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Wolfe

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[54] **THERMAL RESPONSIVE SWITCH DEVICE**

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[51] **Int. Cl.** **H01h 37/40**

[58] **Field of Search** 337/306, 320, 321, 326; 73/368.2

[56] **References Cited**

UNITED STATES PATENTS

3,221,319 11/1965 Lindberg, Jr. ..... 337/326 X

OTHER PUBLICATIONS

"Thermal Treatment & Microporous Structure of Carbonaceous Adsorbents," Proceedings of the Fifth Conference on Carbon, Vol. 1, 1962, pp. 81–87.

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[57] **ABSTRACT**

A thermal responsive control device has a flexible diaphragm for opening and closing a switch. An enclosed chamber communicating with one side of the diaphragm has a quantity of adsorbent material with a charge of gas having a pressure below atmospheric pressure at temperatures less than an operating temperature to maintain the switch closed. With either an over heat condition or a leak in the enclosed chamber, the pressure within the chamber increases to atmospheric pressure opening the switch.

13 Claims, 2 Drawing Figures

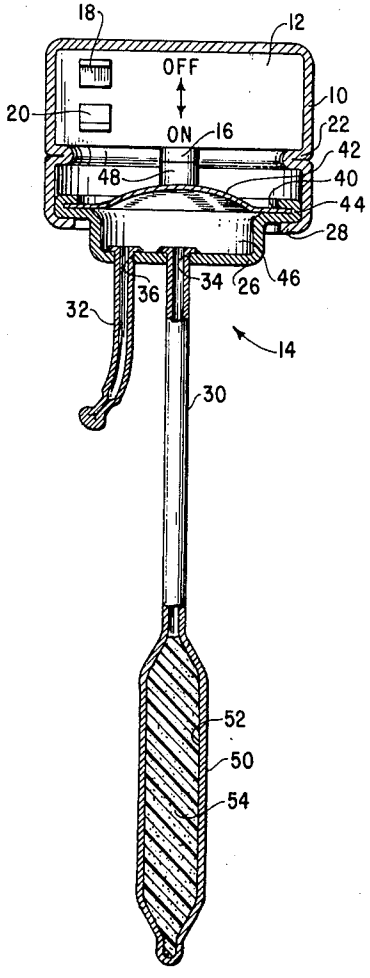


FIG. 1

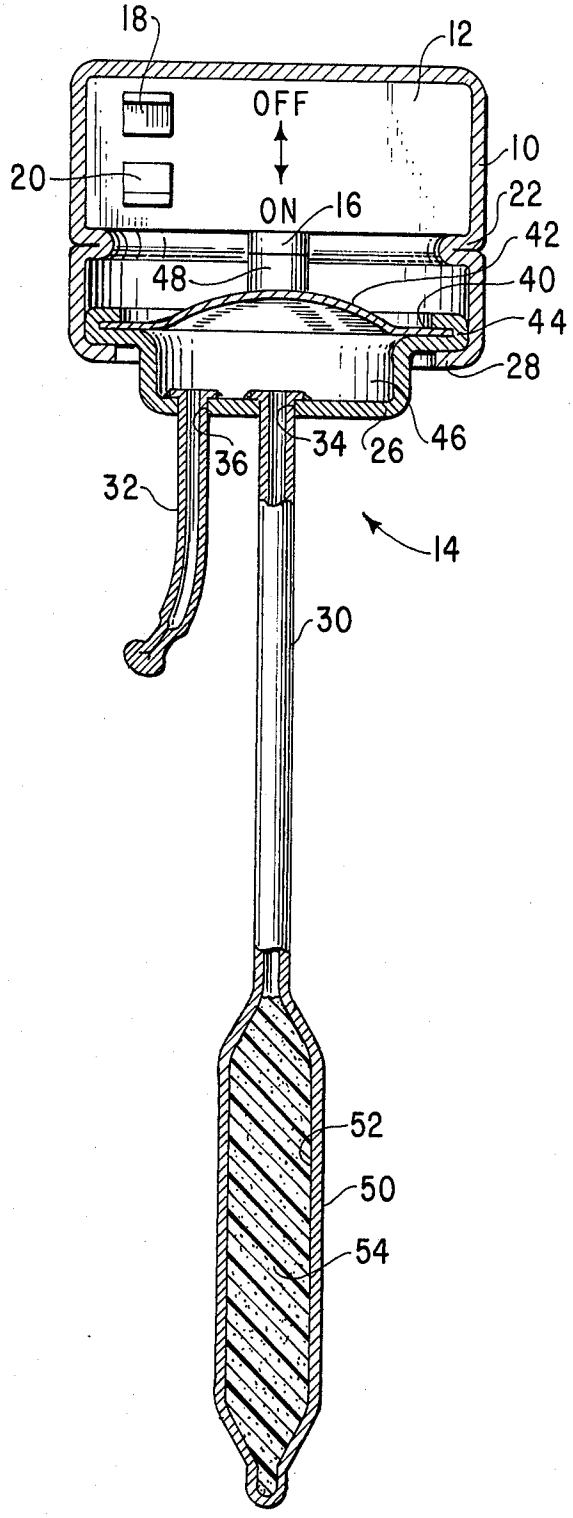
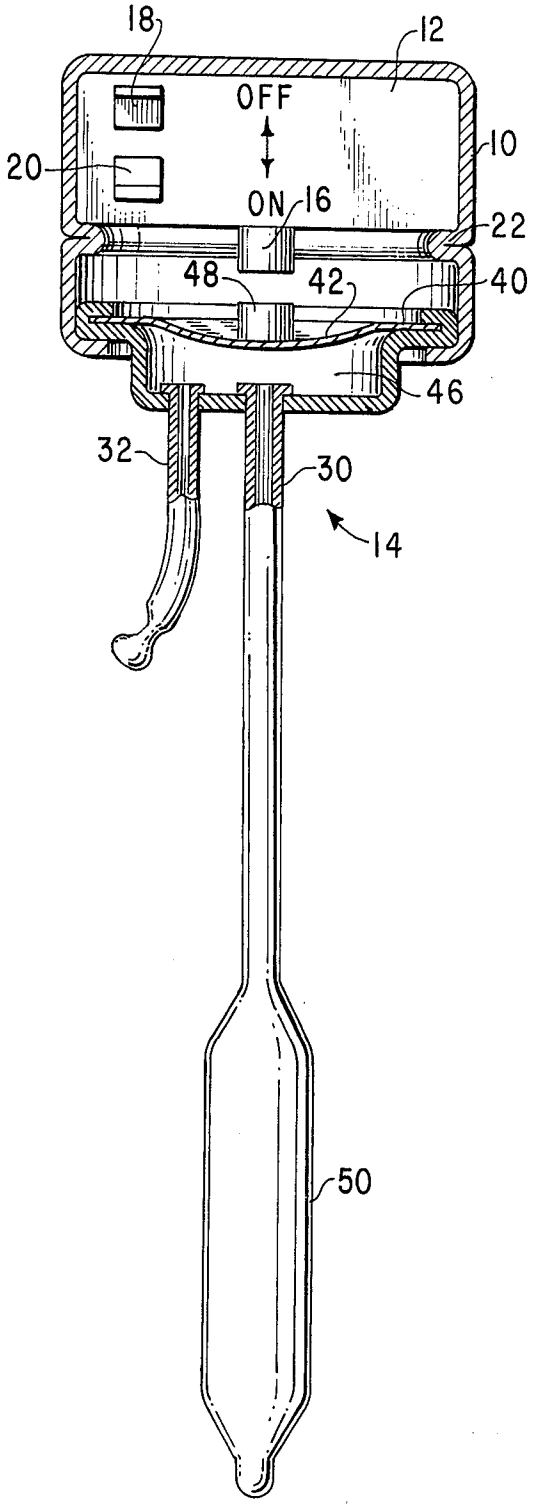

18
12
OFF
10
20
ON
16
22
42
48
40
44
28
46
36
34
26
32
14
30
52
50
54

FIG. 2


18
12
OFF
10
20
ON
16
22
48
42
40
46
32
30
14
50

THERMAL RESPONSIVE SWITCH DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a thermal responsive switch device and, in particular, to a fail-safe limit switch device operated by an internal gas pressure equal to atmospheric pressure. At temperatures less than an operating or limit temperature, the internal gas pressure is normally less than atmospheric pressure.

2. Description of the Prior Art

The prior art, as exemplified by U.S. Pat. No. 3,284,600, contains several liquid and gas charged switch devices charged at a partial vacuum to allow external atmospheric pressure to deflect a diaphragm to close a switch such that when the internal vapor or gas pressure equals atmospheric pressure, either due to a leak or an increase in temperature, the diaphragm is allowed to move to open the switch; such switch devices being known as fail-safe limit switches. Practical prior art fail-safe limit switches have generally been charged with a liquid selected to produce a vapor pressure slightly less than or about equal to atmospheric pressure at the desired operating or limit temperature. Liquid charged switches are subject to the limitations of the availability and various properties, such as the boiling point, of suitable liquids; some liquids irreversibly break down into different materials if exposed to a temperature above a certain maximum temperature, either rendering the liquid charged switch inoperative or greatly changing the operating temperature.

Fail-safe limit switches charged only with a gas have previously not been practical for many applications due to (1) the necessity of a large temperature change to operate the switch, (2) the requirement of a switch sensitive to a small pressure change, and/or (3) the difficulty of manufacturing switches to operate at a set temperature. For example, the above-mentioned U.S. Pat. No. 3,284,600 discloses a control charged to about ⅓ atmospheric pressure at about 21°C, the control having a diaphragm which produces a snap action to open a switch with an increase in pressure to about ⅔ atmosphere; to produce an increase in internal pressure of a gas from ⅓ to ⅔ atmosphere requires an increase in temperature from 21°C to more than 315°C. Slight variations in atmospheric pressure, manufacture, or subsequent changes of parts, such as changes in diaphragm bias, gas charging pressure, and the like, produce large variations in the operating temperature. Thus, in the past, it has been impractical to manufacture, in quantity, gas charged fail-safe switches which operate substantially at a preselected limit temperature.

There are described in the prior art, as exemplified by U.S. Pat. Nos. 2,221,633 and 3,221,319, gas charged switches containing an activated gas adsorbent material, such as activated charcoal, or solid materials which decompose at an elevated temperature to generate a gas pressure; such adsorbent material and decomposable material containing switches not being fail-safe in that they operate at pressure exceeding atmospheric pressure.

Also, the prior art, as exemplified in U.S. Pat. Nos. 1,744,735, 3,258,363, 3,442,819, 3,516,791, and the publication (USSR Academy of Sciences, M. M. Dubinin, "Thermal Treatment and Microporous Structure of Carbonaceous Adsorbents," *Proceedings of the Fifth Conference on Carbon*, Vol. 1, 1962, pages 81–87) contains many adsorbent carbon materials including decomposed polyvinylidene chloride and polyvinylidene fluoride. Adsorbent carbon materials are widely used in removing contaminants, or the like, from gases or liquids. Polyvinylidene chloride and polyvinylidene fluoride, in particular, have been recognized for their molecular sieve property; that is, their ability to absorb certain gaseous materials which have small molecular sizes while being incapable of adsorbing other gaseous materials which have larger molecular sizes.

SUMMARY OF THE INVENTION

The invention is summarized in that a thermal responsive switch device includes electrical contact means for controlling a circuit, means forming a chamber, a charge of gas in the chamber, a quantity of porous adsorbent material in the chamber capable of adsorbing a quantity of the charge of gas, which quantity of adsorbed gas varies with the temperature of the adsorbent material, and movable means responsive to a gas pressure within the chamber equal to atmospheric pressure for operating the contact means, said charge of gas at temperatures below a predetermined temperature of operation having a pressure which is sufficiently less than atmospheric pressure to normally maintain the movable means in an unoperated position.

An object of the invention is to construct a practical gas charged switch device which is operated with either a temperature above a predetermined temperature or a leak within the gas charged system.

Another object of the invention is to provide a fail-safe limit switch which is not dependent upon the boiling point of a liquid charge.

An additional feature of the invention is the employment of an adsorptive carbon material formed from a compound containing both carbon and a non-carbon component by removing the non-carbon component to form a carbonaceous skeletal structure having cavities of sufficient size to receive and adsorb a gas.

Other objects, features and advantages of the invention will be apparent from the following description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross sectional view of a switch device in accordance with the invention.

FIG. **2** is a view similar to FIG. **1** but illustrating another position of the switch device.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As illustrated in FIGS. **1** and **2**, the invention is embodied in a thermal responsive switch device including a housing **10** containing contact means **12** and gas pressure responsive means generally indicated at **14** for operating the contact means **12**. The contact means **12** is shown as a conventional push button switch having a push button **16** for opening a pair of contacts (not shown) connected between terminals **18** and **20** when the push button **16** is depressed to an upward position as illustrated in FIG. **1**. The push button switch **12** includes spring means (not shown) biasing the push button **16** downward to normally close the contacts to complete a circuit between the terminals **18** and **20**. The open and closed positions of the switch **12** are illustrated by the respective indications "off" and "on." The switch **12** is held in the upper portion of the hous-

ing **10** by a deformed ridge **22** in the housing **10** such that the push button **16** projects downward toward the gas pressure responsive means **14.**

The gas pressure responsive means **14** has a support member **26** which is secured to an inwardly formed lip **28** on the housing **10** with one end of tubes **30** and **32** secured and sealed within respective openings **34** and **36** through the support member **26.** A diaphragm **40** having an upwardly deformed bulge **42** is secured and sealed to a crimped portion **44** on the peripheral edge of the support member **26** to form a chamber **46** communicating with the tubes **30** and **32.** The upper surface of the diaphragm **40** is exposed to atmospheric pressure. The diaphragm **40** is made from a suitable flexible elastic material, such as a metal, which can be elastically deflected downward, as shown in FIG. **2,** by the atmospheric pressure above the diaphragm **40** when the pressure in the chamber **46** is substantially below atmospheric pressure. The bulge **42** is formed upward so that it is elastically stressed upward to move a projection **48** on the bulge **42** against the push button **16** with a force sufficient to depress the push button **16** and open the switch **12** when the pressure in the chamber **46** is equal to or slightly less than atmospheric pressure.

The other end of the tube **30** is connected to a bulb **50** having a chamber **52** which contains a porous adsorbent material **54.** The chambers **46** and **52** and the tubes **30** and **32** contain a charge or quantity of gas such as noble gas selected from helium, neon, argon, krypton or xenon. Other gases which are non-reactive at the temperature of use can be employed as long as the gases have a molecular size which is readily adsorbed by the adsorbent material **54.** The particular gas used is selected by considering the cost and desired pressure or volume change per degree temperature change, which pressure or volume change increases directly with the molecular weight of the gas; for example, xenon, produces a greater pressure or volume change per degree temperature change that krpyton.

The adsorbent material **54** can be one of the many activated materials or can be a carbonaceous material formed from a compound containing carbon and a non-carbon component by removing the non-carbon component to leave a carbonaceous skeletal structure having cavities of sufficient size to receive and adsorb substantial quantities of the gas. Preferably, the compound is a synthetic polymer having volatile components, such as hydrogen and a halogen, which can be driven off by heat leaving a carbonaceous skeletal structure which is porous. Suitable synthetic polymers include polyvinylidene chloride and polyvinylidene fluoride, the former available in copolymer form as SARAN 113 from Dow Chemical Company. Polyvinylidene chloride or polyvinylidene fluoride are formed into adsorbent carbons by carbonizing or pyrolytic decomposition in a purifying atmosphere, such as a vacuum or a purging flow of inert gas. Carbonizing is performed by heating to a temperature less than the melting point but greater than the temperature at which decomposition can be initially observed. For polyvinylidene chloride, carbonizing is performed at a temperature in the range from 138°C (280°F) to 177°C (350°F). The duration of heating required for complete carbonization of the synthetic polymer is dependent upon the size of the granules of the synthetic polymer and the temperature employed. Along with utilizing a predetermined temperature and duration for a certain size of granular synthetic polymer, observation of a reduction in gas being removed by a vacuum system or the gas being involved from the granular material are methods of determining complete carbonization. During carbonization, the non-carbon components, hydrogen and the halogen, are volatilized and removed from the synthetic polymer structure leaving a carbon skeletal structure which is highly porous. After the synthetic polymer is carbonized, the carbonized polymer can be subjected to a higher temperature up to 1,510°C (2,750°F) to outgas hydrogen and halogen gases which may have been adsorbed. Outgassing can be completed in a short duration, for example, 15 minutes.

In manufacture of the thermal switch device, the adsorbent material **54** is placed within the chamber **52** of the bulb **50,** and the bulb **50,** tube **30,** tube **32,** support member **26,** diaphragm **40,** projection **48,** switch **12,** and housing **10** are assembled with the free end of the tube **32** left open. The open end of the tube **32** is connected to an evacuation and gas charging apparatus while the bulb **50** is heated to outgas air adsorbed by the adsorbent material **54.** The temperature of the bulb **50** is then adjusted to a predetermined limit temperature or an operating temperature at which the switch **12** is to be opened. A charge of gas is applied to the tube **32** until the switch **12** is operated by upward movement of the diaphragm bulge **42.** At this point, the open end of the tube **32** is sealed and the thermal switch device is completed. The thermal switch device can be connected by the terminals **18** and **20** in any suitable control circuit which is to be deenergized by opening of the switch **12** in response to the bulb **50** being heated to the predetermined limit temperature.

In operation of the thermal switch device, with either the exposure of the bulb **50** to the predetermined operating temperature indicating an unsafe condition, or a leak within the enclosed system including the chambers **46** and **52** and the tubes **30** and **32,** the pressure within the chambers **52** and **46** is increased to about atmospheric pressure whereupon the bulge **52** of the diaphragm **40** moves upward engaging the projection **48** with the push button **16** of the switch **12** opening the contacts and the circuit between the terminals **18** and **20.** In the normally unoperated position, as illustrated in FIG. **2,** the pressure within the chamber **46** is below atmospheric pressure which allows the force due to the atmospheric pressure to depress the bulge **42** disengaging the projection **48** from the push button **16** allowing the spring bias of the switch **12** to close the contacts in the circuit between the terminals **18** anad **20.**

The porous adsorbent material **54** adsorbs a substantial quantity of the gas within the chamber **52** resulting in a significantly greater mass or quantity of gas in the chamber **52** at pressures below atmospheric pressure than is possible without the adsorbent material **54.** The adsorbed quantity of gas varies inversely with the temperature of the material **54;** that is, the quantity of adsorbed gas decreases when the temperature increases, and the quantity of adsorbed gas increases when the temperature decreases. The change in gas pressure in the chamber **52** caused by a change in temperature of the bulb **50** is due to (1) the adsorption or desorption of gas from the adsorbent material **54,** and (2) the increase or decrease in kinetic energy of non-adsorbed gas. The rate of adsorption and desorption of gas in many porous adsorbent materials per degree tempera-

ture change in particularly large at pressures in a range extending from about atmospheric pressure down to a pressure significantly less than atmospheric pressure. The absorption and desorption of gas from the adsorbent material **54** due to temperature change greatly increases the rate of increase or decrease of gas pressure change in the chambers **46** and **52** and tubes **30** and **32** per degree temperature change of the bulb **50**; thus, the utilization of adsorbent material **54** makes possible a practical gas charged fail-safe switch which is operated by an increase in internal pressure to atmospheric pressure either by an increase in temperature or a leak in the internal gas system.

The employment of the gas adsorbent material **54** within the bulb **50** results in a thermal switch device which can be used as a replacement for similar liquid filled safety limit controls. The gas filled limit control has the advantage over liquid filled limit controls in that it can be calibrated at any temperature within a wide range of temperatures whereas the liquid filled limit control is limited to about the boiling point of the liquid charge. Additionally, the gas charged limit control can be utilized for limit temperatures exceeding 357°C (675°F) which is about the boiling point or limit of a mercury containing fail-safe switch device.

Of the adsorbent materials, the carbonaceous material formed by removing a non-carbon component from a carbon component produces more change in pressure or volume per degree temperature change than activated adsorbent materials, particularly when used in conjunction with one of the heavier noble gases, argon, krypton or xenon. While the structural distinction or properties of the decomposed carbon compound, such as the carbonized synthetic polymer, that cause its improved pressure or volume change per degree temperature change cannot be visually observed, various theories of the structural properties have been formulated by observation of other properties of the carbonized polymer. ACtivated materials, such as activated charcoal, have pores or cavities which are funnel-shaped or cone-shaped; whereas, the carbonized synthetic polymer has cavities which are slit-like or have substantial portions with relatively uniform width throughout the depth of such portions. In making activated carbons, the eroding or activation process produces the funnel-shaped cavities; activating or eroding carbonized synthetic polymer with steam or the like will substantially deteriorate and eventually destroy the improved volume or pressure change per degree temperature change of adsorbed gas in the carbonized synthetic polymer. The slit-like cavities of the carbonized synthetic polymer are believed to result from the production of the cavities by removing or volatilizing the non-carbon components of the polymer while in a solid state.

It is also theorized that the width or diameter of the cavities or pores or their inlets substantially effects the adsorbent properties of the carbonized polymer. Using a Kelvin method of measuring pore size, it has been determined that the pore size of carbonized polyvinylidene chloride ranges from 10 to 15 angstroms in width or diameter, while the diameter of pores in activated charcoal ranges from 15 to 200 angstroms with an average pore size much larger than 17 angstroms. An average cavity or inlet width in the range generally from about 9.2 angstroms to about 17 angstroms and preferably from 12 to 15 angstroms in the carbonized synthetic polymer produces the improved volume or pressure change per degree temperature change at pressures in a range extending from about atmospheric pressure down to pressures significantly less than atmospheric pressure. The cavity size of carbonized synthetic polymer can be reduced by heating in the range from 1,510°C (2,750°F) to 2,205°C (4,000°F). A brief activation with steam, carbon dioxide, or the like can be employed to enlarge the cavities.

Van der Waals forces are theorized as being the main attractive force resulting in adsorption of gas molecules. The width of the cavities in the carbonized synthetic polymer being slightly larger than 2 diameters of the monatomic molecules of noble gas results in increased van der Waals forces within the cavities due to the closeness of several crystalline faces, carbon lattice structures, or walls in the cavities. Also, the van der Waals forces are generally greater for larger molecules which results in the heavier monatomic gases having a greater volume or pressure change per degree temperature change than the lighter monatomic gases. Since van der Waals forces are attributed to to weak dipoles, the carbon lattice arrangement produced by the carbonization of a synthetic polymer may have a stronger dipole than other atomic crystalline structure. The apparent van der Waals forces, as judged by internal pressure change per degree temperature change of the carbonized synthetic polymer are approximately 1.8 times that of activated carbon.

Another structural distinction is found in the number of cavities in the unit weight of the adsorbent carbon material. Carbonized polyvinylidene chloride, as measured by a BET method, has a surface area of 1,200 m^2/gram whereas activated charcoal has a surface area in a range of from 500 to 1,000 m^2/gram. The surface area is believed to be proportional to the number of pores. The formation of pores or cavities by removing the non-carbon components from a carbonaceous compound leaving a skeletal carbon structure is believed to result in a more porous structure than that formed by eroding or activating cavities in a carbon material.

One particular advantage of using an adsorbent unactivated carbonized compound as opposed to using an activated carbon is the uniformity that can be achieved in manufacturing the thermal responsive switch device. Different batches of carbonized polyvinylidene chloride produced in different process runs have substantially identical adsorption properties, whereas different batches of activated charcoal vary widely in adsorption properties; thus, the thermal responsive switch device employing an unactivated carbonized compound makes possible the practical manufacture of large quantities of dependable thermal responsive switch devices which utilize adsorbent carbon and a gas.

Since many variations, modifications and changes in detail can be made to the present embodiment, it is intended that all matter in the foregoing description and the accompanying drawing be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A thermal responsive switch device comprising
electrical contact means for controlling a circuit,
means forming a chamber,
a charge of gas in the chamber,
a quantity of porous adsorbent carbonaceous material including a decomposed synthetic polymer selected from the group consisting of decomposed

polyvinylidene chloride and decomposed polyvinylidene fluoride in the chamber capable of adsorbing a quantity of the charge of gas, which quantity of adsorbed gas varies inversely with the temperature of the adsorbent material, and

movable means responsive to a gas pressure within the chamber equal to atmospheric pressure for operating the contact means,

said movable means being in an unoperated position when gas pressure within the chamber is less than a predetermined pressure which is less than atmospheric pressure, and

said charge of gas at temperatures below a predetermined temperature of operation having a pressure which is sufficiently less than atmospheric pressure to normally maintain the movable means in the unoperated position.

2. A thermal responsive switch device as claimed in claim **1** wherein the carbonaceous material is formed by removing the hydrogen and halogen components to form a carbonaceous skeletal structure having cavities of sufficient size to receive and adsorb the gas.

3. A thermal responsive switch device as claimed in claim **1** wherein the adsorbent material has cavities with substantially uniform inlets of a size large enough to allow entrance and adsorption of monatomic gas in the cavities but small enough to retain substantial quantities of adsorbed gas, and the charge of gas includes a noble gas.

4. A thermal responsive switch device as claimed in claim **3** wherein the average width of the inlets of the cavities in the adsorbent material is within the range from 9.2 angstroms to 17 angstroms.

5. A thermal responsive switch device as claimed in claim **1** wherein the decomposed synthetic polymer is formed by a process including the steps of subjecting a synthetic polymer to a purifying atmosphere, and heating the synthetic polymer while subjected to the purifying atmosphere to a temperature above its decomposition temperature but below its melting temperature to form cavities at sites of volatilized components of sufficient size to receive and adsorb molecules of the gas.

6. A thermal responsive switch device as claimed in claim **5** wherein the synthetic polymer includes polyvinylidene chloride, and the synthetic polymer is subjected to a temperature in the range from 138° to 177°C to substantially completely carbonize the synthetic polymer.

7. A thermal responsive switch device as claimed in claim **1** wherein the charge of gas includes a noble gas selected from helium, neon, argon, krypton and xenon.

8. A thermal responsive switch device as claimed in claim **7** wherein the noble gas is selected from argon, krypton and xenon.

9. A thermal responsive switch device comprising

electrical contact means for opening and closing the circuit with spring means normally biasing the contact means closed,

a support member,

a flexible diaphragm secured to the support member to form a first chamber on a first side of the diaphragm, the other side of the diaphragm being exposed to atmospheric pressure,

a tube communicating with the first chamber,

a temperature sensing bulb having a second chamber communicating with the tube,

a quantity of adsorbent carbon material in the second chamber,

said adsorbent carbon material formed by decomposing a synthetic polymer selected from the group consisting of polyvinylidene chloride and polyvinylidene fluoride,

a charge of gas within the first chamber, the tube, and the second chamber having a pressure which at temperatures below a predetermined limit temperature is sufficiently lesser than atmospheric pressure to normally deflect the diaphragm and close the contact means, and

means on the diaphragm for engaging the contact means to open the contact means when the first side of the diaphragm is subjected to a pressure equal to atmospheric pressure.

10. A thermal responsive switch device as claimed in claim **9** wherein

the adsorbent carbon material includes decomposed polyvinylidene chloride.

11. A thermal responsive switch device comprising

electrical contact means for controlling a circuit,

means forming a chamber,

a charge of gas in the chamber,

a quantity of adsorbent material having cavities with an average width in the range of about 9.2 to 17 angstroms in the chamber, and

movable means responsive to a gas pressure within the chamber equal to atmospheric pressure for operating the contact means,

said movable means being in an unoperated position when gas pressure within the chamber is less than a predetermined pressure which is less than atmospheric pressure,

said charge of gas including gas molecules having widths which are readily adsorbed in the cavities, and

said charge of gas at temperatures below a predetermined temperature of operation having a pressure which is sufficiently less than atmospheric pressure to normally maintain the movable means in the unoperated position.

12. A thermal responsive switch device as claimed in claim **11** wherein

the adsorbent material is a carbonaceous material formed by the decomposition of a synthetic polymer,

the cavities have substantially uniform widths throughout portions of the depths of the cavities, and

the charge of gas includes a noble gas.

13. A thermal responsive switch device as claimed in claim **12** wherein the cavities have an average width in the range of about 12 to 15 angstroms.

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