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(54) Improved insulated-glass window.

(57) There is disclosed an improved insulated-glass window which is provided with means to reduce or eliminate glass deflection due to changes in the ambient atmosphere. The means comprises a breather tube or passage (18) communicating between the enclosed window space (14) and the ambient atmosphere and which contains an amount of an adsorbent material (19), such as a molecular sieve.

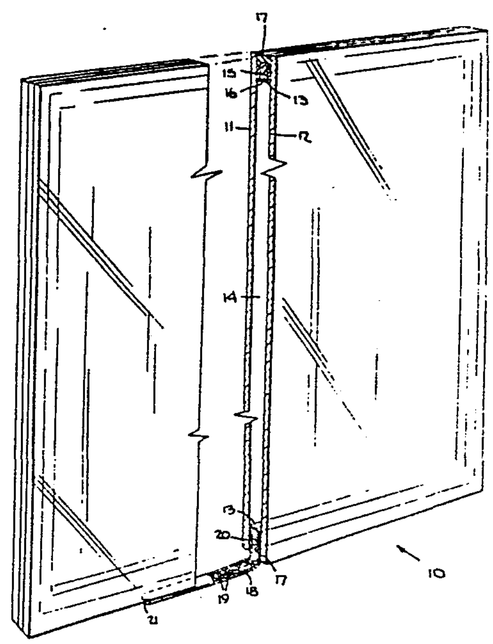

Fig.3.

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DESCRIPTION.

"IMPROVED INSULATED-GLASS WINDOW".

This invention relates to an improved insulated-glass window and more particularly to such a window which is provided with means to reduce or eliminate window deflection due to changes in pressure in the enclosed window caused by pressure or temperature changes in the ambient atmosphere.

In early insulated-glass windows, the glass panes were sealed together to permanently enclose a space between the panes, after first drying the air in the enclosed space. Optionally, a partial vacuum was also formed in the enclosed space. Due to a number of reasons, such as expense, difficulty of manufacture, etc., most insulated-glass windows today are not glass-sealed. Rather, in their simplest form, the glass panes are separated by a channel which extends around the entire window periphery. A suitable sealant is provided outside of the channel around the window periphery to both provide a barrier to the passage of moisture into the enclosed space within the window and also to hold the parts of the window together.

Such channels may be in the form of extruded hollow aluminium and may be filled along the entire length of the channel or only partially with an adsorbent such as a silica gel and/or a molecular sieve material, etc. The purpose of the adsorbent was to assure that the air enclosed by the sealed window remains dry and thereby avoid condensation on an inner surface thereof. Suitable means, for example a small slit along the inner channel surface, was provided to enable the enclosed adsorbent to keep the enclosed air dry. As long as the window periphery remains sealed, the enclosed air remains dry (i.e., its dew point remains low) and condensation is avoided on an inner surface thereof.

One problem with such windows is deflection of the glass pane(s) due to changes in temperature and barometric pressure. Thus, as the temperature of the enclosed air decreases, its volume and exerted pressure also decreases and the lass panes tend to deflect inwardly. Similarly, with increasing temperature, the deflection is outward. Such glass deflection results in distorted visual effects and induces stress in the glass which can result in breakage in some extreme cases.

These temperature-related deflections are quite apart from deflection caused by wind and the like against the window and are most noticeable with large windows and with reflective windows. With large-size windows, deflection is simply more apparent to the eye. With reflective windows (i.e., those windows which are provided with a reflective coating on the inside of the outside pane), deflection is much more apparent due to the presence of the reflective coating. It is also believed that some molecular sieve-type adsorbents exacerbate such temperature-caused deflection because they tend to adsorb nitrogen from the enclosed air and thereby further diminish the volume/pressure of air within the enclosed space.

It has also been observed that with high desiccant loads (i.e., the ratio of the weight of adsorbent or desiccant, in grams, to the weight, in grams, of the air in the enclosed space) on the order of 30 - 40, and at temperatures different from the temperature at which the window was sealed, some molecular sieves adsorb additional air, thereby further worsening temperature change-induced deflection. Furthermore, if air is already adsorbed by the adsorbent prior to completion of the manufacture of the window, part of such adsorbed air may be released into the enclosed space as the temperature increases, which also further worsens any temperature change-induced deflection of the window panes.

The occurrence of deflection in insulated-glass windows has been recognized in the prior art. Thus, U.S. Patent No. 4,144,196 discloses fluctuations in interior pressure in sealed insulating glass, caused by adsorption by and desorption from molecular sieve desiccants, which in turn causes some distortion of view through the windows as well as movement of the glass panes with a resulting tendency to weaken the seal between the two panes (see column 2, lines 3 - 59). K.R. Solvason, in "Pressure and Stresses in Sealed Double Glazing Units", Technical Paper No. 423, National Research Council of Canada, Division of Building Research, Ottawa, August, 1974, describes a method for calculating the pressure differences that occur on sealed double-glazing units due to the combined effects of changes in temperature and barometric pressure.

Union Carbide Corporation Bulletin 4417 (1980), entitled "MOLSIV[R] XL Adsorbents For Climatically Unstable Units", discusses the effects on insulated glass units due to changes in temperature and pressure and notes that the stress in the glass panes caused by inside air expanding or contracting is usually relieved by slight glass deflection.

Other prior art exists which relates to insulated glass windows or other enclosures provided with means communicating between the enclosed space and the ambient atmosphere. For example, capillary breather tubes (i.e., long, small-diameter tubes connecting the enclosed air space and the ambient atmosphere) in insulated glass windows are known. Their usual purpose is to allow pressure equalization during transport prior to installation. To minimize the entry of atmospheric water, which would eventually fog the window, the capillary device depends upon an extremely small diameter tube and long path. Thus, the calculated diffusion of water into the window should be less than the amount expected to fog the window during its estimated life. Such tubes are primarily designed for use only prior to installation and, at the time of installation, they may be pinched off, thereby sealing the tube against the ambient atmosphere.

Tightly-sealed enclosures known as "glove boxes" or "dry boxes", primarily for laboratory or industrial use, are known. These are typically used to manipulate materials under controlled atmospheric conditions, and may be provided with a passageway, containing silica gel and/or molecular sieve desiccant, communicating with the ambient atmosphere.

U.S. Patent No. 3,274,751 relates to a method of ventilating an enclosed space by transferring gas into and out of the space through a heat barrier and/or means to control the moisture of the gas. Desiccant materials such as silica gel, molecular sieves, activated carbon or alumina, etc., can be used for these purposes. Similar and related concepts are disclosed in U.S. Patent Nos. 2,675,089 and 2,944,627 and in German Patent No. 971,886.

British Patent No. 1,249,050 discloses a desiccant package containing silica gel, activated clay or molecular sieves, to prevent or reduce condensation in the engine compartment of a motor vehicle. The desiccant may be reactivated when the engine is subsequently operated.

The present invention comprises a sealed insulated-glass window unit which is provided with an adsorbent-containing passage communicating between the enclosed air space and the ambient atmosphere. Window deflection due to temperature and/or barometric pressure changes are thus eliminated or substantially reduced. The adsorbent-containing passage enables the unit to inhale-exhale air as necessary to compensate for deflection while still maintaining a low dew point in the enclosed space. Air dried by the adsorbent will be admitted to the unit when the external pressure is greater than that existing in the unit's enclosed space and air will be rejected through the adsorbent when the reverse situation occurs. This rejection of air will regenerate the adsorbent in the passage. Thus, pressure variations may be rapidly equalized and the effective life of the window unit is increased.

The invention will now be further described by way of example with reference to the accompanying drawings in which:-

Figures 1 and 2 are perspective and cross-sectional views of a prior art sealed insulated-glass window unit,

Figure 3 is a perspective view of a sealed insulated-glass window of the present invention, and

Figure 4 is a cross-sectional view of part of this arrangement of Figure 3.

Figures 1 and 2 illustrate a typical prior art sealed insulating-glass window. Referring to Figures 1 and 2, a sealed insulated-glass window 10 is shown which comprises two glass panes 11 and 12 separated by a channel 13 disposed around the entire periphery of the window, and thereby defining an interior space 14. Sealant 17, disposed around the entire periphery of the window 10, serves to hold the entire unit together as well as a moisture barrier.

The channel 13 contains within it an adsorbent material, for example in the form of beads 15. The adsorbent may extend in the channel along all or only part of the periphery of the window. The channel 13 is either perforated or not completely sealed so that the air in enclosed space 14 may contact the adsorbent.

For example, a slit 16 may be provided along the inner periphery of channel 13 for this purpose. The particular configuration of such slit or perforation is not critical and does not per se form a part of the present invention. Similarly, the shape or configuration or material of construction of channel 13 and the type of sealant 17 are not critical and also per se form no part of the present invention.

Specifically, the shape or configuration of the channel is not critical to the present invention since its primary purposes are only to separate the glass panes from one another and define the enclosed space and to hold or contain the adsorbent. Therefore, any conventional type of channel, used in conventional sealed insulating-glass windows, can be employed in the present invention. Similarly,the nature or type or configuration of the slit or perforations in or along the inner periphery of the channel is not critical. The primary purpose for such a slit or perforation is to provide access to the air in the enclosed space such that the adsorbent contained or held within the channel can adsorb moisture or other gases contained within the enclosed air space. Therefore, any configuration or type of slit or perforation along the inner periphery of the channel to accomplish such purpose can be employed in the present invention.

The particular sealant used in the present invention is also not critical. The primary purposes of the sealant are to provide a moisture barrier and to hold the entire unit together. In the prior art, three different types of sealant systems have been employed. The first is referred toas a single seal and generally employs a thermosetting-type of polymer, such as a polysulfide, a urethane, a silicone, etc., which is simply filled into the space between the glass panes outside of the channel, as illustrated in Figure 1. The second type of sealing system is referred to as a dual seal and comprises, in addition to a polymeric sealant along the outer periphery of the channel between the glass panes, a sealing bead of non-setting material disposed along the top and bottom of the channel in contact with the upper and lower glass panes. A suitable indentation in the channel may be provided in which such a sealing bead sits. In addition, such a bead typically extends along the entire length of the channel around the periphery of the window unit. The primary purpose of such a bead is to serve as a water-barrier and it typically serves no adhesive function in holding the window together. The bead may be comprised of a polymer such as polyisobutylene.

The third type of sealing system is a so-called hot melt unit. This sytem is similar to the single seal system but instead of thermosetting polymer, a thermoplastic polymer, such as polyisobutylene or other forms of butyl rubber is employed. In this system, the thermoplastic polymer is simply extruded or applied into the space outside the outer periphery of the channel and between the glass panes.

The particular adsorbent contained in the channel of the window of the present invention is also not critical. Generally, the selection of the adsorbent depends at least in part upon the particular material used as the sealant. More particularly, when a thermosetting polymer sealant is employed, the type of adsorbent used depends in part upon the nature and type of solvent used in the polymer. For example, where a polysulfide single sealant system is employed, which normally contains an organic solvent such as toluene, xylene, methyl ethyl ketone, alcohols, and the like, the adsorbent selected must be one capable of adsorbing such organic solvents as they migrate into the enclosed space between the glass panes of the unit. For example, a large-pore size molecular sieve or a silica gel adsorbent may be employed to adsorb these organic solvents. A typical blend of adsorbents which may also be used in such a case may be a blend of a small-pore size molecular sieve (in order to adsorb moisture) and a silica gel adsorbent (for adsorption of organic solvent materials). Alternatively, a large-pore size molecular sieve may be employed since it adsorbs both moisture and organic solvents.

With the dual sealant system, using a sealing bead of polyisobutylene for example, there would be little or no solvent migration into the enclosed space since such migration would normally be prevented by the sealing bead. Therefore, the selection of adsorbent may be made generally without regard to the particular solvent used in the polymer sealant. It is, however, recommended that either a large pore size molecular sieve or a silica gel be used as one of the adsorbent materials in the channel in order to guard against the possibility of solvent migration past the sealing bead.

With the hot melt sealant systems, there are no solvent migration problems. The preferred type of adsorbent with such a sealant system is a small-pore size molecular sieve.

Generally speaking, any of the known types of adsorbents may be employed in the sealed insulating-glass window units in the present invention, such as activiated carbon, activated alumina, silica gel, zeolite molecular sieves and the like. These are all known materials and are all commerically available. By "zeolite molecular sieves" are meant crystalline metal aluminosilicates, either naturally occurring or synthetic, which are available in different pore sizes. The pores or channels of the zeolite molecular sieves are of uniform size ranging from about 3 to about 10 Angstroms, depending on the unit structure of the particular species. A very complete description of these materials may be found in "Zeolite Molecular Sieves" by D.W. Breck, John Wiley and Sons, New York (1974), incorporated herein by reference. Suitable examples of zeolite molecular sieves are those materials which are known by the generic names Type 3A, Type 4A and Type 13X. The kinetic diameter of the water molecule is considered to be about 2.7 Angstroms. The pore sizes of Types 3A and 4A molecular sieve are about 3 and about 3.8 Angstroms, respectively. Therefore, Types 3A and 4A are typical choices as small-pore molecular sieves where water adsportion is the principal objective. Molecules of organic solvents emanating from certain sealants as described hereinabove are usually larger in diameter than the water molecule and hence the use of a large-pore molecular sieve such as Type 13X or Type Y (about 7.4 Angstroms diameter) is indicated to take up such molecules. The molecular sieve adsorbent is normally employed in the form of beads or extruded pellets, although the particular configuration or shape of the adsorbent is not critical to the present invention.

Where a blend of adsorbents it utilized, it is convenient and it is therefore preferable to use an agglomerated adsorbent body which contains two different adsorbents in the same body. Such materials are commercially available, for example, from the Union Carbide Corporation under the tradename XL Adsorbents. In addition to molecular sieve adsorbents in bead, pellet or other agglomerated form, silica gel adsorbents are available in the form of mesh and it is possible to employ a blend of molecular sieve agglomerates and silica gel mesh as the adsorbent mass in the present invention.

Figure 3 is a perspective view of a sealed insulating-glass window unit of the present invention provided with an adsorbent-containing breather tube. The description hereinafter will make reference to a "breather tube" for purposes of convenience only. It is to be expressly understood that the exact configuration of the passage or conduit communicating between the enclosed window and the ambient astmosphere is not critical and may vary as desired. The same reference numerals are utilized in Figure 3 as in Figures 1 and 2 to designate the same parts. Referring to Figure 3, it is seen that the window 10 is provided with the breather tube 18 which communicates, via opening 20, from the interior of channel 13 (and,via slits or perforations 16, from the enclosed space 14 within the window) to the ambient atmosphere via opening 21. Contained within breather tube 18 is an amount of adsorbent material 19. The particular location in the window structure where the breather tube is provided is not critical, and would depend upon factors such as where the window unit is to be ultimately used, the size of the window, the size and length of the tube itself, aesthetic conditions, etc. In Figure 3, the tube is shown as being provided along one edge of the unit. Any convenient design means may be used to provide access to the ambient atmosphere. For example, when the window is installed, a removable plug may be provided to open the breather tube. In actual use however, and for purposes of the present invention, the tube may be located in any convenient place within the structure of the window construction. The only critical design feature is that the tube connects the enclosed space within the window (preferably through channel 13 as shown in Fig. 3, primarily for aesthetic considerations so that the tube is not visible) to the ambient atmosphere. Of course, the tube must be sized depending upon the various factors discussed below and the size and length of the tube will dictate to a degree its location in the window structure.

The preferred adsorbent contained within the breather tube is a molecular sieve, although if properly designed, any conventional adsorbent such as those mentioned above may be employed for this purpose. The particular adsorbent selected will depend upon the particular sealant system used (for the reasons discussed above), the location where the window is to be ultimately used, the materials expected to be adsorbed in use, the size and length of the tube, economics, etc. Those skilled in the art, given the necessary design and engineering constraints of the window in use, should be capable of selecting an appropriate adsorbent for the breather tube.

Since the primary purpose of the breather tube is to eliminate or substantially reduce the occurrence of deflection of the panes of the window while preventing at the same time the introduction of moisture to the enclosed space within the window, the breather tube should be sized to attain this objective. More specifically, the size and length of the tube, and the amount of the adsorbent contained within it, are dependent upon the rate of air flow through the tube necessary to obtain equilibration of pressure thereby avoiding deflection of the glass panes and the requirment to prevent excessive moisture introduction into the enclosed window space. Since it is preferred to equilibrate as rapidly as possible the pressure within the enclosed space, with respect to the pressure in the ambient atmosphere, the minimal size and length of the tube is therefore that necessary to obtain rapid equilibration. However, a countervailing consideration is that the larger the tube becomes, the larger the tube becomes, the larger the risk that excessive moisture will enter the enclosed window space and fog the glass panes. The maximum dimensions of the breather tube are dictated by the limiting factor of moisture introduction and by economics. The relationships and guidelines in designing the proper size of breather tube will be discussed below.

Of equal importance in consideration of the use of breather tubes are the rate of pressure equalization afforded by the tube and the rate of moisture ingression into the window through the tube. Qualitatively, the considerations are to allow sufficient dimension of the tube that resistance to flow of air should be relatively small thus allowing for reasonably short equilibration time and at the same time the available cross-sectional area should not be so large that moisture can readily diffuse into the air space. The following discussion concerns the design of the length and inner diameter of an empty, capillary tube (not of this invention) to determine the effective life of a window unit in which it is installed. Based on these design criteria and certain modifications thereto, as discussed below, a breather tube of the present invention (i.e. containing an adsorbent material and generally larger in diameter than a capillary tube) may be similarly designed to achieve the objectives of the present invention.

The equilibration of pressure through any breather tube (i.e., capillary or a larger molecular sieve-filled tube) takes place by motion of air through the tube. The fluid motion is driven by the existing pressure gradient across the length of the tube. For capillary tubes, such motion is described quantitatively by the equations for Hagen-Poiselle flow. Such flow is steady or at least quasi-steady, and the simplification of ignoring the acceleration term from the Navier Stokes equations affords a closed-form solution that closely approximates the true behaviour of the fluid flow through a capillary tube under the relatively mild pressure gradients normally experienced. It can be shown that the mass flux through a capillary tube of inside diameter D under the influence of a preassure gradient $(P-P_o)/L$, where P is the internal pressure, P_o is the external pressure and L is the length of the capillary tube, is given by:

$$\frac{dm}{dt} = -\frac{(P-P_o)}{L} \quad \frac{\pi}{128} \quad \frac{r}{q} \quad D^4 MW_{Air} \qquad (1)$$

where r is the fluid density and q is the fluid viscosity.

Writing the ideal gas law in the form P = MRT/V and holding V, the volume, and T, the temperature, constant and differentiating with respect to time, equation (2) results:

$$\frac{dP}{dt} = \frac{RT}{V} \frac{dm}{dt} \qquad (2)$$

Direct substitution of (1) in (2) yields a first order ordinary differential equation of the form:

$$\frac{dP}{dt} = -\frac{RT}{V} \quad \frac{\pi}{128} \quad \frac{rD^4}{q} \quad \frac{(P-P_o)}{L} \qquad (3)$$

which describes the pressure equalization caused by mass flow through a capillary tube of diameter D and length L into a volume V held at a pressure P. Taking the LaPlace transform of equation (3) in time, subject to an initial condition that $P = P_i$ at time $t = o$, yields a solution in the form of a convolution integral:

$$P(t) = P_i e^{-Kt} + \int_0^t K\, P_o(t-\tau)\, e^{-K\tau}\, d\tau \quad (4)$$

Equation (4) is the most general form of the isothermal equation for a capillary tube. The factor K is just an inverse time constant and it is given by the equation:

$$K = \frac{RT}{V} \frac{\pi}{128} \cdot \frac{D^4}{L} \frac{r}{q} \quad (5)$$

Equation (4) has several simple forms depending on the nature of $P_o(t)$. For P_o, the outside pressure, held constant, equation (4) reduces to:

$$P(t) = P_o + (P_i - P_o)e^{-Kt} \quad (6)$$

When P_o is a function of time such as $P_o = P_A(1 + \varepsilon \cos \omega t)$ equation (4) becomes:

$$P(t) = (P_i - P_A)e^{-Kt} + P_A + \frac{\varepsilon KP}{\omega^2 + K^2}(K\cos \omega t + \sin \omega t - Ke^{-Kt}) \quad (7)$$

Thus, for P_o equal to some periodic function, the value of K, the inverse time constant, will affect the amplitude and phase lag of the pressure inside the unit. Examining the extreme value of K approaching zero, it is found that P approximates P_i and hence, there is no pressure equalization. As K approaches infinity, P approaches P_o.

These results agree with the conclusion that one would expect no flow from a hole of vanishing diameter and one would expect instant equilibration with a very large hole.

Moisture can enter an insulated glass unit through a capillary tube by several mechanisms. One is by convection during the pressure-equalization step and another is by molecular diffusion. Surface diffusion may be very important, but because its effect is linear with the diameter of the tube (compared to molecular diffusion which is a function of D^2 and convection which is a function of D^4), the effect of surface diffusion will not be a significant factor in the design of a capillary tube.

The diffusion of water through air in a capillary tube may be desribed by the equation:

$$N_{H_2O} = \frac{vPA}{RTL} \ln \frac{y_i}{y_o} \qquad (8)$$

where N is the molar flow rate; v is the diffusivity; y_i and y_o are the concentration of water in air inside and outside the unit; A is the cross-sectional area offered by the tube; and L is the tube length. Multiplying (8) by the molecular weight of H_2O would provide a mass flow equation. Writing out the expression for A in (8) results in:

$$\dot{M}_{H_2O} = MW_{H_2O} \frac{vP\pi D^2}{4RTL} \ln \frac{y_i}{y_o} \qquad (9)$$

It is the function of the adsorbent to hold y_i very low even while y_o, the outside water concentration, is very large.

One may use equations (9) and (5) to design a capillary breather tube. From (9), it is apparent that the moisture diffusion rate is a strong function of D. Further, from equation(6), the time for equilibration from a step change (i.e., a finite and instantaneous change) in outside pressure will be approximately 5/K. From (9), it may be recognized also that y_i at atmospheric pressure can be expressed as an equivalent dew point. At a specific temperature and dew point a molecular sieve adsorbent will have a characteristic loading and by subtracting the residual water level on the molecular sieve one can arrive at a working differential capacity for the molecular sieve at a particular dew point.

Mathematically it may be written:

$$t_{sat} = m_{MS} \frac{\Delta W}{100} \quad \frac{1}{\dot{M}_{H_2O}} \qquad (10)$$

where m_{MS} is the mass of the molecular sieve in the window. This is simply the total water capacity at dew point or the mass of the molecular sieve, m_{MS} times the differential capacity ΔW (wt %) divided by equation (9), the rate of ingression of water by diffusion. This provides two convenient time quantities, t_{sat}, which may be on the order of 2 - 10 years, and the time for equilibration of a step change in pressure, t_{eq} = 5/K, which should be on the order of 2 - 10 hours.

As a hypothetical example, a 38 inch x 74 inch x 0.625 inch (i.e., the inside gap between the panes of glass) insulating glass window, a unit very likely to experience large deflections, may be used. Having an internal volume of about 1 cubic foot this unit will serve as a convenient reference. If the two long sides are filled with a Type 13X molecular sieve, the unit should contain about 250 gms of adsorbent. Y_i is selected as equivalent to a -40°F dew point while y_0 is held equivalent to saturated air at 77°F. As a reference capillary breather tube, D = 0.015 inch and L = 10 inches are selected. Under these conditions M_{H_2O} from equation (9) is approximately 1.6 x 10^{-3} gm/hr. At a -40°F dew point at 77°F the working capacity of the Type 13X molecular sieve is approximately 20 wt % so the time until saturation at -40°F dew point is about 1305 days or about 3.5 years. By similar order of magnitude calculations the time constant for such a capillary breather tube is about 0.64 hour, so the time for equilibration of a step change is about 3.2 hours. With these values as a reference, one can easily investigate the sensitivity of this capillary breather tube to changes in dimensions. The time to saturation will vary linearly with L/D^2 and the time to equilibrate a step change will vary linearly with L/D^4.

Presented in the following cables are the life, that is time to saturation, and equilibration time, as functions of the capillary breather tube dimensions.

TABLE 1

UNIT LIFE, YEARS (TIME TO SATURATION AT -40°F D.P.)

*D \ *L	2.5	5	10	15
0.010	1.97	3.93	7.88	11.80
0.015	0.875	1.75	3.5	5.25
0.020	0.492	0.984	1.96	2.95

* in inches

TABLE 2

EQUILIBRATION TIME, HRS. (RESPONSE TO STEP FUNCTION)

*D \ *L	2.5	5	10	15
0.010	4.05	8.1	16.2	24.3
0.015	0.8	1.6	3.2	4.8
0.020	0.25	0.50	1.0	1.5

* in inches

Clearly, the expected life and the equilibration time of an insulating glass unit with a capillary breather tube are very sensitive to the tube dimensions. The size of the insulating unit on which a capillary breather tube is installed is also critical to the extent that for small units with internal volume significantly less than 1 cubic foot the equilibration time will drop significantly, but as the unit size goes down so will the amount of molecular sieve contained by the unit. The optimum capillary breather tube for a large unit will thus not serve very well for a small unit and vice versa.

Those skilled in the art should realize that equations (5), (9) and (10) provide a sufficient basis for the design of capillary breather tubes. The foregoing discussion, and equations, are for empty tubes of capillary size. For molecular sieve-filled breather tubes of the present invention, which are generally larger than capillary size, the additional factor of resistance to air flow caused by the adsorbent must be considered. Therefore, it is necessary to modify the foregoing equations to account for that additional flow resistance (i.e., instead of equation (1), which is based on Hagen-Poiselle flow, an equation based on the Ergun equation - which describes fluid flow through porous media - should be used). Those skilled in the art are capable of making these modifications.

A prime advantage of the adsorbent-containing breather tubes of the present invention is that, whereas a capillary tube results in a finite life for a window unit in which it is installed, more rapid equilibration of pressure is achieved and the life of the window unit is greatly extended with breather tubes of the present invention, since any air entering the enclosed space is dried by the adsorbent.

As illustrated in Figure 3, the breather tube of this invention communicates with the enclosed space through the window channel 13. The other end, of course, is exposed to the ambient atmosphere but should be protected from direct exposure to liquid water. As discussed above, this would be a design consideration which those skilled in the art could easily determine.

The breather tube can be formed of metal, plastic, or any other appropriate material. The tube should be filled with the appropriate amount of adsorbent, or in the case of a plastic tube, it may be convenient to shrink-fit a plastic tube around an elongated adsorbent pellet, such as a molecular sieve. Sufficient porosity would be present in any case to allow air to move through the tube. As pressure differentials develop between the enclosed window and the ambient atmosphere, air will flow in or out as necessary to equalize the pressure and eliminate window deflection. The foregoing design equations, modified as described above to account for fluid flow through porous media, may be employed to properly size the breather tube and amount of adsorbent.

If the tube is properly sized and the proper amount of adsorbent incorporated therein, as moist atmospheric air enters the window through the tube (which will occur whenever the atmosphere pressure is greater than the pressure of the air in the enclosed window space) the adsorbent will adsorb the water and admit only low dew point air into the window. Subsequently, when the enclosed window space pressure exceeds the atmospheric pressure, dry air will flow from the enclosed space through the breather tube to equilibrate the pressures. The dry air in this event will strip moisture from the adsorbent and carry the moisture out to the atmosphere. The pressure changes during this equilbration step should be slow enough that the adsorbent will achieve equilibrium with the gas during this part of the cycle, a relationship defined by the equilibrium adsorption isotherm. Those skilled in the art are aware of such isotherms for a given adsorbent.

Although the precise dimensions of a breather tube will depend on the foregoing factors, typically most insulated-glass windows may employ a breather tube having a path length of about 10 to 12 inches and an inside diameter of about 0.035 inches or larger. Of course, the interior dimension of the breather tube may be limited by the size of the adsorbent available. If necessary, the adsorbent may be ground, for example, in a ball mill, to produce a smaller size for incorporation into a small-diameter breather tube.

The configuration of the breather tube should be such as to keep the adsorbent within it. For example, the diameter of the tube may be necked-down at either or both ends and suitable means such as porous sheets of felt or the like could be provided near the necked-down end to keep the adsorbent particles within the tube. Any other suitable arrangement for insuring that the adsorbent particles remain in the breather tube may be employed.

While the present invention has been described hereinabove by reference to the drawings which illustrate a window containing only two glass panes, it is, of course, possible to have more than two glass panes, such as three or more as is conventional in the art.

The foregoing explanation has been provided in order to enable those persons skilled in the art to practice the present invention. It is not the intention to limit the present invention by reason of the foregoing description; rather, it is the intention that the invention be limited only by the scope of the claims appended hereto.

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CLAIMS.

1. A sealed insulating-glass window which comprises at least two glass panes (11,12) separated by a channel(13) disposed around the periphery of the window thereby defining a space (14) therebetween, an adsorbent (15) contained within said channel at least partly along its length and sealing means (17) around the periphery of the window to seal said enclosed space (14) from the ambient atmosphere, characterised by a passage (18) communicating between said enclosed space (14) and the ambient atmosphere, said passage (18) containing an amount of an adsorbent (19) to prevent the introduction of excessive amounts of moisture into said enclosed space (14) through said passage (18).

2. A sealed insulating-glass window as claimed in claim 1, characterised in that said adsorbent comprises a molecular sieve.

3.A sealed insulating-glass window as claimed in claim 1, characterised in that which includes two panes of glass.

4. A sealed insulating-glass window as claimed in claims 1 or 2, characterised in that including more than 2 panes of glass, each being separated by a channel thereby providing an enclosed spaced between adjacent panes of glass.

5. A sealed insulating-glass window as claimed in any one of the preceding claims, characterised in that said adsorbent comprises a blend of at least two different adsorbent materials.

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Fig. 1.

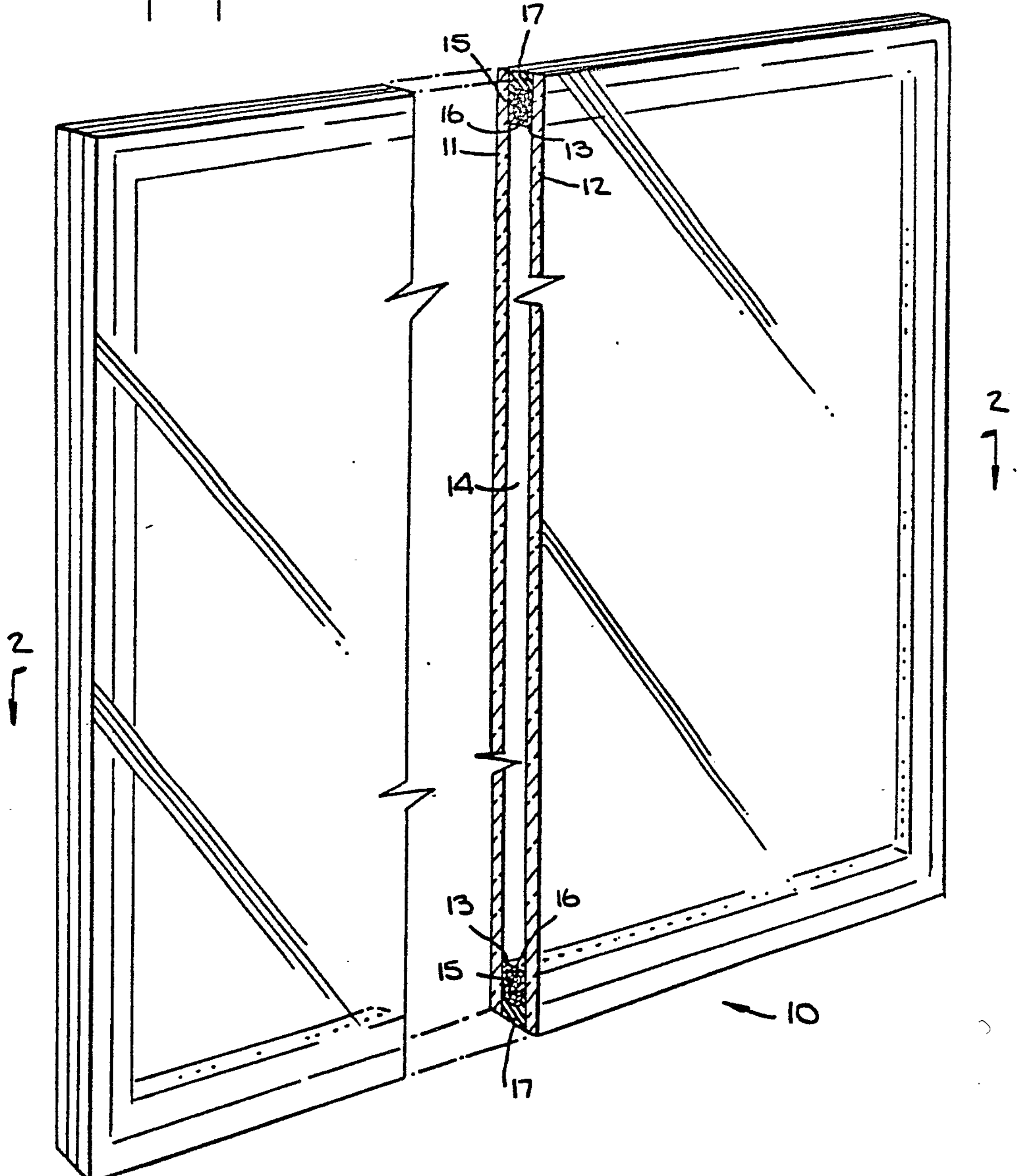
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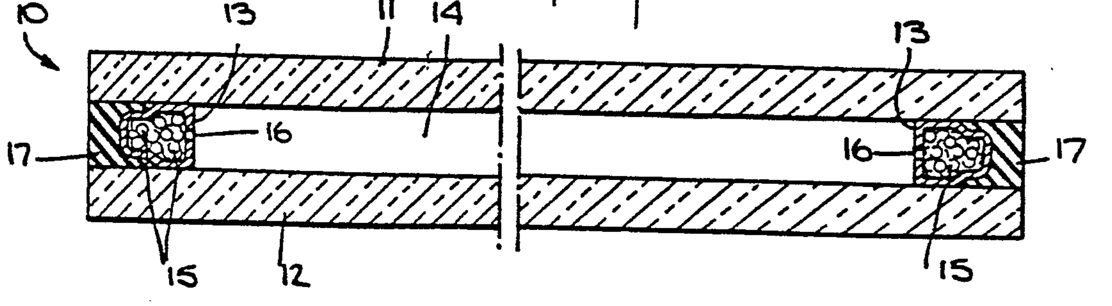
Fig. 2.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