth. Then superposed pieces of the glass cloth with a size of 50 mm by 50 mm were used to be disposed on the wall surface of the housing so as to cover 50% of the inner wall surface area of the housing. An electric arc was produced, and a change in pressure within the housing was measured. The resulting comparison value indicated 0.62.

Example 6

Glass fibers were similar to those in Example 1 and long fibers having a single fiber diameter of approximately 6 to 13 µm were twisted into a yarn (of #75 1/5 counts, and wefts 150 1/9) which was woven into a plain fabric having a density (number/25 mm) of warpe 12 and wefts 12, a thickness of 0.32 mm, a weight of 310 g/m^2, a bulk density of 0.968 g/cm^3 and a percentage of voids of approximately 62% to prepare a non-treated glass cloth. Six superposed pieces of the glass cloth with a size of 50 mm by 50 mm were used to be disposed on the wall surface of the housing so as to cover 50% of the inner wall surface area of the housing. An electric arc was produced and a change within pressure in the housing was measured. The resulting comparison value indicated 0.65.

Example 7

As an inorganic fibrous system material alkali-containing sodium borosilicate glass (which is generally an A glass) fibrers were used by adding a small amount of an organic binder to raw cotton made of short fibers thereof having a type specific gravity of 2.46 g/cm^3 and a single fiber diameter of 10 to 15 µm and working a molded glass branket having a bulk specific gravity of 0.012 to 0.024 g/cm^3 and a molded glass board having a bulk specific gravity of 0.032 to 0.064 g/cm^3 into sizes of 50 mm b7 50 mm^t. They were disposed on the wall surfaces of housing so as to cover 50% of the inner wall surface area of the housing. An electric arc was produced, and a change in pressure within the housing was measured. The resulting comparison values indicated 0.52 with the roll and 0.55 with the board.

Example 8

As an inorganic fibrous system material ceramic fibers of alumina silica matter excellent in refractoriness, heat insulation, chemical resistance and electric insulation, and a raw cotton bulk material of long ones thereof having a true specific gravity of 2.7 g/cm^3 and a single fiber diameter of approximately 3 µm were added with a small amount of inflammable organic fiber and woven into a ceramic fiber cloth or tape having a thickness of 2 mm through reinforcing strings. What has a size of 50 mm by 50 mm was disposed on the inner surface of the housing so as to cover 50% of the inner surface of the housing. An electric arc was produced, and a change in pressure within the housing was measured. The resulting comparison value indicated 0.60.

Example 9

A ceramic fiber bulk material similar to that in Example 4 was molded into a layer after which it was needling processed into a blanket having a bulk specific gravity of 0.13 g/cm^3 and a thickness of 12.5 mm. The bulk material was added with an inorganic binder and molded into a board having a bulk specific gravity of 0.3 g/cm^3 and a thickness of 10 mm. The bulk material was processed with a minute amount of an organic binder and molded into a felt having a bulk specific gravity of 0.10 g/cm^3 which felt was worked to a thickness of 10 cm. Each of them having a size of 50 mm by 50 mm was disposed on wall surface of the housing so as to cover 50% of the inner surface of the housing. An electric arc was produced, and a change in pressure within the housing was measured. The resulting comparison value indicated 0.55 with the blanket, 0.59 with the board and 0.56 with the felt.

Example 10

As an inorganic fibrous system material synthetic acrylic fibers passed through the flame resisting step in air at 200 to 300°C to form flame resisting fibers, which passed further through the carbonizing step in an inert gas at 1,000 to 1,500°C to form carbon fibers excellent in heat and corrosion resistances. The carbon fibers had a true specific gravity of 1.7 g/cm^3 and a single fiber diameter of 12 to 24 μm and were twisted into a yarn of high strength carbon fiber with a filament number of 1,000 which was woven into a plain fabric having a density (number per 25 mm) of warps 22.5 and wefrs 22.5, a thickness of 0.15 mm, a weight of 120 g/m^2, a bulk specific gravity of 0.8 g/cm^3 and a percentage of voids of approximately 53% resulting in a non-treated cloth of carbon fibers. Therteen superposed pieces of the cloth with size of 50 mm by 50 mm were used to be disposed on the wall surface area within the housing. An electric arc was produced, and a change in pressure within the housing was measured. The resulting comparison value indicated 0.63.

Example 11

A yarn with a filament number of 1000 formed of carbon fibers similar to those in Example 7 was woven into a plain fabric having a density of warps 12.5 and wefts 12.5, a thickness of 0.27 mm, a weight of 200 g/m^2, a bulk specific gravity of 0.741 g/cm^3 and a percentage of voids of approximately 56% resulting in a non-treated cloth of carbon fibers. Eight superposed pieces of the cloth with a size of 50 mm by 50 mm were used to be disposed on the wall surface of the housing so as to cover 50% of the surface area within the housing. An electric arc was produced, and a change in pressure within the housing was measured. The resulting comparison value indicated 0.65.

Example 12

As the inorganic fibrous system material natural crysolite asbestos fibers of $3MgO \cdot 2SiO_2 \cdot 2H_2O$ matter excellent in heat resistance and having a true specific gravity of 2.4 to 2.6 g/cm^3 and a single fiber diameter of 1.8 to 0.3 x 10^{-5}mm (as standarized according to JIS R 3450 (Asbestos Yarn)), either alone or with other organic fibers were twisted into an asbestos yarn (of the first kind) having a diameter of 1.1 mm. The yarn was plainly woven into an asbestos cloth having a thickness of 2.9 mm, a weight of 850 g/m^2, a bulk specific gravity of 0.425 g/cm^3 and a percentage of voids of approximately 83% (as prescribed in Class No. 2 according to JIS R3451 (asbestos Cloth)). The asbestos cloth was used with a size of 50 mm by 50 mm to be disposed on the wall surface of the housing so as to cover 50% of the inner surface area of the housing. An electric arc was produced, and a change in pressure within the housing was measured. The resulting comparison value indicated 0.58.

As described above, the voids in various inorganic fibrous system materials have the great effect of absorbing light energy to reduce the pressure in the interior of switches. The fibrous blanks are good in their characteristic of pressure absorption even though they are in the form of spun and woven products such as a cloth, a tape etc., or of molded products such as a blanket, a board, a felt etc. However, the thicker the thckness of the fibrous blank the morethe characteristic thereof will be increased. The greater the specific surface area to cause the surface of the fibrous blank to include a large number of communication void pores per unit area, that is, the smaller their bulk specific gravity, the more the effect will be exhibited. The form of a blanket, a board, a felt or the like having a bulk specific gravities ranging from about 0.01 to 0.5 g/cm^3, a percentage of voids of not less than approximately 80% and large in specific surface area is used as a sound absorbing material, a heat insulating material etc. and can be said to be good pressure suppression materials. These molded products, however, are composed of a fibrous bulk material, as raw cotton, an inorganic or an organic binder and a surface treatment agent. They desirably include the organic component as small as possible in view of an amount of a generated gas or gases with the surface not clogging with a binder other than the fibrous matter.

In this respect, spun and woven products such as a cloth, a tape, etc. having generally the bulk specific gravity of 0.5 to 1.5 g/cm^3 which is greater than that of molded products and 40 to 90% of communicating voids and large in specific surface area without using a surface treatment agent are composed of fibers themselves and standardized and the optimum materials in view of the quality of the form itself.

In the fibrous blanks according to the said Examples, the bulk specific gravity per unit volume or unit area, the percentage of voids and the specific surface area depend upon the type of fibers used in the blank, the aggregation of the fibers, the diameter and length of single fiber, the yarn diameter, the manner of weaving, the number of intertexture of yarn, the density of intertexture etc. and there are may kinds of forms of products. Particularly, the woven clothes, and tapes are in the form of a plain fabric, a satin fabric, a twill fabric, a gauze fabric etc. and the different in spacing between warps and between wefts from one another. The pressure suppressing material is preferable of a plain fabric because warps crossing the wefts to lie above the latter alternate those crossing the wefts to lie below the latter as do the wefts to increase the strength of the resulting texture, and the spacings between the warps or between the wefts are distribured on the plain fabric to render the number thereof per unit area large.

But, where the spacing between adjacent yarns is not less than 1 mm, the pressure absorbing effect is reduced, and the texture of the blank itself becomes weak.

The characteristic tendency of said exmaples, however, is common to spun and woven products and molded products in view of the form of product to exhibit the pressure suppressing effect and can be said in conjunction with all the inorganic fibrous system materials. It is important that the shape of the void pores has a size somewhat exceeding the weavelength range of light to be absorbed and that the proportion of open voids occupying the surface of the blank or the specific surface area of the open voids is large. In the absorption of light within the void, a deep void is effective and particularly communicating voids are desirable. Since light generated from an electric arc in a switch is distributed from several hundred Å to 10,000 Å (1 μm), the void pores are suitable having on order of magnitude somewhat exceeding it and the fibrous materials having the area of the open pores occupying the surface is of not less than 40% of the percentage of voids, are suitable for absorbing light emitted by an electric arc.

As inorganic fibrous blanks other than those in said Examples of the inorganic fibrous system materials, there can be used, in addition to the E and A glasses, fibers of alkali glass of soda line borosilicate matter (which is generally called a C glass), alkali-resisting glass of SiO_2-R_2O-ZrO_2 system, and high elasiticity glass and optical glasses and others as special ones for the galss fiber nature. The glass fibers themselves have the transmission to light and the peculier feature that they absorb light energy through boundary surface thereof.

In the ceramic fibrous matter, there can be used, a high refractory alumina system, a zironia system, a silica system, a boran system and a silicon nitride system fiber other than the alumina-silica system.

In the carbon fiber matter there can be used, in addition to a carbon fiber, graphitic fibers with the high refractoriness and the high modulus of elasticity, prepared through the step of graphtizing carbon fibers in an inert gas at a high temperature of 2,500 to 3,000°C. The carbon and gaaphite fibers have electric conductivities, but they have the advantages that they are high melting points nature and light and high in strenth. The graphite fiber is black and laege in the effect of absorbing optical energy.

In the asbestos matter there can be used, in addition to chrysotile asbestos, crocidolite asbestos of $Na_2Fe_5Si_8O_{22}$ matter and ammocite asbestos of $(FeMg)_6Si_8O_{22}(OH)_2$ matters.

Also as the artificial mineral fiber there can be used rock wools obtained by melting and fibrizing natural rocks such as basalt and andesite, and slng wools obtained by fibrizing melted slug upon refining metals. Raw materials for these fibers are inexpensive and excellent in refractoriness and there are advantages as fibrous materials used as general fibrous materials.

In addition various whiskers of the SiC matter and other can be also used. The inorganic fibrous system materials such as said glass fibers, ceramic fibers, carbonaceous fibers, mineral fibers, asbestoses, various whisbers etc. can be used, by winding spun and woven products such as the yarn (the yarn), roving material, rope (cord), braid etc. other than the cloth (cloth), and tape (ribbon) as the form of products, to suitable thickness, connecting and stacking them. Also there can be used molded, worked products and products manufactured like paper such as a sponge, a molding a paper mat etc. other than a blanket, a bord and a felt as well as bulk materials themselves by means of a measure such as filling or the like.

Further, it is possible to use, in combination, different kinds of the fiber materials, different forms of products and fibers having differnt bulk specific gravities, different percentages of voids, different specific surface areas and different thickness even though they have the same kind and the same form of the product.

The glass fibers, carbonaceous fibers, ceramic fibers, mineral fibers, asbestos fibers etc. as described above are also in many cases used with electrically insulating materials, construction and civil materials and industrial structural materials as composite materials for plastic reinforced fibers, concrete or cement reinforced material etc. But they are made into materials tending to reduce in voids to be dense and therefore lessen the effect as the pressure suppression material for absorbing optical energy.

While the foregoing has shown the case of the inorganic high porous material or the inorganic fibrous system material is alone used as the light absorber, the two may be put together. Alternatively the one may be used as a core material to reinforce the other.

Now it is undesirable that the inorganic high porous material or the inorganic fibrous system material is broken or produces a minute powder to be attached to a movable mechanism or mechanisms of a switch or to be caught by contacts. To this end, it is desirable to compact the surface of the inorganic high porous material or the inorganic fibrous material in the state in which open pores or the meshes on the surface are not closed as much as possible. An examples of compacting the surface is shown.

Example 13

Paraffin was impregnated into or coated on the surface layer of the porous pottery of corderite matter obtained by Example 1 to cover or fill open pores and the paraffin attached to the surface was removed by grinding or polishing and therewith the surface was rendered smooth and a polishing powder or the like was removed. Thereafter the surface was coated with a graze paste of the K_2O-CaO-MgO-$A\ell_2O_3$-SiO_2 systems and fired at a temperature of from 1150°

to 1250°C to be brazed thereby to compact and strengthen peripheral portions of the open pores. At the firing step the paraffin attached to or filling the open pores is burnt down to leave the open pores on the surface in the state approximating that before the grazing.

This is used as the light absorber. Fig. 11 is another embodiment of the present invention and a sectional view of a circuit interrupter using a light absorber of an inorganic high porous material or an inorganic fibrous system material. (35) is a light absorber of an inorganic high porous material or an inorganic fibrous system material and minutely the material described in Examples 1 to 13 and disposed on one part of wall surfaces on both sides of housing (3) and along these wall surfaces. The inorganic high porous material or the inorganic fibrous system material (35) is desirably disposed at a position where it directly receives energy of light of an electric arc (32) but it may be disposed at a position where it receives light reflected from the wall surface or the like. Since in the present invention a pressure in a gas space upon the generation of an electric arc can be much lowered as compared with the prior art, an exhaust hole (36) (see Fig. 1) may be omitted which hole are normally disposed on the housing (3) to discharge a gas to the exterior of the housing (3) upon the generation of an electric arc.

Figs. 12 to 16 show another embodiment of the present invention in which a light absorber (37) of a high porous material or a fibrous system material of the inorganic matter is disposed on the inner surface of the switch. An Fig. 14 is a sectional view as taken on the line A-A of Fig. 13 and Fig. 16 is a sectional view as taken on the line B-B of Fig. 5.

In said Fig. 12 (1) is a cover and (2) is a base. A construction in which they are formed of synthetic resistor materials respectively and which has a turnable operating handle (22) on the central portion is identical to that of said Fig. 1

In Fig. 13 to Fig. 16 (37) is a light absorber forming the essential part of the present invention.

Said light absorber (37) is formed into a plate and installed on the inner surfaces of the cover (1) and the base (2) as in Fig. 13 to Fig. 16. But a place of installation is a place easy to be most irradiated with light of the electric arc in Fig. 13 and in short disposed adjacent to the stationary contact (6) and the movable contact (9).

While the light absorber has been disposed on the inner wall of the housing in this embodiment the light absorber may be used on one part or the whole of the housing.

Also a reinforcing sheet may be integrally joined to the rear surface of the light absorger and in short that surface opposite to that irradiate with light from the elecrric arc. As the reinforcing sheet, copper, aluminum, stainless steel, silicon steel sheet, iron or the like may be used. They may be joined by using a bonding agent but heating joining means is effective.

Upon joining the light absorber (for example, a porous ceramic such as alumina, corderite magnesia or the like to the reinforcing sheet, the heating joining means is to insert a copper sheet between the light absorber and the reinforcing sheet and heat it with heat at about 1200°C whereupon the melted copper easily adheres to the reinforcing sheet and also penetrated into the structure of the light absorber resulting in the integral joining:

INDUSTRIAL APPLICABILITY

The present invention is not always limited to circuit interrupters and can be applied to the housing of current limiters, electromagnetic switches etc. and usually what generates an electric arc within a small-sized housing.

CLAIMS

1. A switch comprising at least one pair of contact members each formed of an electrical conductor and a contact fixed thereto, said contact members performing the opening and closure operations, a housing for accommodating said contact members therein, and a light absorber disposed at a position where said light absorber receives energy of lgitht of an electric arc generated upon the opening and closure operations of said contact members, said light absorber being formed of at least one of inorganic high porous materials having an apparent porosity of not less than 35% of a inorganic fibrous system materials and porosus blanks.

2. a switch according to claim 1 wherein the inorganic high porous material has the apparent porosity of from 40 to 70% of the porous blank.

3. A switch device according to lciam 1 wherein the inorganic high porous material is at least one of potteries, refractory articles, glasses, cement cured members which are porous.

4. A switch according to claim 1 wherein the inorganic high porous material has the means pore diameter of from a few thousand angstrom units to a few thousand μm.

5. A switch according to claim 1 wherein the inorganic fibrous system material has a percentage of voids of not less than 40% of a fibrous black thereof.

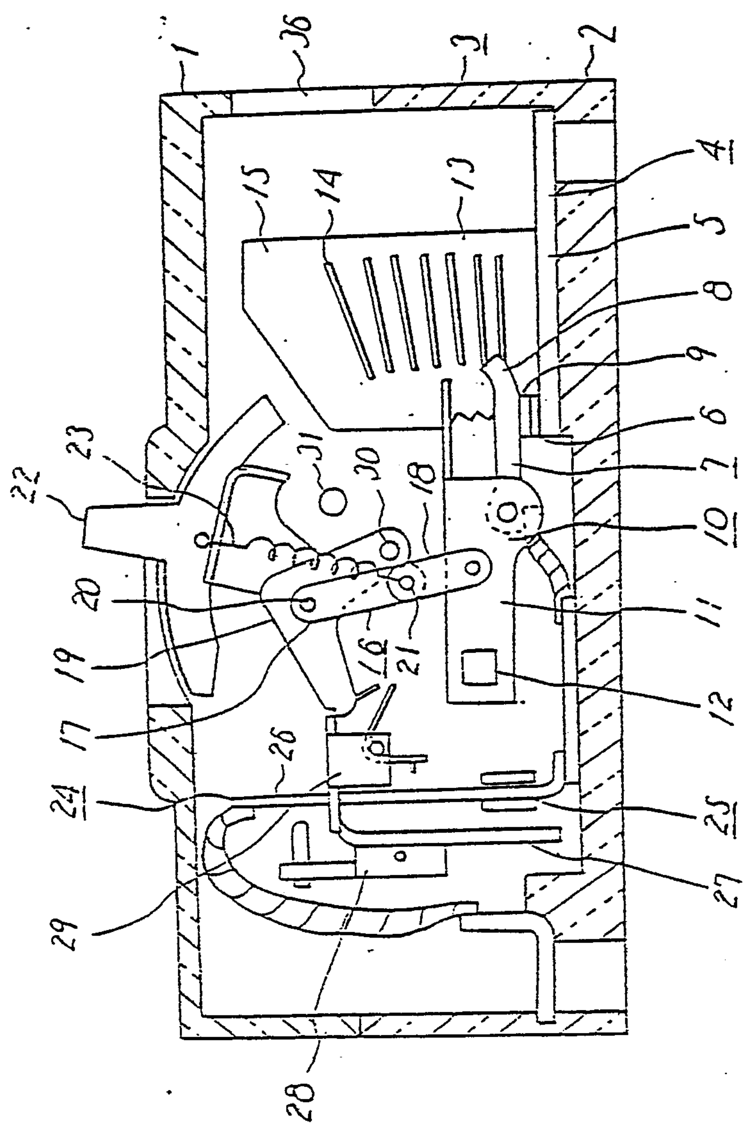
6. A switch according to claim 1 where the inorganic fibrous system material has a bulk specific gravity of from 0.01 to 1.5 g/cm^3 of a fibrous blank thereof.

7. A switch according to claim 1, whrerin the inorganic fibrous system material is one or more of galss fibers, ceramic fibers, rock wools, slug wolls, carbonaceous fibers and whisbers.

8. A switch according to claim 1 wherein the surface of the light absorber is compacted.

9. A switch according to claim 1 wherein the light absorber is disposed at a position where the light absorber directly receive energy of light of the electric arc.

FIG. 1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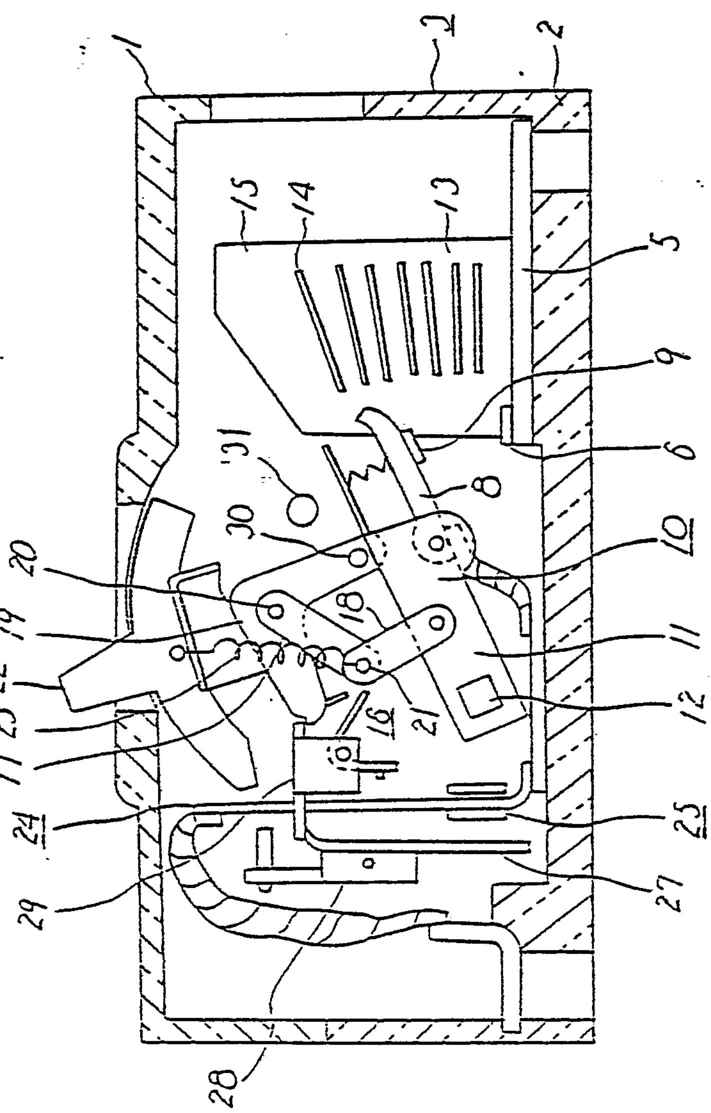

FIG. 2

FIG. 3

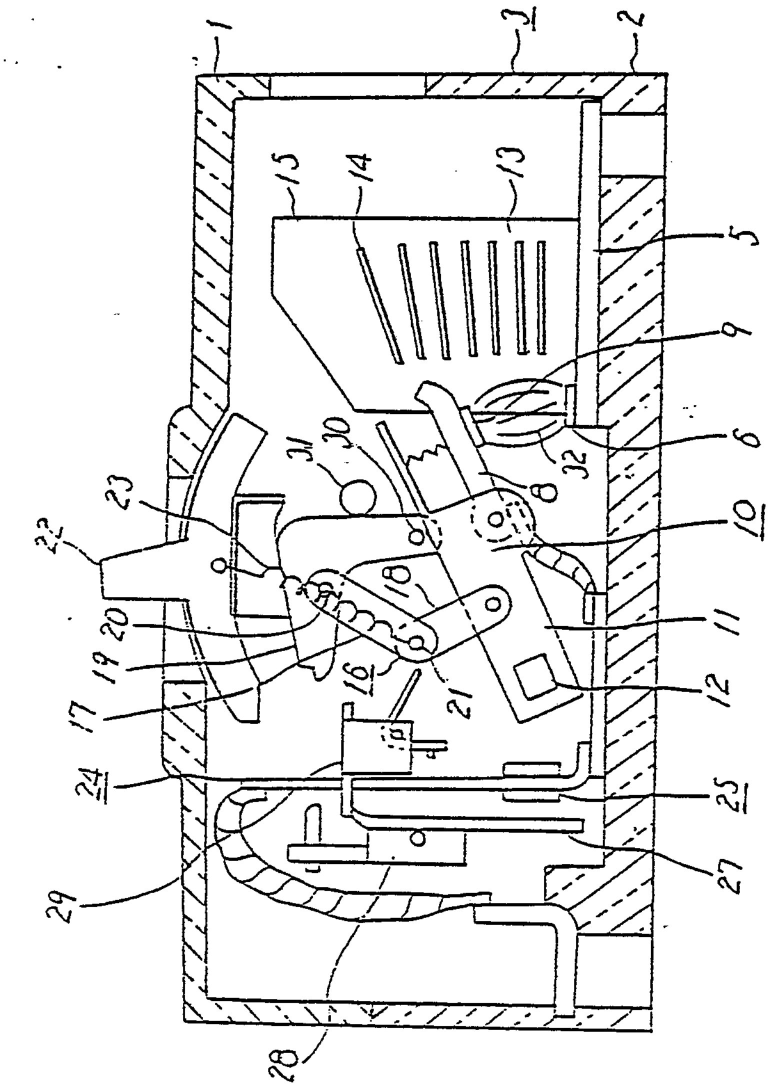
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FIG. 4

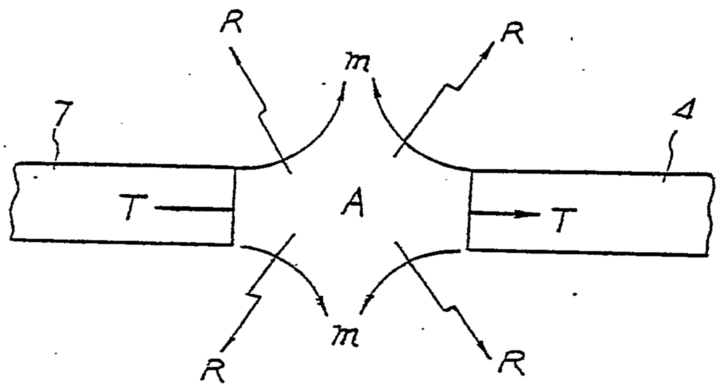

FIG. 5

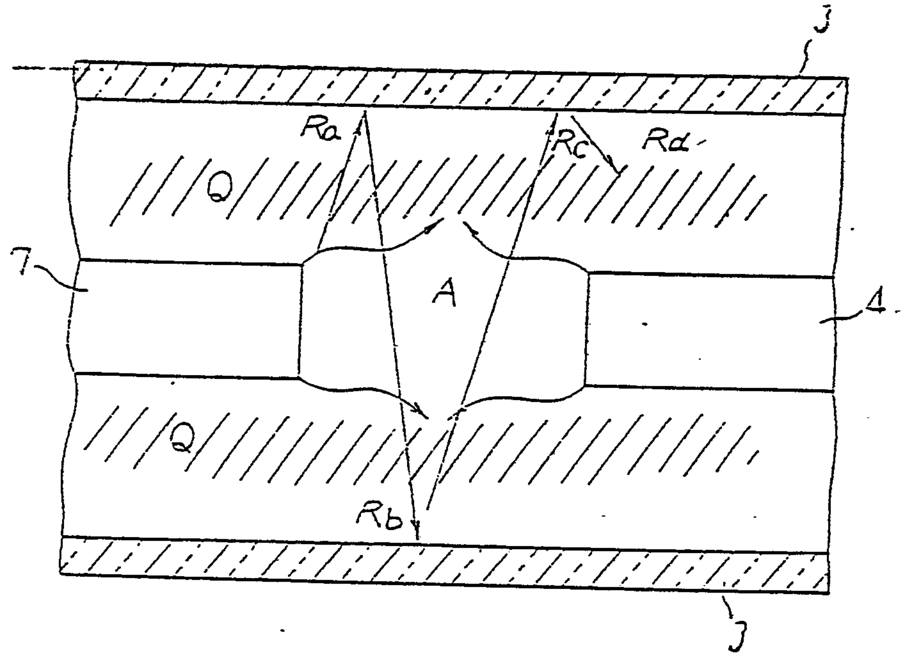

FIG. 6

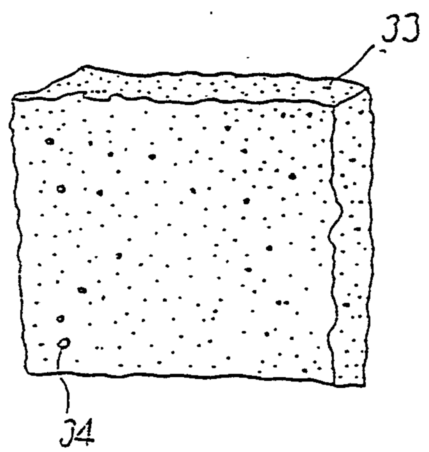

FIG. 7

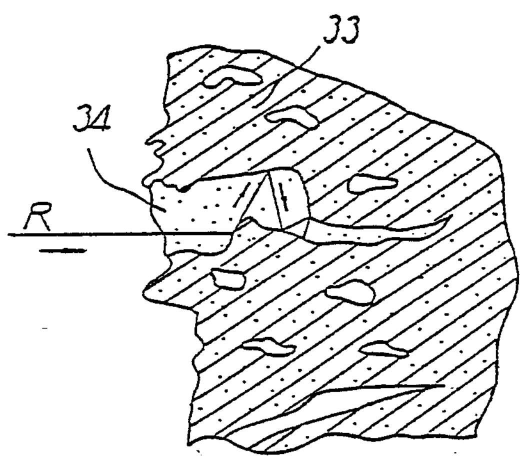

FIG. 8

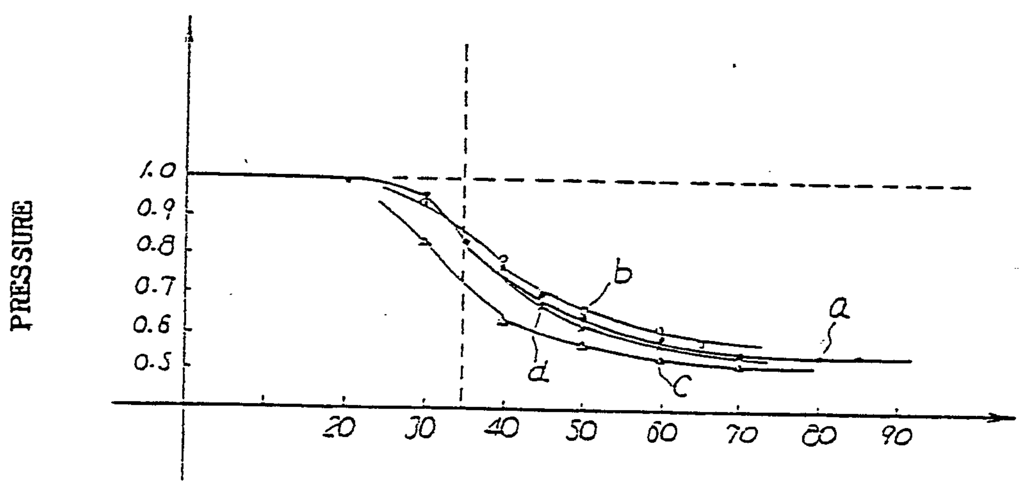

FIG. 9

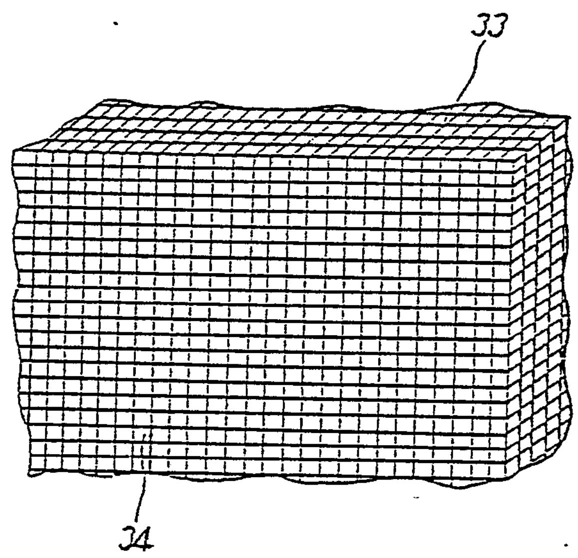

FIG. 10

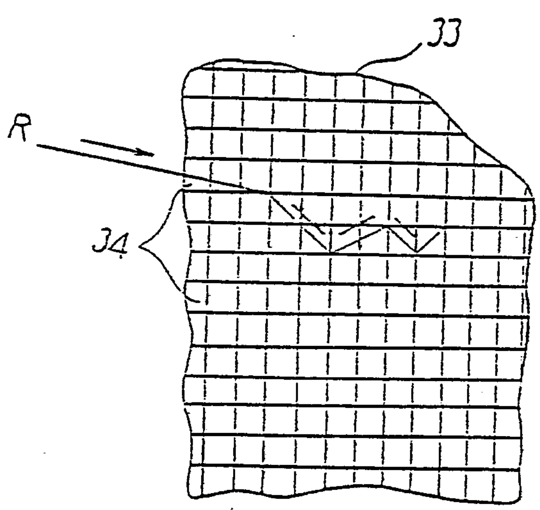

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FIG. 11

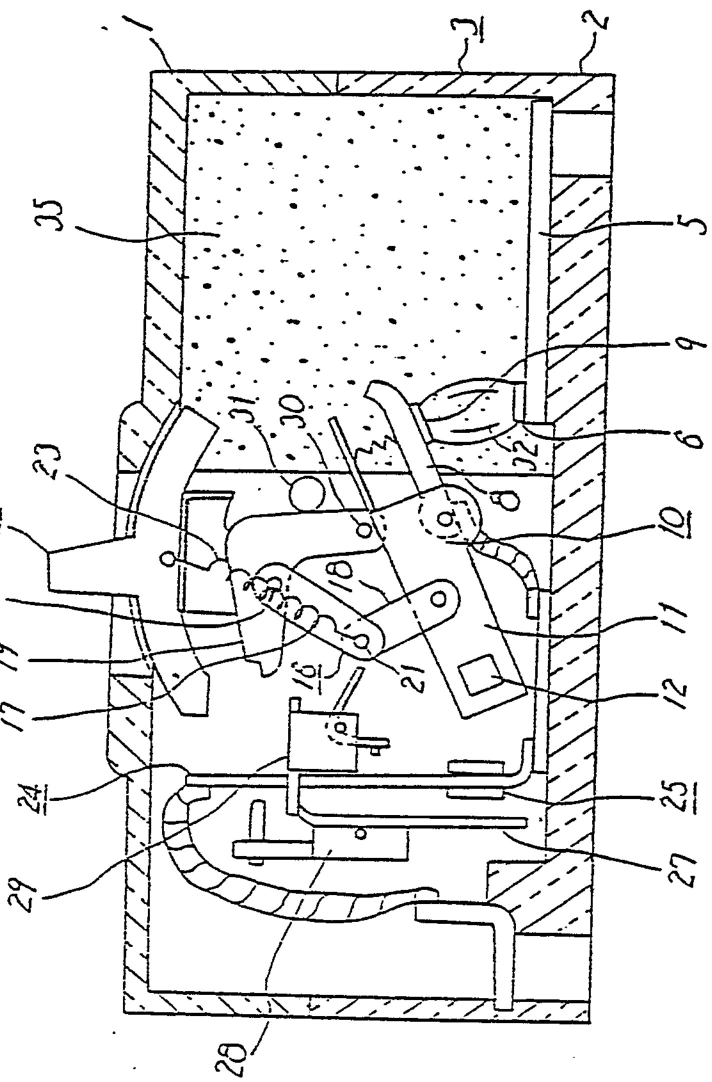

FIG. 12

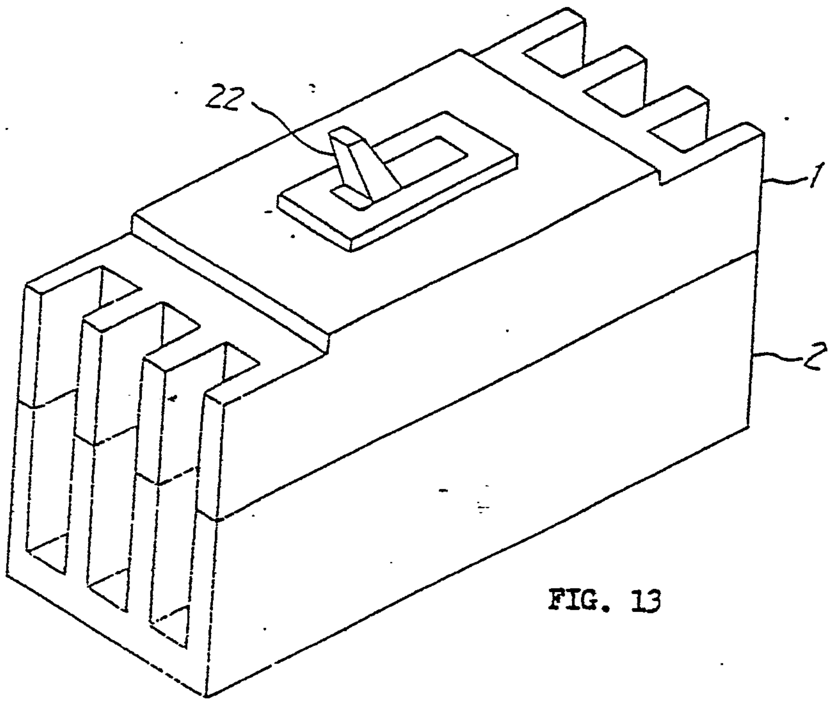

FIG. 13

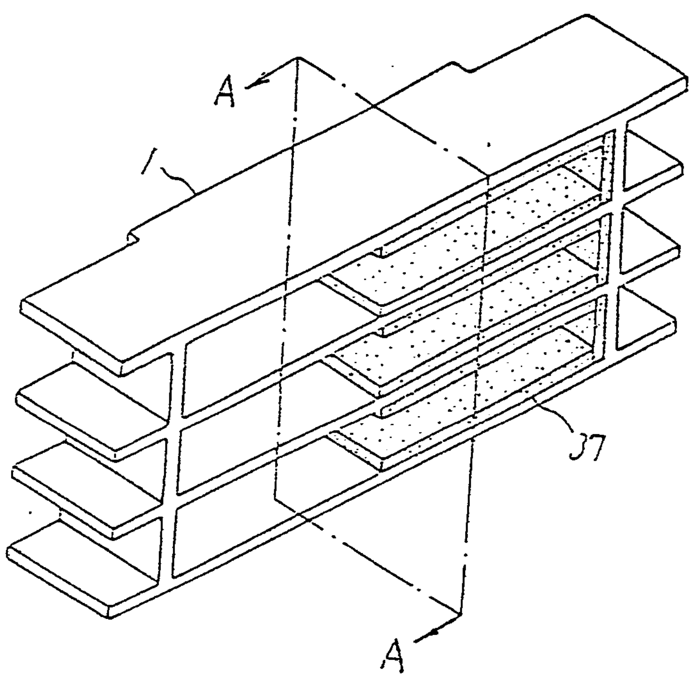

FIG. 14

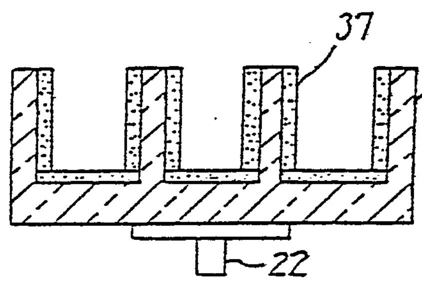

FIG. 15

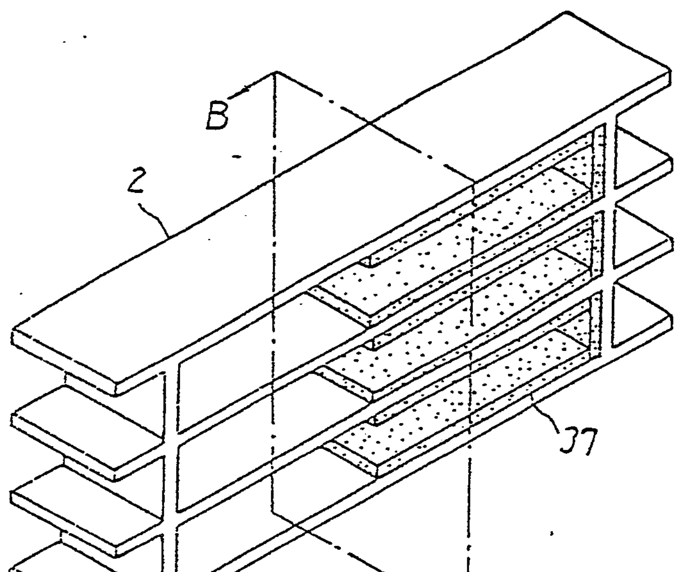

FIG. 16